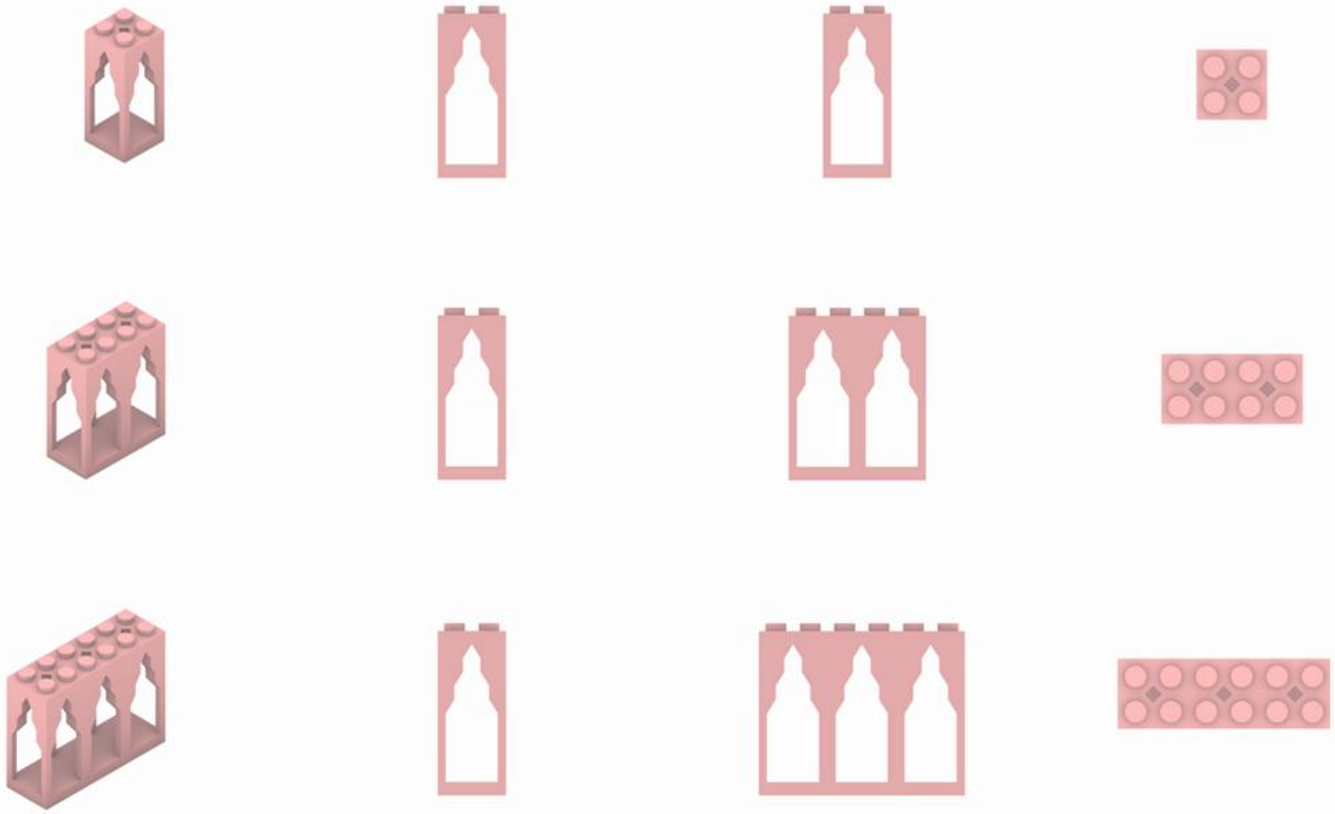
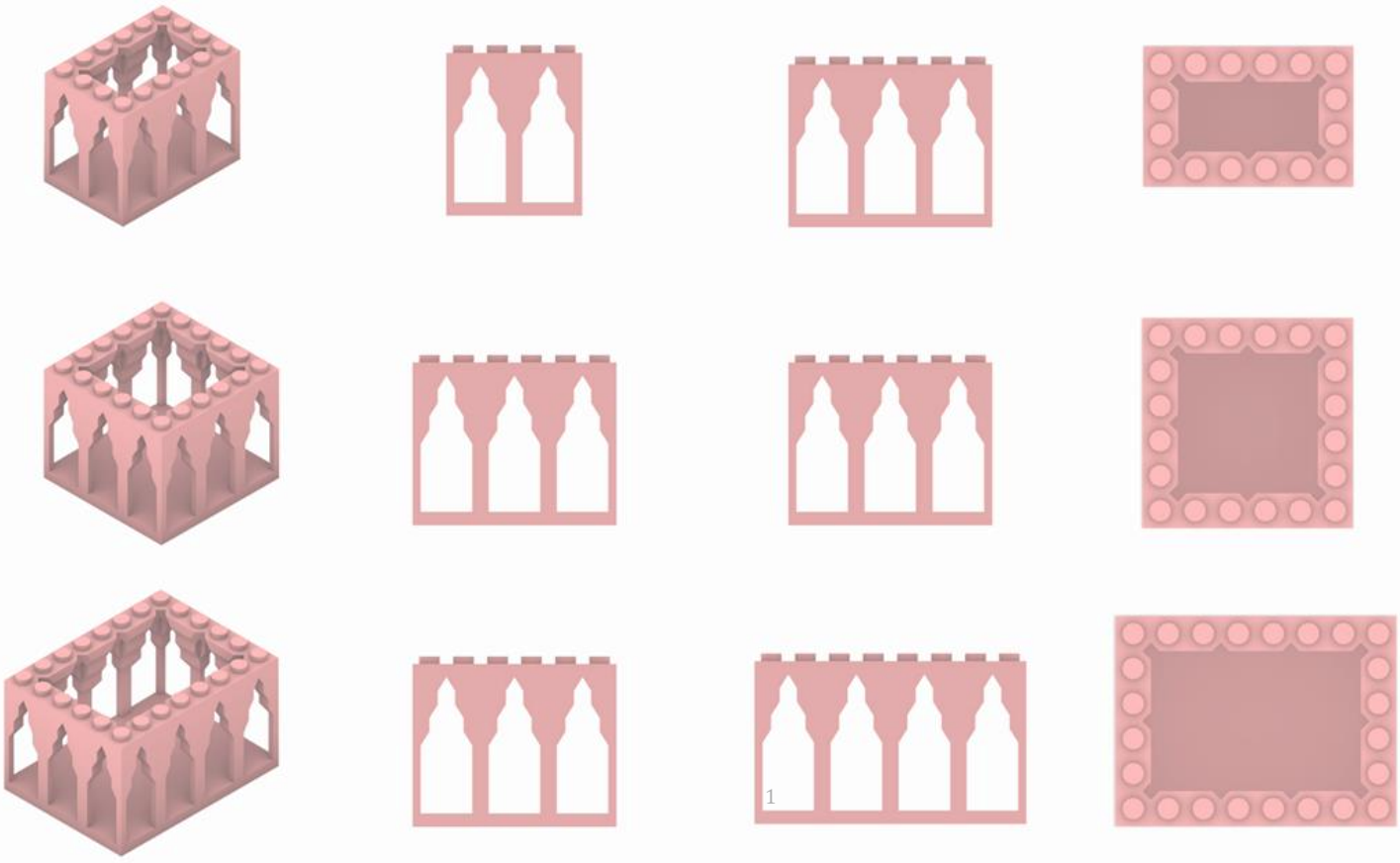


# A Participatory Design Game for social housing configuration in the context of Manaus, in Brazil



# A Participatory Design Game for social housing configuration in the context of Manaus, in Brazil

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**Abstract** – The emic structure of space heavily depends on the social, cultural, and economic context (Hillier, 1989). Yet, many social housing projects disregard this crucial aspect by standardizing the configuration of space (Sanoff, 2000). To be able to avoid the standardization of configuration and benefit from the cost-efficiency of mass production (Pine, 1993, Tseng, 2007), we propose a serious game that utilizes participatory design and gamification to facilitate co-creation and enable people to re-enforce their social and cultural preferences in the configuration of the spaces while benefiting from the economic viability of a mass-produced kit-of-parts. The proposed construction game is a mix of board game with Lego pieces. Each Lego piece have different possible dimension depending on the function which is being represented. The gameboard represents the plot on which the housing will be implemented. During the Planning phase of the game the players will use those components to generate a draft configuration that translates their preferences and requirements. Later in the Configuration stage, the game mechanisms are introduced to engage the players to communicate and discuss their ideas, make trades and commitments between them. The proposed configuration comprises fully modular pieces, so it could be easily manufactured and replicated. A test case base is conducted to further analyse on how effective the game has been in facilitating the participation in housing configuration, without the obstacle of technical knowledge of the architectural design and construction.

**Key words –** Participatory design, Serious Game, Mass Customization, Social Housing, Modularity.

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# 1. Research Framework

## 1.1. Background

The non-participation of users in the design process and all the consequences that arise from it like an increase in criminality in the neighborhood, post-occupancy renovation and ghost towns, point out the gaps in the mass housing production method. Although certain countries have already achieved a stable population growth and therefore the need for new housing, some countries in Africa and Asia according to the World Urbanization Prospects by UN (2018) are facing a rapid growth of 2.5 billion urban dwellers between 2018 and 2050, leading to a massive demand of new housing developments. Here is the opportunity to tackle this situation with a new method where the diversity of nationalities, cultures and social existences are respected in the design process, by using a participatory design game method that can be adjusted to different realities, empower the end-users, and consider their requirements.

The mass dwelling production, like some examples of social housing, is characterized by limited users' participation, no customization and monotonous massive production. The minimum or total absence of users' participation in the design process tends to deliver a design that lacks in fulfilling their requirements and their natural desire to culturally express and identify with their dwelling and feel belonging to a community. Those requirements can differ between dwellers in an objective and subjective matter. Here the objective is referred to as any quantifiable aspect, such as the number of rooms needed in a house, and the subjective related to abstract things, like the social logic of space. For example, for different dwellers housing can have distinct values and significance depending on their social, economic, and cultural backgrounds.

This subjective matter can be hardly considered in the material world when the end-user is not part of the design process. And treat them apart from the design process does not help in fulfilling the user's needs and preferences. As mentioned in 'The social logic of space' by Hillier and Hanson (1988)[1], to assume that the 'social' subject and the 'spatial' object act like a distinct and independent existence is equivocated, since the physical world made by a human is already a social structure. Therefore, to replicate those abstract subjects in the material world of housing production it is important to recognize those who hold knowledge and experience of the related matters and bring them to work together.

In addition to the participatory factor in the design, which helps to add characteristic value to the project, we cannot ignore the fact that the creation of a unique and customized project to the needs of a family can take time. However, time is a limited resource during the design process. Therefore, it is fundamental to consider a method of mass customization to speed up this process and still deliver customized design. The use of modular design, which can be easily replicated and adapted, together with participatory design and gamification is part of the main method developed in this graduation project. The game methodology which allows us to compress and simulate the real-life situation, and have the essential characteristics examined (Sanoff, H. 1979), helps as well to grasp complex relationships about the environment to create changes that are responsive to human needs (Sanoff, H. 1979).

Housing goes beyond just being a shelter. It can provide security along with economic, social, cultural, and psychological dimensions (Wood & Salway, 2000). For each dweller, this can be expressed in different ways within the house. This project will not give a solution to all these complexities but aims to present a method toward a meta-game that enables participatory design for co-designing and allows people to participate with their social and cultural preferences in the spatial decision-making process of housing configuration, without the obstacle of technical knowledge. The societal relevance of this research is the empowerment of people, through their participation in the design and allowing them to reinforce their social and cultural values and preferences in the design. While the scientific relevance is the development of a participatory design game method for the early stage of the design process

[1] Bill Hillier, "The Social Logic of Space."

that considers social and cultural complexities using scientific methods and theories like participatory design, shape grammar, space syntax, discrete architecture, and game design theory.

## 1.2. Context

The research explores serious games as a participatory design methodology for social housing. To exemplify the application of the game in a context, in which the participatory design game method can be understood and assessed, it was chosen a study case from Brazil, particularly from the city of Manaus, located in the North Region of the country. Manaus is the capital and the biggest city of the state of Amazonas, with an estimated population of 2.255.903 (IBGE, 2021).

Manaus faced two rapid economic growth which led to rapid population growth and urbanization. The formal market did not attend to the increasing housing demand of the population, especially among lower-income families which had to resort to slums, squatters, and informal settlements. Some housing policies were made to minimize the situation, and one of them led to the construction of the biggest social housing complex ever made in Brazil, with more than 8.000 housing units.

Despite the initiative, the families which eventually lived in this complex were not considered during the design process, driving them to struggle to adapt to the new housing. In some cases, those houses were abandoned or made informal renovations. Those post-occupancy processes show the gaps in mass housing production, which is linked with the no user participation in the design decision-making process and consequently with the dissatisfaction of the dwellers with dwellings that do not consider their preferences and needs.

This project will briefly present the chosen context, its history, population, and some of the housing policies to understand better the complexities involved in mass housing production, social housing and the diverse social and cultural values present within the city of Manaus. Besides, this information will help to set design principles adjusted to the context so it can be develop a participatory design game method which can deliver a customized design that considers the social and cultural preferences of the dwellers.

## 1.3. Problem Statement

Despite its cost efficiency, the mass housing strategy tends to deliver designs that can not fulfil inhabitants' preferences and needs. Consequently, social, and cultural values tied to the space are lost or forced to change, impacting the sense of identity, and belonging of inhabitants to their own homes. On the other hand, custom designs are not affordable for most people. Therefore, there is a need for developing a new participatory design method that (1) provides a cost-efficient process and (2) allows participation of the end-user in the co-creation of the design; thus, enabling an affordable spatial configuration that preserves and reinforces the socio-cultural values.

## 1.4. Research Question

How can we allow future inhabitants to custom design their future affordable homes so their social and cultural patterns of using space can prevail?

- How can we keep the construction cost down while providing for customization?
- How can we facilitate the discussions of the multiple actors in the design process?
- How can we keep the design process simple and affordable while providing for customization and expression of subjective patterns of using space?
- How can we ensure a certain level of quality while allowing for mass customization?

## 1.5. Objective

Create a method for gamification of design that is based on discrete architecture, shape grammar, modular design, mass customization and participatory design that can be adjusted to different realities, enabling people to take part in the design decision-making process, without the obstacle of technical knowledge.

## 1.6. Scope and Limitations

This research focuses on participatory design method for social housing configuration that reflects the users' social logic of the space. It does not dive into technical implementation, constructability, quantifying costs, and affordability, although its relevance. This paper presents an alternative way of configuring and participating in the design process, where the subject aspects of the social logic of the space are considered. The research aims to develop a meta-level game that could be adapted to different realities and contexts in the world.

## 1.7. Methodology

The methodology applied in this project will be as follows:

- Understand the problem complexities, followed by literature research on any related approach and method in the past to solve similar problems.
- Case study: defining a context help to set a framework and assess the method being created. Besides local cultural and social values could be identified, which highlighted aspects of the participatory design game method that should be considered in the design of the meta-level game.
- Meta-game: the abstraction of the method being developed assisted in the development of a framework that points what are the elements that must or not be adapted to the context, helping to deliver a custom-made game.
- Testing case: series of tests and workshops were made to analyze the game and reflect on its improvement.
- Defining a case: an example case from the context of the case study which will help to show how the developed method works.

# 2. Literature Research

## 2.1. Mass-Customization

Mass customization can be described as a production method that tries to provide a personalized item to clients at near-mass production efficiency (Friedman et al., 2011).[2] Although mass customization and mass productions seem to be conflicting goals, they can be achieved by producing products, that meet the individual needs of diverse consumers, through flexible processes and organizational structure (Pine, 1993). Rocha et al (2015)[3] argue that mass housing customization has been related to environmental and social sustainability as it can potentially decrease waste from changes carried out by occupants after moving in and provide an opportunity for increasing their sense of identity and ownership.

The approach of considering needs in terms of space, as the type of space, the relationship between them and how much space the users need or want, shows the best potential to avoid unnecessary demolitions and renovations of the housing post-occupancy, and even to allow families to stay in the same home for longer (Vecchia and Kolarevic, 2020)[4]. It is commonly seen in countries where informal self-help housing and illegal settlement are common, that mass housing will pass through some type of renovation to attend to users' preferences related to the space or in extreme cases those houses will be sold or abandoned. Brazil is one of the examples that go through those consequences.

According to Friedman et al. (2011) the mass customization strategies are based on two main characteristics: the level of customer involvement and the type of modularity [5]. Therefore, the first can be achieved through the participatory design method and the second through discrete architecture and shape grammar, which will be described further in the following sub-chapter. Using modularity to build

[2] Friedman, Sprecher, and Eid Mohamed, *Implementation of Mass Customization Strategies in Housing*.

[3] Rocha, Formoso, and Tzortzopoulos, "Adopting Product Modularity in House Building to Support Mass Customisation."

[4] Vecchia and Kolarevic, "Mass Customization for Social Housing in Evolving Neighborhoods in Brazil."

[5] Friedman, Sprecher, and Eid Mohamed, *Implementation of Mass Customization Strategies in Housing*.

dwellings has been pointed out as an important tactic to improve the performance of the house-building industry (Hofman et al., 2009)[6]. In that sense, the time and effort go into designing modules that can be combined to provide a variety of solutions (Halman et al., 2008) [7].

A modular system offers components that are interchangeable, autonomous, loosely coupled, and individually upgradeable since the interfaces are standardized (Hofman et al., 2009) [8]. According to Baldwin and Clark (1997) there are three interconnected characteristics of modularity that must be balanced: modularity in use, modularity in production, and modularity in design [9].

- Modularity in use is the ability to give variation. Customers can mix and match parts to suit their own needs and preferences. Since less design effort is needed than with fully tailored solutions, the expenses of providing variety can be decreased by adopting modular product designs.
- Modularity in production is reached by breaking down the manufacturing and development process into manageable operations that may be completed independently of one another.
- Modularity in design is the partition of information into visible design rules and hidden design parameters:
    - Design Rules can be described in three types: architecture, interfaces, and standards. Architecture defines which modules are part of the system and what functions they will perform. The interfaces specify how the modules interact and how they fit together. And standards guide the conformity of the modules.
    - Hidden design parameters allow design freedom within the boundaries of a module and are effectively regulated by the module supplier.

In this research, the modularity will be present in the development of the game pieces, the shape grammar, and space modules, which will be described further in the Game Development chapter. It is relevant to inform you that the manufacturing process and production will not be tackled. Beyond the design rules created for this project, will be highlighted which ones must be eventually changed and adapted to be coherent to the context which is being implemented.

Modularity has a strong tie with the Open Building approach, which works with the introduction of several levels of decision-making in the building process, and the possibility of decoupling building parts with different life cycles (Kendall and Teicher, 2000) [10]. John Habraken during the 1960s promoted the Open Building concept to the building design. The concept introduces a bottom-up design approach, Habraken proposed two basic categories of action: community action and inhabitant action. Without the individual inhabitant, the outcome is normally uniform and brutal, as can be seen in most mass housing project (Schnabel et al., 2015)[11]. At the same time, the community, identified as the designers are necessary to guarantee technical quality results (Schnabel et al., 2015). The goal is to achieve a coherent balance between both, which is only possible by the involvement of all parties during the building process and design. Therefore, it is important to have professionals and laypersons on equal feet, to assure communication and collaboration.

Building design can be categorized into three levels of decision-making, although being separated they are dependent on each other (Schnabel et al., 2015). The levels are the tissue, the support, and the infill (*Figure 1*).

[6] Hofman, Voordijk, and Halman, "Matching Supply Networks to a Modular Product Architecture in the House- Building Industry."

[7] Halman, Voordijk, and Reymen, "Modular Approaches in Dutch House Building."

[8] Hofman, Voordijk, and Halman, "Matching Supply Networks to a Modular Product Architecture in the House- Building Industry."

[9] Baldwin and Clark, "Managing in an Age of Modularity."

[10] Kendall and Teicher, *Residential Open Building*.

[11] Schnabel, Lo, and Gao, *ModRule*.

- Tissue is related to the urban scale, the town fabric. It constitutes a higher level than the support level. The town fabric can remain the same even when the building is replaced or altered.
- Support provides serviced space for occupancy (Kendall and Teicher, 2000)[12]. Supports are dealt with as discrete spaces. It can be either new constructions or from existing buildings, either way the support accommodates and limit the infill (Schnabel et al., 2015).
- Infill involves all the system and elements needed by the dweller to occupy and unfinished space within a serviced shell (Kendall and Teicher, 2000), therefore every installation that makes the space habitable.

The picture below shows (1) the idea of separating and accepting the discreteness of five scales of spatial design, (2) the different life cycles of the designed spatial configurations, (3) the ways in which can be accommodated for adaptation and participation in their corresponding decision-making process, and (4) identification of the corresponding parties and territories involved in each scale of spatial design.

In each described level there is an "ultimate customer", which is the consumer on the infill level, the housing corporation or developer on the support level, and the municipality on the tissue level (Schnabel et al., 2015). It is relevant to mention that some of the customers are beyond just consumers, they are stakeholders that have interests and concerns in something related to the level.

When linking the open building design concept in housing design or planning we can identify three problem areas of different scales (tissue, support, and infill) that can use the participatory method to achieve what Schnabel et al. (2015) call the balance between the technical optimization and social optimization. Connecting to this research, the use of the participatory design method can assure that social and cultural values are considered and incorporated into the design, while the technical knowledge is provided by the designer that develops modular system of the game pieces and shape grammar.

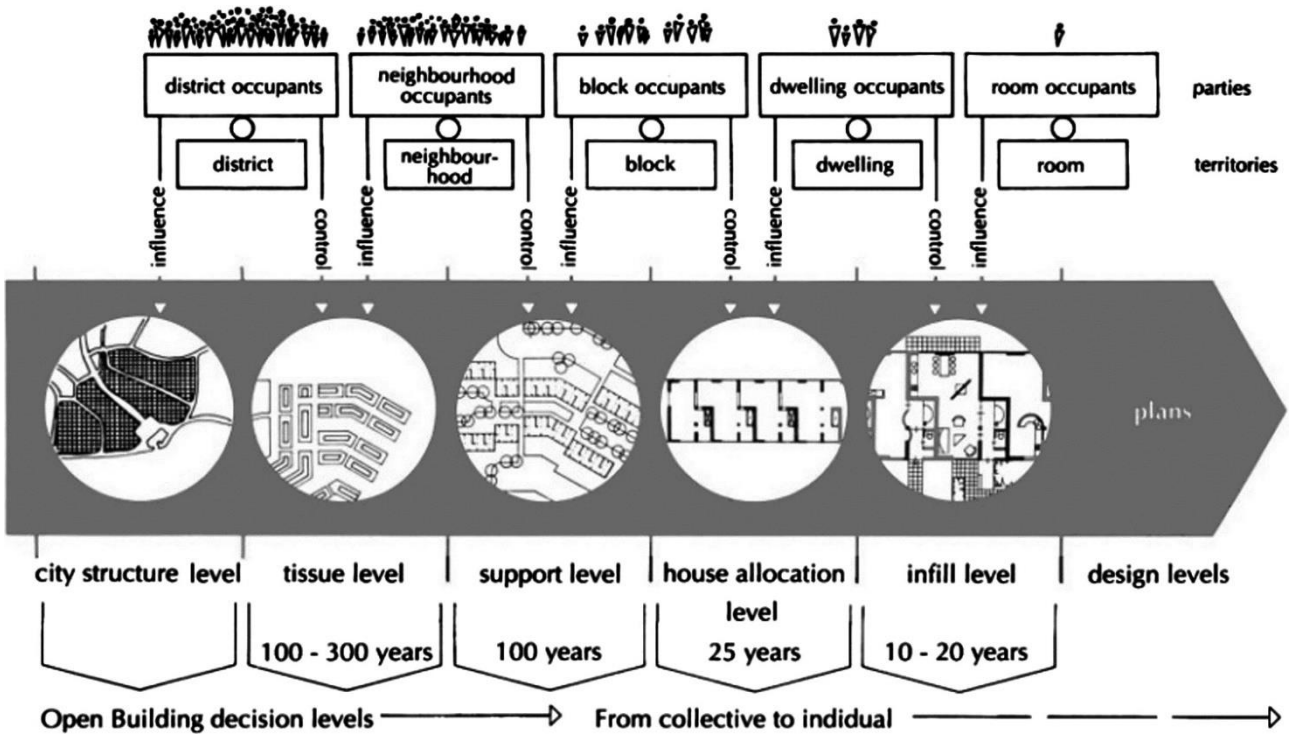


*Figure 1: Open building (John Habraken, 1961)*

[12] Kendall and Teicher, *Residential Open Building*.

Inspired by Habraken (1988)[13] work, the way how this game can assure that cultural values are considered is by studying in depth the (1) building types (spatial organization, physical system and stylistic ways) of a particular cultural tradition and (2) and its design principles, so it can be decided how they will be used in the game. The objective is not to copy or make any superficial borrowing of any culture, but to transform what was done in the past into something compatible with the values that are held today. The goal is to learn from the cultural heritage, not to deny present-day realities, and to establish a continuity between tradition and renewal (Habraken, 1988).

## 2.2. Cultural Values

Humans do not only exist in a space, but they also define spatial form by arranging people in space (in relation to each other) and arranging the space itself (Hillier and Hanson, 1984). Cultural differences can be recognized through the spatial order and sometimes a similar spatial configuration has different meanings to different societies (Hillier and Hanson, 1984). Therefore, the cultural value of a building depends on the society or individual who is giving the significance, or in which is being implemented.

Cultural significance is a concept used by the conservation community to describe multiple values related to objects, buildings, or landscapes (Avrami et al 2000). Those values can be aesthetic, historic, scientific, and social according to UNESCO's World Heritage Convention (2008). Cultural values are subjective and extrinsic (Hodder 2000) and depending on groups and even individuals they may differ simply because people attach different weights to them, and levels of relevance to objects, buildings, or spaces (Pereira Roders & Hudson 2011).

From the four values mentioned above, this research will be focused on the social values, which can be related to (1) an association such as "spirit of the place" (Mason, 2002), (2) feelings of identity, distinctiveness, social interaction, and coherence (English Heritage 2008), and (3) spiritual or emotional link between people and buildings, objects, and places (Tarrafa Silva and Pereira Roders, 2012).

As can be seen in table 1, social values are the ones that make people create a memory of the space and feel attached to it. Therefore, this brings a sense of identity and of belonging to a certain place, which is normally not considered during the mass production process. Consequently, forces people to find ways to translate their social values into the space, leading them to change housing configuration or to leave the dwelling after a while. Limiting the individual or the collective to order the space in a way that respects their social values, can affect their well-being, and the dwelling environment may become a barrier to personal fulfilment (Turner and Fichter, 1972). Acknowledging the lack of social values considered during the mass production process and its consequences, it becomes clear the relevance of embedding them to provide a spatial configuration that fulfils the user preference.

Although social values significantly influence the relation between the user and the space, it is still a subjective and abstract aspect that can not be measured or quantified. So, the way to consider and incorporate them is by bringing the user to actively participate in the design decision-making of the space. The participatory method can engage discussion between users, which consequently can bring awareness and perception (Burns, 1979) of why certain values are important and their attributes. Another way to incorporate these values into the design game is by doing prior research about the context in

[13] Habraken, "Type as a Social Agreement."

*Table 1: Retrieved from: Cultural Heritage Management And Heritage (Impact) Assessments. Da Silva, A.M.T.P.; Roders, A.R.P.*

*Table 1: The cultural values (ICOMOS Australia, 1999; Manson, 2002; Pereira Roders, 2007; English Heritage, 2008)*

| | | Secondary Values | References |
|---|---|---|---|
| Primary values | Social | Spiritual | beliefs, myths, religions (organized or not), legends, stories, testimonial of past generations; |
| | | Emotional, individual | memory and personal life experiences; |
| | | Emotional, collective | notions related with cultural identity, motivation and pride, sense of "place attachment" and communal value. |
| | | Allegorical | objects/places representative of some social hierarchy/status; |
| | Economic | Use | the function and utility of the asset, original or attributed; |
| | | Non-use | the asset's expired function, which has it value on the past, and should be remained by its existence (of materials), option (to make some use of it or not) and bequest value (for future generations); |
| | | Entertainment | the role that might be have for contemporaneous market, mainly for tourism industry; |
| | | Allegorical | oriented to publicizing financially property; |
| | Political | Educational | the education role that heritage assets may play, using it for political targets (e. g. birth-nations myths, glorification of political leaders, etc.); |
| | | Management | made part of strategies and policies (past or present); |
| | | Entertainment | it is part of strategies for dissemination of cultural awareness, explored for political targets; |
| | | Symbolic | emblematic, power, authority and prosperous perceptions stem from the heritage asset; |
| | Historic | Educational | heritage asset as a potential to gain knowledge about the past in the future through; |
| | | Historic-artistic | quality of an object to be part of a few or unique testimonial of historic stylistic or artistic movements, which are now part of the history; |
| | | Historic-conceptual | quality of an object to be part of a few or unique testimonial that retains conceptual signs (architectural, urban planning, etc.), which are now part of history; |
| | | Symbolic | fact that the object has been part/related with an important event in the past; |
| | | Archaeological | connected with Ancient civilizations; |
| | Aesthetical | Artistic | original product of creativity and imagination; |
| | | Notable | product of a creator, holding his signature; |
| | | Conceptual | integral materialization of conceptual intentions (imply a conceptual background); |
| | | Evidential | authentic exemplar of a decade, part of the History of Art or Architecture; |
| | Scientific | Workmanship | original result of human labour, craftsmanship; |
| | | Technological | skillfulness on techniques and materials, representing an outstanding quality of work; |
| | | Conceptual | integral materialization of conceptual intentions (imply a conceptual background); |
| | Age | Workmanship | craftsmanship value oriented towards the production period; |
| | | Maturity | piece of memory, reflecting the passage/lives of past generations; |
| | | Existential | marks of the time passage (patine) presents on the forms, components and materials; |
| | Ecological | Spiritual | harmony between the building and its environment (natural and artificial); |
| | | Essential | identification of ecological ideologies on its design and construction; |
| | | Existential | manufactured resources which can either be reused, reprocessed or recycled; |

design principles behind the spatial organization, physical system, and stylistic ways (Habraken, 1988) of that context and propose elements that are inspired by them, like the shape-grammar created in this research. Besides the design game should be open for adjustment whenever the game works with a different context.

## 2.3. Social Logic of Space

Users' requirements can differ between dwellers in an object and subject matter. Here the objective is referred to as any quantifiable aspect, such as the number of rooms needed in a house, and the subjective related to abstract things, like the social logic of space. For example, for different dwellers housing can have distinct values and significance depending on their social, economic, and cultural backgrounds. This subjective matter can be hardly considered in the material world when the end-user is not part of the design process. And treat them apart from the design process does not help in fulfilling the user's needs and preferences.

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## 2.4. Space Syntax

Space Syntax is a set of theories and techniques that look at the link between human societies and space from the perspective of a theory of the structure of inhabited space in all its forms: buildings, towns, cities and even landscape. [14] This theory leads us to think about the space before form, denying the space-as-form and society-as-content concept[15] (Hillier&Hanson, 1984, p.9). It highlights how the configuration influences the flow of movement, how people move through the spaces, how they interact with each other within them, and what this means for the social, economic, and environmental impacts they then have.

Hillier and Hanson (1984) focus on examining the space independently of its forms, shape,

[14] Bafna, "SPACE SYNTAX: A Brief Introduction to Its Logic and Analytical Techniques."

[15] Bill Hillier, "The Social Logic of Space."

dimension, orientation, or location, instead they focus on the topology of the space. For Hillier the topology of the space "can reflect and embody a social pattern[16]" (Hillier, 2005: 104), which is an architectural plan this pattern incorporates collective values and the social structure of a society[17]. In general, the space has two topological properties, the first is 'permeability', which refers to how spaces are connected or organized, and the second is 'difference', referring to the amount to which spaces can be distinguished from one another based on their placement in a system or network of spaces.[18]

Human societies use space as a crucial and important resource in organizing themselves (Bafna, 2003).[19] The mutually and dynamic constructive relation between society and space shows that they can relate in two ways, one being the space reflecting and embodying the social pattern and the other which the space can shape a social pattern (Hillier, 2005) [20]. How the space can shape a social pattern can be in a 'conservative' or in a 'generative' way. The first mode structures and reproduces existing social relations, usually by using space to segregate, restrain and structure movement (Hillier, 2005). While the second creates the potential for new relations by using space to create co-presence through integration, allowing new structures and patterns (Hillier, 2005).[21]

The space syntax theory enables the configured space to be analyzed through its building floor plan or urban fabric plan by its topological relation (Bafna, 2003).[22] Basically, the method reduces the configured space to a graph (map), that can be translated and examined in two common techniques: the convex and linear or axial maps. The first technique is the linear or axial map (Figure 2), which represents a set of fewest and longest lines in a building plan or urban plan, which represents the access to all spaces and allows a person to move everywhere in an environment, the capacity to walk from one space to another (Dawes and Ostwald, 2018, pp.7).[23] The axial map can be represented as a graph, where the lines are represented by nodes and each intersection as an edge (Bafna, 2003, pp.23)[24]

A convex map (Figure 3) is a spatial setting that is separated into a set of "fewest and fattest" convex spaces (Hillier & Hanson, 1984, pp.97-98).[25] However, the concept of fattest leaves room for interpretation, not being defined within the space syntax literature (Bafna,2003, pp.23) [26] To create a convex map is necessary to abstracts the building plan into a unit of spaces, called "convex spaces". After being identified, the next step is to mark on the map any trafficable connection between those spaces. Later, these spaces are translated into nodes, in this way the building plan or urban plan is transformed into a graph of spaces and accessibility. This graph captures the interior social structure of the space (Hanson 1998). By adding a node to the graph that represents the exterior of the building, social relation can be compared to the social relationship between visitor and inhabitant, or between inhabitants.[27]

There is a simplified version of the convex space technique, which will be used in this project, named "functional space analysis", where nodes are considered as room functions (Hanson, 1998)[28], allowing to simplify the process and accommodate small spaces in the graph, regardless of the space being strictly convex or not. Globally, in this research, the space syntax theory and method helped to abstract and identify the topological structure of the end-users' configured houses, allowing them to represent their social patterns and values in the built environment.

[16] Hillier, "The Art of Place and the Science of Space."
[17] Dawes and Ostwald, "Space Syntax."
[18] Dawes and Ostwald.
[19] Bafna, "SPACE SYNTAX: A Brief Introduction to Its Logic and Analytical Techniques."
[20] Hillier, "The Art of Place and the Science of Space."
[21] Hillier.
[22] Bafna, "SPACE SYNTAX: A Brief Introduction to Its Logic and Analytical Techniques."
[23] Dawes and Ostwald, "Space Syntax."
[24] Bafna, "SPACE SYNTAX: A Brief Introduction to Its Logic and Analytical Techniques."
[25] Bill Hillier, "The Social Logic of Space."
[26] Bafna, "SPACE SYNTAX: A Brief Introduction to Its Logic and Analytical Techniques."
[27] Dawes and Ostwald, "Space Syntax."
[28] Julienne Hanson, "Decoding Homes and Houses."

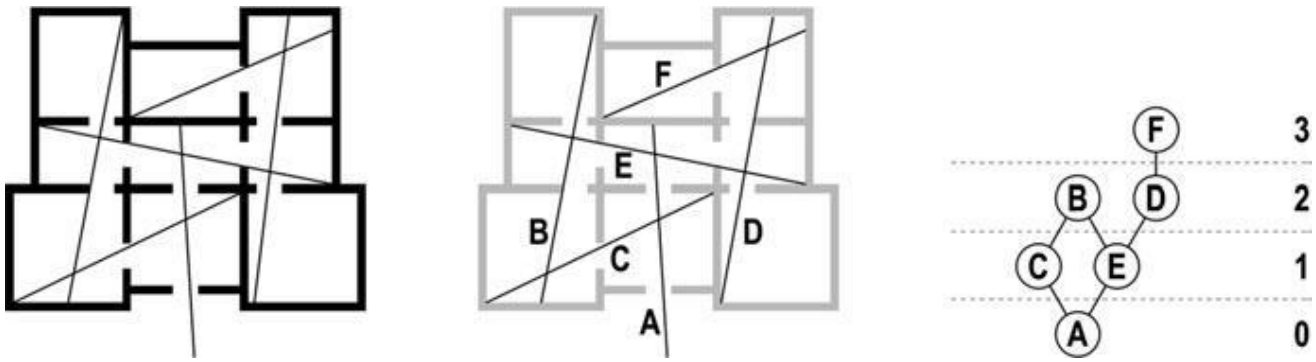



*Figure 2: Axial Map. (i) Simple building plan with axial lines marked, (ii) annotated axial line map of this plan, (iii) graph of the axial map. Font: Dawes and Ostwald, 2018.*

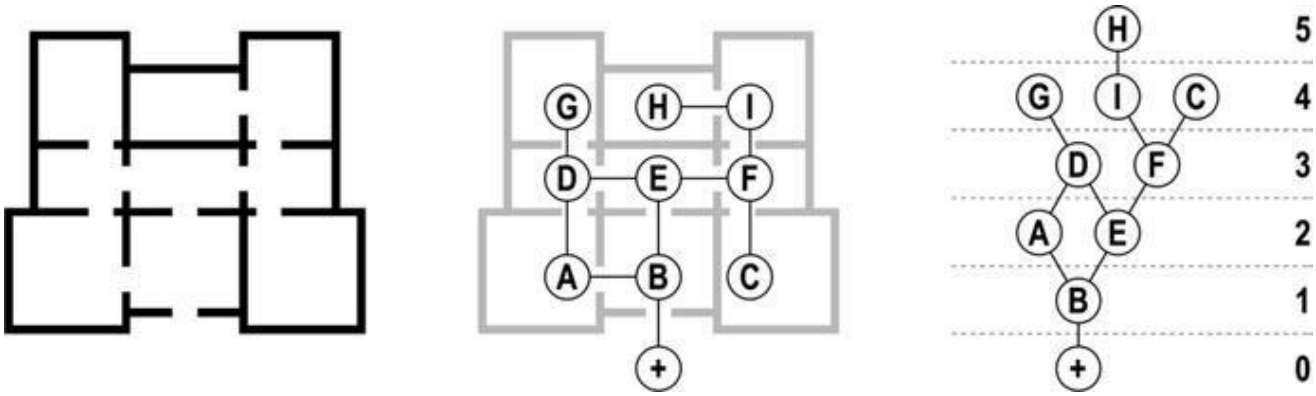



*Figure 3: Convex Map. (i) Simple building plan, (ii) annotated convex space map of this plan, (iii) graph of the(iii) graph of the convex map. Font: Dawes and Ostwald, 2018*

## 2.5. Generative Design and Shape Grammar

Generative design, as one of the branched of the computational design field, enables the designer to systematically manipulate, engage with, and interact with design (McCormack et al., 2005)[29], while it can be used to formulate or automate parts of the design process (Gu and Behbahani). [30] The reason for using the generative design method in architecture is to assist the human designer to explore the design space more formally and effectively, in addition to achieving cost reduction (through reduced time and labor), optimization, accuracy, consistency, etc. (Singh and Gu, 2012 ).[31]

Generative design has a set of different techniques, but this research will be focusing on the shape-grammar theories and practice. Due to its articulated nature, shape grammar is useful when working with modularity (Özkar and Stiny 2009), which is one of the key points for the formulation and applicability of this research. Besides, the shape-grammar approach can reduce cost in mass customization design[32] (Duarte 2001), since its built-in design knowledge lowers the requirements for additional human experience and expertise during the generation process (Gu and Behbahani )[33]. Shape grammar has other potentials besides the design generation, which

[29] McCormack, Dorin, and Innocent, "Generative Design."
[30] Gu and Behbahani, "Shape Grammars: A Key Generative Design Algorithm."
[31] Singh and Gu, "Towards an Integrated Generative Design Framework."
[32] Duarte, "Customizing Mass Housing."
[33] Gu and Behbahani, "Shape Grammars: A Key Generative Design Algorithm."

will not be developed further in this project, like analysis, optimization and grammar studies.

Introduced by Noam Chomsky, generative grammar is a linguistic theory which considers grammar as a system of rules that can be applied repeatedly to generate an infinite number of sentences. Following the same logic, but applied in architectural design, shape grammar is based on shapes, formation rules, geometric transformation and architectural elements (Tepavcevic and Stojakovic, 2012).[34] Its application can be such stylistic analysis, design generation, and customization (Gu and Behbahani)[35].

Shape grammar can be defined in a computational and visual-spatial way (Tepavcevic and Stojakovic, 2012).[36] The first theory described shape grammar as a rule-based system in artificial intelligence which generates geometric shapes, consisting of shape rules and a generation engine that select and processes rules recursively/repeatedly (repeat itself indefinitely), starting from an initial shape way (Tepavcevic and Stojakovic, 2012). Those rules define the way of replacing a particular shape and how to do it, they can be geometric transformations like rotation, scale, reflection, and translation. It can be used as a synthesis tool, generating complicated forms which start from a simple shape (Fasoulaki, 2008)[37].

The second way of understanding shape grammar is through the visual-spatial definition/thinking. As suggested by Özkar and Kotsopoulos, 2008, it is a theory that represents a philosophy of looking at the world that is not through learnt or imposed decompositions (definitions) but through those that have a practical meaning at that point in time.[38] In other words, it is a series of visual rules that tells the particular shape to be replaced (to another one) and how they are replaced (Özkar and Kotsopoulos, 2008). Recognizing the particular shape, and its possible replacement, is an operational rule, indicating the action that will be placed.

A visual way of understanding the shape rules is the following pair: left-hand side (LHS) and right-hand side (RHS) shapes, representing the before and after the rule being applied, respectively where the LHS is the input and the RHS the spatial transformation output of the LHS shape (Gu and Behbahani, 2018)[39]. Those rules (Figure 4) can transform the shape in five common ways, which are addition, subtraction, division or split, modification (preserve the geometry, but modify its properties), and substitution (replace one shape to another)[40] (Knight 1999).

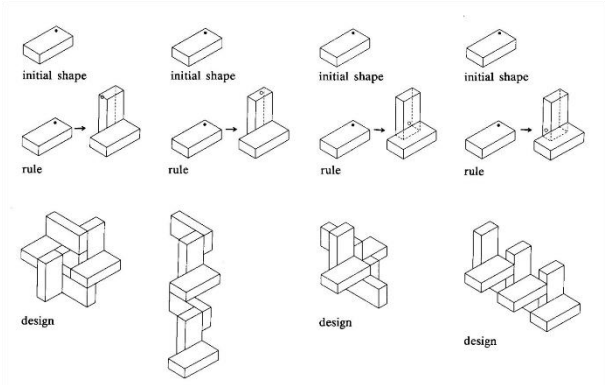



*Figure 411: Shape Rule. Source: Lecture Notes of Computational Design I: Theory and Applications from Prof. Terry Knight*

For this project, it is relevant to understand how to develop a shape grammar since this will represent part of the game development. According to Gu and Behbahani (2018), there are three procedures for developing grammar: corpus selection, grammar development and evaluation. The same authors argue that the Corpus selection of a shape grammar is a compilation of design examples which are selected out of a particular style or class and that the purpose of this method is to extract commonalities and remove superficial characteristics to reach essential properties that

[34] Tepavcevic and Stojakovic, "Shape Grammar in Contemporary Architectural Theory and Design."
[35] Gu and Behbahani, "Shape Grammars: A Key Generative Design Algorithm."
[36] Tepavcevic and Stojakovic, "Shape Grammar in Contemporary Architectural Theory and Design."
[37] Fasoulaki, "Integrated Design."
[38] Özkar and Kotsopoulos, "Introduction to Shape Grammars."
[39] Gu and Behbahani, "Shape Grammars: A Key Generative Design Algorithm."
[40] Knight, "Shape Grammars."

constitute the generalized concepts of the style or class (Gu and Behbahani, 2018).

Pauwels et al. (2015) affirm that such corpus is necessary only for grammars that aim to represent or reproduce existing style to analyse it, but not for original grammar, which aims to develop a new design[41]. However, in this project the corpus stage is not used for analytical purposes, instead is an opportunity to offer a shape grammar that replicated a specific style or set of styles from the particular context in which the game is being implemented, so the end-users can choose the one of which they can relate to it.

Moving forward, shape grammar development is a logical argumentation process based on shapes and their operations (Gu and Behbahani, 2018). The defined shapes and rules can also retain composition that gives a brand identity or design style (Özkar and Stiny, 2009)[42]. In case of developing a shape grammar based on an existing corpus, Duarte (2001)[43] suggests a four-step process consisting of rule inference, prototyping, reverse grammar, and testing.

The first step is the analysis of the corpus to identify the spatial or form-related structure of the style. The second step aims to find similar features of the structure identified in the first step. The third step, reverse grammar, test the possibility of tracing back the existing design to its initial shape. And the last step, testing, evaluates the grammar application in producing multiple designs (Gu and Behbahani, 2018) [44]. The evaluation, as the last stage of shape grammar development, tests the feasibility and efficiency of the grammar to generate design, free from errors and provides control over unexpected design emergence (Gu and Behbahani, 2018).

For this research, three general shape grammar will be mentioned (see section 4.5 Shape Grammar). They were crucial for generating different designs, designs with cultural expression and designs that the user could relate to it.

## 2.6. Discrete Architecture

The discourse of discrete architecture has been unfolded into many branches: discrete system, discrete building elements, discrete assembly, discrete construction system, discrete materials, discrete computation, discrete fabrication, and so on. In general, this method consists of repeating parts or pieces that aggregate together, allowing the building to easily be scaled up or down, and to be re-assembled. Those parts have no embedded function such as column, slab, or beam, they just represent autonomous parts that can be repeatedly connected. The versatility and accessibility of those parts allow them to be articulated and aggregated together in different ways, offering the possibility of an open-ended architecture, recreating forms that do not have an embedded function (Retsin, 2019)[45].

As Bafna states, it is useful to convert the space into a discrete configuration because different labels can be applied to its individual parts; consequently, these parts can be assigned to different groups, people, or activities; different rules of behaviour and conventions can be associated with different parts of the space; and individual parts of space can be recognized as carrying a specific symbolic or cultural charge (Bafna, 2003)[46]. Which is useful to this research since the spatial (geometric) design of game pieces is developed as such that they are an open representation of space, the user will define or label the space as your need, just as they will embed in the space their social and cultural values. The same logic is applied to the Lego pieces used in this project.

The discretization of a design space supports the modularization of buildings as a product, allowing, therefore, the reduction of the costs of production (Azadi and Nourian, 2021)[47]. Besides, modularity is one of the important

[41] Pauwels et al., "Shape Grammars for Architectural Design."
[42] Özkar and Stiny, "Shape Grammars."
[43] Duarte, "Customizing Mass Housing."
[44] Gu and Behbahani, "Shape Grammars: A Key Generative Design Algorithm."
[45] Retsin, "Discrete: Reappraising the Digital in Architecture."
[46] Bafna, "SPACE SYNTAX: A Brief Introduction to Its Logic and Analytical Techniques."
[47] Azadi and Nourian, *GoDesign*.

elements of mass customization strategies, since with a set of modules it is possible to create several design variants (Rocha et. al, 2015)[48]. More than the possibility of replicability and customization, the discrete design offers a participatory framework for collective production, by putting at the center the design of an open-ended tectonic system that encapsulates knowledge (Sanchez, 2019). Having said that can be assumed the viability of offering to the end-user a customized house by means of modular architecture, discrete design, and participatory method.

## 2.7. Participatory Design

Participation can be considered as direct public involvement in the decision-making process, where citizens collaborate in social decisions that determine the quality and direction of their lives (Sanoff, 1988)[49]. According to Henry Sanoff's experience (1988), user satisfaction relies more on the feeling of having influenced the decision than on the degree to which his or her needs have been met. Among the benefits of this method, the author mentions: (1) the meeting of social need and effective utilization of resources; (2) influence in the design decision-making process and increase of awareness of the consequences of the decisions made; and (3) the designer have more updated information, enabling rational design methods without affecting the creative process (Sanoff, 1988).

To participate effectively it is important to identify (1) the parties to be involved in participation; (2) what is the intention of the participation; (3) where do we wish the participation road to lead; (4) how should people be involved, pick the appropriate method that matches with the desired objective; and (5) when in the planning process is participation needed or desired.[50]

There are multiple forms of participation, and they can be categorized in different ways depending on the authors. To Deshler and Sock (1985) there are two types of participation: (1) Pseudo-participation, where the control of the project is on the administrators or the designers, here the user act as a passive figure that listens to what is being planned for them (Sanoff, 2000) [51] and (2) genuine participation, people are empowered to control the action taken.

Burns (1979) highlights important aspects of the participation, that can be classified in four categories:

- Awareness: discover the reality of a certain place/context or situation, so that every one of the processes is talking the same language based on their experiences in the field where change is being proposed.
- Perception: understanding the situation, and all its ramifications, physical, social, cultural, and economic. The aim is to share each other's understanding, objectives, and expectations of the participants so they become a resource for planning and not hidden agenda that could.
- Decision-Making: users make physical designs based on their priorities for professionals to use as a resource to make plans. The result of the two previous topics for a program
- Implementation: when-to, how-to, where-to, when-to and who-will-do-it must be added to what people want and how it will look. (Sanoff, 1988)

The participatory approach gives the designer a role that is not limited to producing finished and unalterable solutions, instead, its job is to match the appropriate method to the purpose and to extract solutions from a continuous interaction (confrontation) with the end-user. The designer (architect or planner) provides the technical knowledge and shares the consequences of various alternatives, raising awareness to the user, while the user exposes their opinions and contributes with their expertise, and it is expected to both be open for discussion of various alternatives (Sanoff, 1988). [52] The

[48] Rocha, Formoso, and Tzortzopoulos, "Adopting Product Modularity in House Building to Support Mass Customisation."
[49] Sanoff, "Participatory Design in Focus."
[50] Sanoff.
[51] Sanoff, *Community Participation Methods in Design and Planning*.
[52] Sanoff, "Participatory Design in Focus."

process needs to be transparent, so the decisions are understood by the people who made them.

Identifying and reflecting on that matter helped to structure the participation framework of the method being developed in this graduation project. The participatory method will be used to empower the end users to configure their houses according to their needs and preferences, therefore, they will be actively cooperating and in control during the game process, and aware of the consequences of their decision-making.

## 2.7.1.Tools and Techniques

According to Al-Kodmany (2001) [53] tools used in participatory design (and planning) are divided into two categories. The first is the tradition which uses physical tools like pen and paper, paper maps, photographs and models. The second one is computerized which works with GIS, three-dimensional modelling, virtual reality, and urban simulation. Those tools help to enhance participatory planning and design. However, each of them has its strengths and weakness (Al-Kodmany, 2001).

In general, traditional tools are less intimidating, more intuitive and inviting to participants. When players feel more comfortable, the degree of involvement is higher, allowing meaningful discussion about the project, interaction with the data and social interaction between different stakeholders with different and opposing interests. Therefore, by encouraging people's participation and facilitating the interaction of the participants with the method and a physical tool this can be the foundation of fruitful discussion and interaction between players, that lead to an ideas proposition. The disadvantage of the non-computerized tool is that they can not represent a realistic visualization of possible design alternatives like computerized tools. Besides, the traditional tools present limitations on the scale provided (only one scale) on the information that can be analyzed, displayed, and visualized, and it is less effective to evaluate the potential design and complex project.

In that sense, it was important to recognize that both tools have their benefits and that most likely certain groups are more familiarized and comfortable with the manipulation of one tool than the other. Therefore, the conclusion reached was to concentrate on the traditional tools to be used by the end-user, while the computerized tools being used by the provider of the technical knowledge.

Moving forward the participation techniques available, are multiple, such as strategic planning, visioning, charrette process, fishbowl planning, community action planning, participatory action research, and participation games. For this graduation project, the chosen method to be worked with further is the participatory game.

Henry Sanoff (2000) describes the game as a simulation of a real-life, permitting the players to act out scenarios and experience community interactions. The participatory game is seen by him as a participative technique for solving a problem that involves a real-life situation that has been identified, abstracted in its essence, compressed in time so that the problem's core aspects can be examined, and the ultimate result is a simulation process. Therefore, this method consists of players, placed in a predefined setting, with constraints represented by rules and procedure methods (Sanoff, 2000).

Design game uses the gaming method to design through the involvement of people in the design or planning process. During a design, game players make choices, hold positions, and debate them. The choices that individuals make are based on their feelings, self-concepts, and values. This practice aims to have a plan of action for a group of people, that requires compromising among them. This exercise gives the chance for each participant to learn about each other's value differences and use the game props to clarify and reconcile those differences (Sanoff, 2000).

Sanoff (2000) elaborated a set of considerations to be followed when designing a game:

- Define the problem area to be simulated.

[53] Al-Kodmany, "Visualization Tools and Methods for Participatory Planning and Design."

- Define the objective and scope of the simulation.
- Define the people and organizations involved.
- Define the motives and purposes of the participants.
- Define the resources available to the participants.
- Determine the transactions to be simulated and the decision rules to be followed.
- Formulate the evaluation method.
- Develop the prototype.
- Test and modify the prototype.

Those considerations helped define the framework of the participatory design game method, the set of rules to be implemented and the game flow or process, all those topics will be further developed in the next chapters.

### 2.7.2.Participation in Housing

Sanoff argues that housing is more than a physical structure and that there is a complex world of cultural actions and material practices within it. In essence, housing has a social and cultural value, whose shape is often determined by cultural tradition (Sanoff, 2000). For Duncan (1985), the symbolic meaning and use of the house differs between cultures, but also among different groups within a society (Duncan, 1985). Habraken[54] (1972) supports the notion of housing as subjective and not related to any particular shape, instead what determines it to be housing is the housing process, which is the human act of living there, therefore housing is determined by the human act (Habraken, 1972 and 1986).

Unfortunately, mass housing demands beforehand to define what a dwelling is, before even the user is in any way concerned or involved (Habraken, 1972). In most housing production systems, dwellings are designed to be standard, tied to fixed notions, static formulas, and ideology (Sanoff, 1988). Turner and Ficher (1972) believe that when people have no control over the housing process, nor responsibility for key decisions in the design, construction, or management process, the dwelling may become a barrier to social well-being, and to achieve personal fulfilment, and a burden on the economy. Turner (1977) defines the housing process as the interaction of the people (user or actor) and their product, through the medium of their roles and responsibilities (or activities)[55].

Mass housing system forces dwellers of different socio-cultural values to adapt and live in housing units that accommodate general average needs. The consequence of this system can be housing abandonment or informal adaptation, between both cases the informal renovations are more often seen in the biggest social housing complex made in Brazil, in the city of Manaus. The informal construction, besides being outside the institutional framework of the official, it is capable of building houses that are suited to the end-user needs (Sanoff, 2000) since the user is in charge of the decision-making process of the design. Acknowledging all the information above mentioned, it becomes clear the importance of user participation during the designing process of dwellings, and that participation must be contextual, far from the stereotypical assumption of someone's needs and preferences.

## 2.8. Game Review

Although the set of considerations made by Sanoff (2000) for designing a game, it was crucial to play some serious games and non-serious games to get familiar with potential and dynamics of the games in general and to identify Sanoff's considerations in those games. The games that will be mentioned in this review are the ones that had significant influence or inspiration on this graduation project game, being: Atlantis Escape, Cartographer, Urban Climate Architect and Gifts of Culture.

Atlantis Escape (Figure 5) is a non-serious game in which the goal is to find the shortest path from the high tower to the exit on the game board, using the specified puzzle pieces. They are five different puzzle pieces with different elements

[54] "1972 Habraken Supports | PDF | Force."

[55] Turner, "Housing by People: Towards Autonomy in Building Environments."

such as staircase, bridges, and tunnels. They are used to create a path from the tower door to the exit on the game board. The path should be continuous and connected to navigate from one puzzle piece to another. This game stimulated the reflection and development of the topological relation between the special Lego pieces that were developed, where the openings of those pieces should be put to the player easily visualize how they could navigate from one space to another or one floor to another.

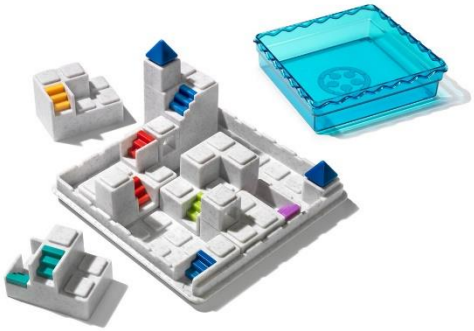


*Figure 5: Atlantis Escape. Font: Smart Games*

Cartographer: A Roll Player Tale is a complex game in a sense of having multiple rules to be followed. As an order from the queen, the cartographer needs to map the territory which she is claiming. The queen specifies which are the lands she values the most, and consequently are the one that gives higher scores. However, the cartographer needs to be careful to map the territory since there is an opponent who contests the queen's claims, so the cartographer needs to reduce their influence in the land. The scoring cards (Figure 6) from the Cartographer game inspired the scoring mechanism of the spatial quality criteria in the evaluation stage of the game. It helped to simplify some complex rules from the building code of Manaus into generic and easy-to-understand scoring cards. The method of the players being the ones to count their scores inspired the evaluation process of this participatory design game to be made by the player (end-user) itself. This way the players would understand why their configuration design is valid or not, how the spatial validity could be achieved, what is their spatial quality scores, and how the spatial quality could be improved.


*Figure 6: Scoring Cards. Font: Tony Mastrangeli.*

Urban Climate Architect (Figure 7) is a serious game in which the player chooses between three cities to design an environmental-friendly city by dragging building houses, streets, offices, industrial plants, trees, ponds, parks or green spaces onto the empty area. Each of those elements just mentioned has an impact on the climate of the city, the impact information is displayed automatically for each move that the player makes, together with short tips of what the player should do. This automatically answer was disregarded for the participatory design game, because can overwhelm and intimidate the player with information. There is why it was designed during the evaluation stage of the game, so the players could focus on deliberating and understanding their preferences in the configuration without being constrained (without worrying) by the impact of each move since this would be tackled later.


*Figure 7: Urban Climate Architect. Font: Urban Climate Architect Website.*

The three cities' options located in different global regions, were an exercise to reflect how the evaluation result could differ depending on the location even when using the same configuration, therefore the importance of adapting the evaluation criterion to the context's

climate and building code and any other requirements.

Another serious game played was the Gift of Culture (Figure 8). It is a role-playing board game that simulated a diverse cultural community. Each player takes on the roles of various groups who live in the flood-prone region. Despite the fact that they represent a variety of viewpoints and values, they all share the same goal: a better life for their group. Each of the activities available to players has its own set of benefits and drawbacks. Sharing information and collaborating on projects can considerably improve their outcomes, but different cultural backgrounds make this difficult. The Gift of Culture allows participants to see how cultural differences can cause problems while also being beneficial.


*Figure 8: Gift of Culture.*
*Font: https://giftsofculture.socialsimulations.org/*

Although the participatory design game is being developed it is not a role-playing game, this feature was used while testing the game in the workshop since it was not possible to use actual dwellers that pass through the process of living in standard social housing. It was noticed the relevance of engaging discussions between players for them to understand that each player has their preferences about the configuration and how cultural factors affect the space configuration. Therefore, the first stage of the participatory design game called 'planning' was created to initiate the discussion about the configuration of the space, while the second stage, 'zoning', uses some play mechanism to encourage the players to share information and consequently improve their collaboration.

Playing those games from an analytical perspective helped to observe other aspects of the game like playability, satisfaction, engagement, rules, constraints, limitation, storytelling and learning process. It proved the capacity of games to create a collaborative environment, allowing all the perceptions to be represented, simulate the real-life situation and create a shared understanding of problems and potential solutions. In general, the analysis and reflection of all the games played helped in the development of the participatory design game.

# 3. Case Study

## 3.1. Housing Policy in Brazil

Rapid urbanization and population growth without proper housing policy tend to generate informal settlements and squatting. Brazil had a significant migration flows from rural areas to the large metropolitan center during the second half of the 20th century, these migrants settled on the outskirts of towns or in empty places inside of them, frequently those areas were steep terrain with landslide risk or in flood-prone areas near rivers (Brueckner et al., 2019) [56]. Three main aspects of this housing policy problem can be distinguished: economic, social and political (Silva, 2011)[57]. Each of which have different expression and influence.

For this section, we will outline the process related to the housing policy that has a direct relation to the context of Manaus. Therefore, the primarily focus will be on the My Home My Life Program (Programa Minha Casa Minha Vida - PMCMV). PMCMV is a federal program that provides housing to low-income families, by facilitating financially the purchase according to the family income. Families with income ranging from zero to about two times the minimum wage are eligible for that program's subsidy, which can cover up to 90% of the cost of each housing unit (Vecchia and Kolarevic, 2020)[58].

[56] Brueckner, Mation, and Nadalin, "Slums in Brazil."
[57] Silva, "A evasão e o mercado imobiliário informal nos conjuntos habitacionais do Recife (2000 – 2010)."
[58] Vecchia and Kolarevic, "Mass Customization for Social Housing in Evolving Neighborhoods in Brazil."

The main stages for the implementation of a new social housing development can be seen in the following flowchart from Vecchia and Kolarevic (2020). The first step is to register families that are eligible and interested in purchasing a social housing unit. Next step, the local authorities assist the families in registering in the federal government's social program system (Cadastro Unico). Information like the identification of each family member, their work condition, the family's income, and their current living conditions are kept within that system, among other data.

After the family has provided the information needed, the main action happens between local authorities, the finance agency Caixa Econômica Federal (CEF) and the developer. The developer must be approved by the CEF, proving its capability to work on federal projects and that it has the financial means to keep construction going with its capital until the CEF inspect the construction and determines whether it meets its standards before paying for each stage of the construction (Vecchia and Kolarevic, 2020). As responsible for the design development and construction, the developer must present a design that will be accepted by the local authorities. The municipality usually only considers if the design follows local legislation, without considering the quality of the design.

It is interesting to observe in the flowchart (Figure 9) that the relation between the families and the housing development project made by the developer has no direct connection, showing no participation during the design process. Consequently, the developer provides standard housing that will most likely not attend to the users' needs and preferences. After the dwellers move into the new housing, it is common to make renovations, even if it is informal or illegal. This post-occupancy renovation shows the gap between the current method of mass housing production and the need for housing customization and users' participation. The following sub-chapter will show the common post-occupancy renovations and how this helped in the design of the participatory design game.

## 3.2. Post-Occupancy Renovation

The Post occupancy process of social housing complexes outlines the need for change, according to Brandão (2011)[59] the following aspects frequently appear in post-occupancy studies as motivators for change: aspects related to function, such as the layout and size of the rooms; the size of the housing unit; aspects related to visual and auditive privacy; aspects

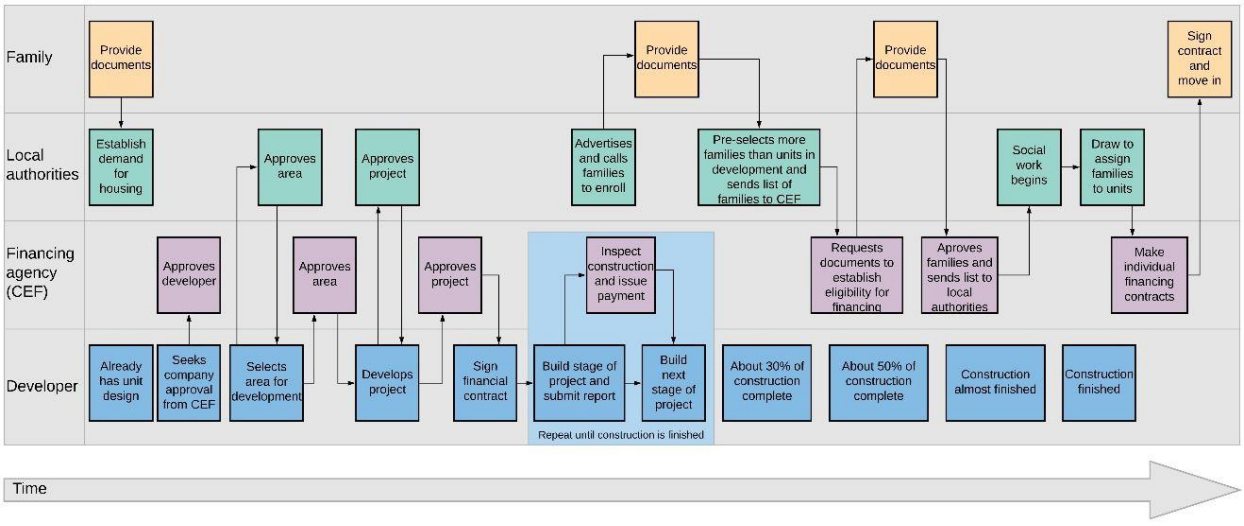



*Figure 9: Flowchart of main stages of the process of provision of social housing. Font: Vecchia and Kolarevic (2020)*

[59] Brandão, "Disposições técnicas e diretrizes para projeto de habitações sociais evolutivas."

related to personalization and definition of territory; changes in the family, such as the size of the family; economic and educational level. The post-occupancy renovation process highlights a couple of gaps in the mass housing production, like lack of fulfilment of user needs, minimum or no user participation during the design process, and the need for demolition and renovation of the housing unit to adapt it to the user's preference and need. Therefore, it becomes clear the need for a participatory design game method to be used in housing design and production.

In general, the post-occupancy processes in social housing units include geometric changes and an increase in the dwelling area. Digiacomo (2004)[60] analyzed several social housing developments in Brazil and mention the following changes as the most frequent:

- Intervention on the façade, including building a wall.
- Adding a garage.
- Increasing the area of the kitchen.
- Creating or increasing the area of the laundry.
- Creating a separate space for business, studies, or hobbies.
- Creating more bathrooms.
- Creating more space for storage.
- Changing the relationship between the kitchen, dining room, and living room.
- Adding one more room.

It is usual for low-income families to run small businesses from home to help into the family income. Thus, it is common to see in social housing complexes adaptation or expansion of the housing unit to embed those commercial activities within the dwelling. Although it was not made extensive research on site in Manaus to identify this renovation, the changes mentioned earlier will be considered in the development of the game, modular design, game pieces and shape grammar, which will be shown in the X chapter. It is relevant to mention that the research about the context is crucial whenever the participatory design game is being used in a different context, to offer a tailored game design for the need of the user.

The post-occupancy changes are seen as positive and beneficial for the living condition of the dwellers (Vecchia and Kolarevic, 2020) [61]. However, those renovations frequently result in inadequacies, like infringing on public space, lack of ventilation and natural light, blocking off windows of the original unit, improper rainwater discharge, steep and irregular stairs, and opening windows directly onto the neighbor's lot, among others (Brandão, 2011)[62]. Another example is the use of ceiling slabs as an extension of the house, which can cause serious accidents (Estevão and Medvedovski, 2017) [63]. These inadequacies can eventually cause health problems for the inhabitants and hazardous living conditions.

Two conclusions can be drawn for the design game development, the first is the need for a customized program requirement during the design process, this would eventually avoid inadequate renovation in the short term. Even if some renovation is needed in the future the fact that modular design is being used, allows that expansion can happen concisely and formally. The second is the need for an evaluation process in the game to assure spatial quality and validity.

Despite the low-income situation of dwellers, it is possible to observe that they invest significantly in expanding their units in permanent ways, showing the relevance of making their living space according to their needs and preferences. Even if the outcome of the participatory design game could only be partially constructed, its modularity of it would allow being constructed space module by space modules over time, respecting the economic constraints of the family.

## 3.3. Context

### 3.3.1. Short History of Manaus

[60] Digiacomo, "Estratégias de projeto para a habilitação social flexível."
[61] Vecchia and Kolarevic, "Mass Customization for Social Housing in Evolving Neighborhoods in Brazil."
[62] Brandão, "Disposições técnicas e diretrizes para projeto de habitações sociais evolutivas."
[63] Estevão, "Entrevista com Mariana Estevão."

The history of Manaus is characterized by two periods of strong economic growth in successive eras. Both of which resulted in rapid population growth and consequently, high demand for homes, particularly among lower-income families.

At the end of the XIX century, due to the concentration of natural rubber plantations in the Amazon region, it easily took the monopoly of this natural resource, to the point of being more profitable than the industrialized products made back then in the country. Before this period, the geographical distance between the Amazonas State and the central power of the country played a significant role in the overall relationship, usually, the state was being neglected and not provided by development projects for the region. During this period, many migrants, specially from the Northeast region of the country, came to the countryside of Amazonas looking for job opportunities, resulting later in big housing demand in Manaus.

In 1967, the Brazilian Government develop an economic plan for the region, resulting in the foundation of the Manaus Free Trade Zone Superintendence (Superintendência da Zona Franca de Manaus – Suframa), which promoted commercial, industrial and agricultural poles. The Free Zone attracted workers from different parts of Brazil to the point that the population in Manaus almost doubled size in only ten years, increasing from 175.343 inhabitants in 1960 to 314.197 inhabitants in 1970 (IBGE) (Figure 10). The formal market did not attend to the increasing housing demand of the population, specially among lower-income families which had to resort to slums, squatters, and informal settlements.

After the implementation of the Free Trade Zone, Manaus starts expanding. Nogueira and Sanson (2007)[64] point out that the city changes from having 37 neighborhoods in the 80s to 63 in the present day, many of them being a result of a process of informal settlement consolidation. According to the Joao Pinheiro Foundation (2013), Manaus is the fifth Brazilian county with the biggest relative housing deficit, representing 22.9% of the total housing in the city. Housing deficit is considered any housing with the following aspects: precarious homes, family cohabitation, the excessive burden of urban rent and excessive density of rented homes.

State and National housing policies were created to minimize the situation presented above. One of them related to PMCMV, led to the construction of the biggest social housing complex ever made in Brazil, with 8,895 housing units. Despite the initiative, the families which eventually lived in this complex were not considered during the design process, some of them struggled to adapt to the new housing, leading to subletting and returning to live in their previous houses or next to it, or built illegally extension of the house to fulfil their spatial needs.

Depending on the family and population that moved to those housing units, the applied renovation would be different, since this is connected to their needs and requirements that can be related to their social and cultural values as well. In the following sub-chapter, an overview of two distinct populations will be done to observe and reflect on the housing configuration of their culture and highlight their connection.

| Região | Capital | 1872[1] | 1890[1] | 1900[1] | 1920[1] | 1940[1] | 1950[1] | 1960[2] | 1970[2] | 1980[2] | 1991[3] | 2000[3] | 2010[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | Porto Velho | ... | ... | ... | ... | ... | 27.244 | 51.049 | 88.856 | 138.289 | 286.471 | 334.585 | 428.527 |
| N | Rio Branco | ... | ... | ... | 19.930 | 16.038 | 28.246 | 47.882 | 84.845 | 119.815 | 196.871 | 252.885 | 336.038 |
| N | Manaus | 29.334 | 38.720 | 50.300 | 75.704 | 106.399 | 139.620 | 175.343 | 314.197 | 642.492 | 1.010.544 | 1.403.796 | 1.802.014 |

*Figure 10: Population in Demographic Censuses, according to capital cities - 1872/2010 Fonte: IBGE, 1872, 1890, 1900, 1920,1940, 1950, 1960,1970, 1980,1991, 2000 e 2010.*

[64] Nogueira and Sanson, "A Expansão Urbana e Demográfica Da Cidade de Manaus e Seus Impactos Ambientais."

### 3.3.2.Population

During the rapid population growth, it was identified people from distinct backgrounds. This research will discourse about two of them, the indigenous people and riverside people, each of these groups have different culture, architecture and in some cases even languages. The first group being described are the indigenous people. In 2010 there were 3837 indigenous in Manaus (IBGE, 2010), from 34 different ethnicities, distributed in 51 of the 63 neighborhoods in the city (COPIME, 2015). The ethnicities were:

> Munduruku, Tikuna, Sateré-Mawé, Desana, Tukano, Miranha, Kaixana, Baré, Kokama, Apurinã, Tuyuka, Piratapuya, Kamaiura, Kambeba, Mura, Maraguá, Baniwa, Macuxi, Wanano, Tariano, Bará, Arara [do Aripuanã], Karapãna, Barasana, Anambé, Deni, Kanamari, Katukina, Kubeo, Kulina, Marubo, Paumari, Arara do Pará e Manchineri.

In this research all the ethnicities mentioned but present a global vision of villages and dwellings configuration will not be analysed in depth. According to Oliveira Júnior (2009)[65], each indigenous ethnicity has a specific spatial distribution in their village that goes beyond the necessity of shelter, revealing their beliefs, culture, clan and family structure. The way how paths, courtyard, housing sectorization and village configuration are allocated differs from ethnicity. In general, villages can be circularly, rectangularly or linearly configurated, while their dwellings can have a floor plan of different shapes, like circular, elliptic, rectangular, and polygonal (Costa et al, 1986)[66].

Graph maps of some indigenous villages and dwellings were made and analysed (Figure 11 and Appendix A). As an overview, it could be identified that:

- No matter the village configuration, spaces related to social activities or communal areas are always the most connected space within the village, showing their relevance to the community.
- The same village configuration has some similarities in the housing arrangement, but spaces with other functions may differ in their disposition. Even when the configuration is similar the relation of closeness between functions may differ, this can be influenced by cultural and geographical reasons.
- Villages with circular configurations are more interconnected than villages with linear or sparse configurations.
- Same shape dwellings may have different configurations within them.
- Dwellings do not have the same function within it, for example, the cooking area can be outside the dwelling, as a wider communal area.

Some of the Christopher Alexander (1977) patterns were recognized during the graph analysis, like the Community of 7000 (12th), Access to Water (25th), Activity Nodes (30th), Household Mix (35th), House Cluster (37th), Small Public Square (61st), Grave Sites (70th) and Paths (120th). The transition of the indigenous groups from village to city is highlighted by a process of resignification. Some patterns are lost like the Grave Sites, Small Public Square and Access to Water. With the purpose to maintain their culture, they try to replicate the spatial configuration of the village in the city dwelling.

The second group to be described are the riverside people. Categorized as Traditional People and Communities from the Amazon, the riverside people, known as “Ribeirinhos” have an intrinsic relationship with the river, which for them is a source of life, transport, commerce, and housing. Their background is a mix of habits and customs from indigenous and (Brazilian) north-eastern migrants that came during the rubber extraction period.

These communities have adapted to the dense forest, lowland, and floodable lands, residing in most cases in stilt houses on the riverside or floating houses on the river (Menezes & Perdigão, 2021) (Figure 12). Which highlights the importance of their relationship with the

[65] Oliveira Júnior, “Arquitetura ribeirinha sobre as águas da Amazônia.”

[66] Costa et al., “Habitação Indígena Brasileira (Costa & Malhano 1986).”

topology of the site as can be seen in the following picture.

According to Oliveira Junior (2009), traces of indigenous heritage can be seen in the village configuration of riverside people. Different from

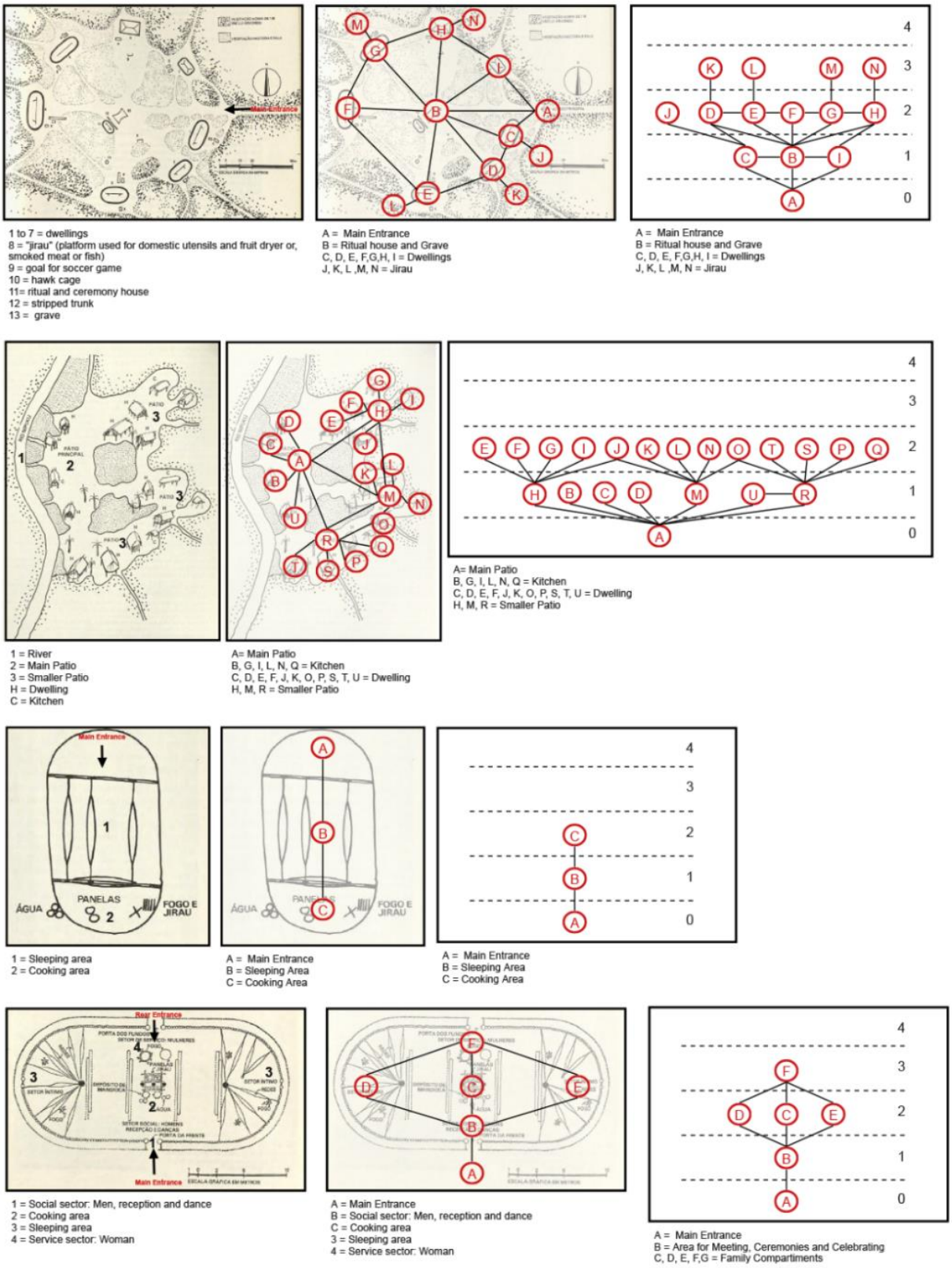



*Figure 11: Graph Maps of Indigenous Villages and Dwellings. Source: Housing and Village drawings from Habitações indígenas (Indigenous Dwellings). of Sylvia Caiuby Novaes. Graph Maps by Author, 2022.*

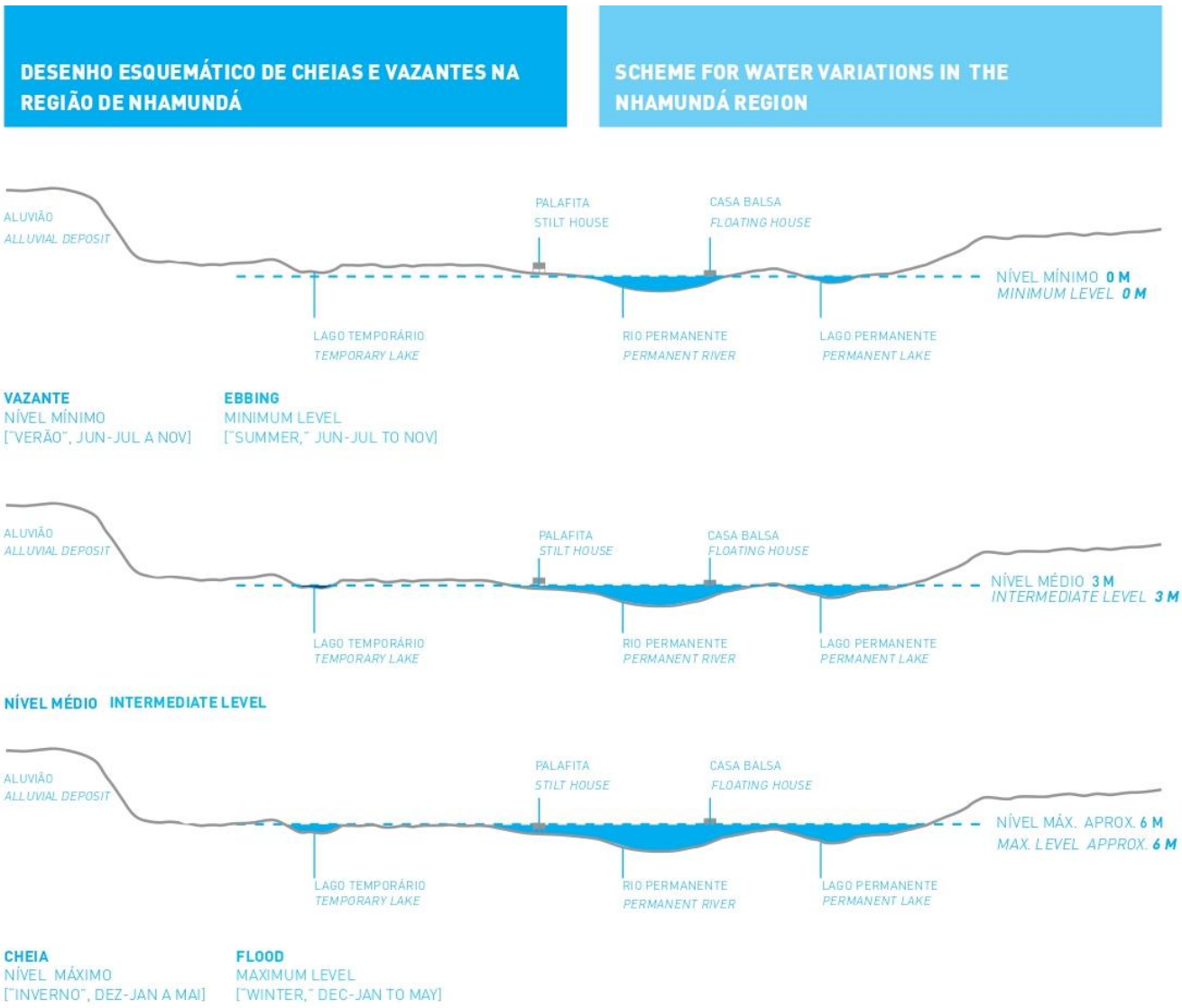



*Figure 12: Scheme for Water Variation. Source: Casas do Brasil 2013, The Amazon Riverside House.*

the configuration variety among the indigenous people, Ribeirinhos village has the same linear configuration, that follows the order river-house-farm/garden-forest (Figure 13), that repeats along the river. The forest and the river act as an extension of the house, generating a relationship of continuity between these spaces.

Although the village configuration is the same among riverside people, from the graph maps drawn was identified that the housing configuration differs from family to family (Figure 14 and appendix A). Other relevant points identified were:

- Verandas are a mandatory space, no matter if it is in stilt or floating houses. They usually represent the space with more connections in the graph map.
- Depending on the water level (ebb or flood) the access to the housing may alter the graph map.
- Housing typology (stilt or floating hose) has no interference in the configuration of the space.

Verandas are an important space for riverside people's lives. They play the role of the first layer of the "intimacy gradient", the 127th pattern described by Christopher Alexander (1977)[67], being the communal areas, a filter before the next space of the housing that is less public and more private. During the flood period,

[67] Alexander, Ishikawa, and Silverstein, "A Pattern Language: Towns, Buildings, Construction."

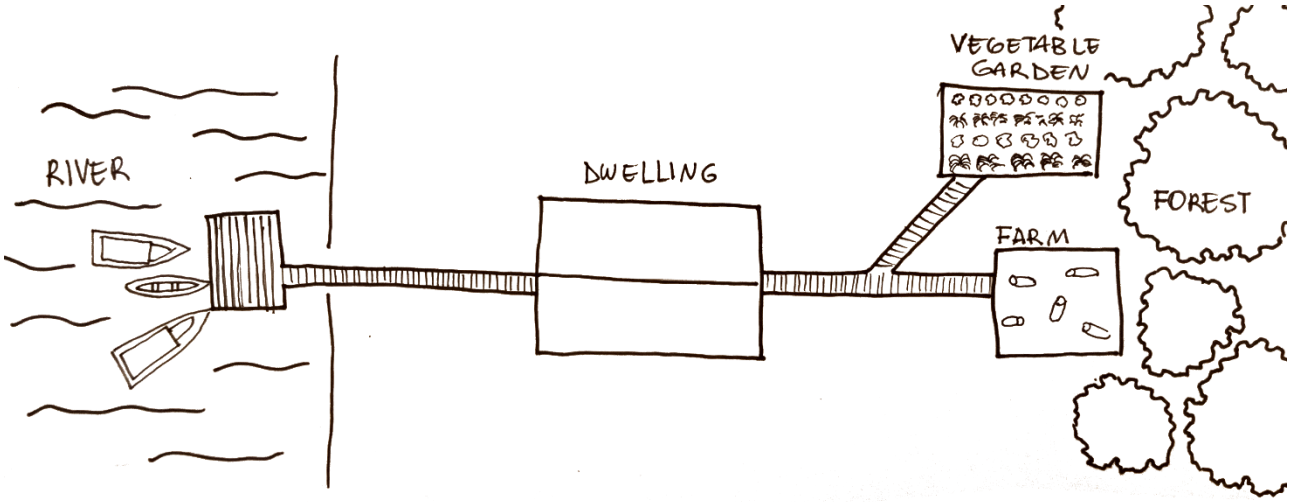



*Figure 13: River-house-farm/garden-forest disposition of Riverside people. Source: Author, 2022.*

it is common that bridges are built between verandas of the neighbors' housing, creating temporary paths (120th pattern of Christopher Alexander, 1977) that are compatible with the process of walking in that period. As with the indigenous, the transition of riverside people from their villages to the city has the same impact of losing patterns that they were used to and trying to replicate the configuration of their previous dwellings in the city one.

The process of describing these populations, drawing graphs, and discussing them in this section does not aim to compare ethnicities, communities, or people, but rather to identify and acknowledge that there are differences. When these populations are moving to the city, to standard housing or housing that does not translate their ways of configuring space, they struggle to adapt to it and, consequently start to make renovations. Therefore, these differences must be respected and considered during the design process and the design game here developed.

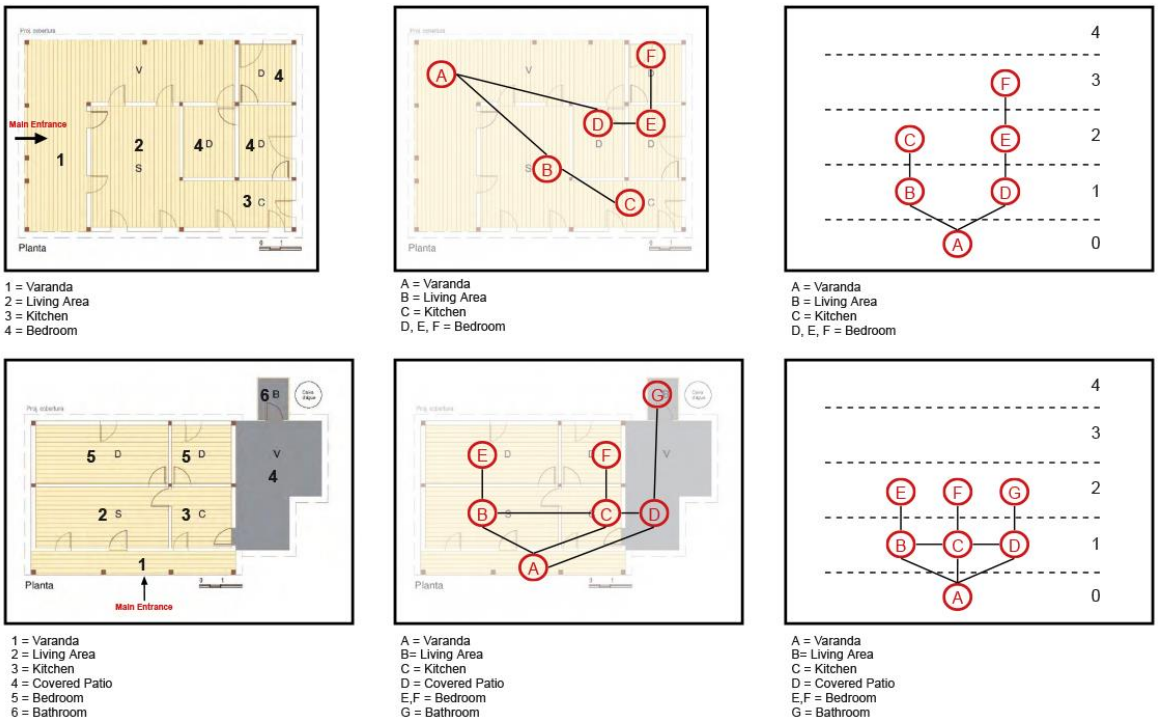
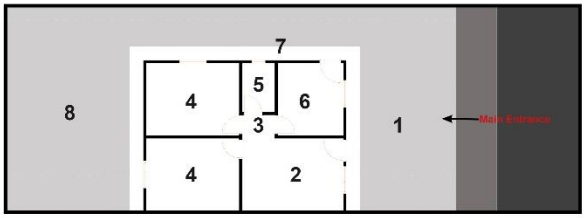


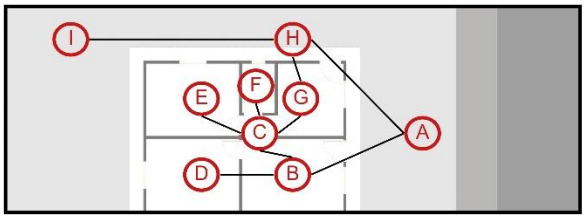

*Figure 14: Graph Maps of Riverside Peoples' Dwelling. Source: Housing drawings from Ana Carolina Brugnera, 2015, and Graph Maps by Author, 2022.*

### 3.3.3.PMCMV in Manaus

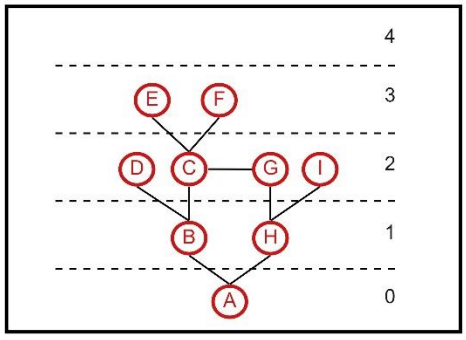
The social housing complex of PMCMV in Manaus constructed 8895 housing units. Two different configurations were offered for the dwellers, one for the apartment units and the other for house units. As can be seen in the following picture (Figure 15), the monotonous configuration of the housing would not fulfil the users' requirements, especially after seeing in the previous section that each population and even each family have a different understanding of how space should be configured.




1 = Front yard
2 = Living Area
3 = Corridor
4 = Bedroom
5 = Bathroom
6 = Kitchen
7 = Laundry
8 = Backyard




A = Front yard
B = Living Area
C = Corridor
D, E = Bedroom
F = Bathroom
G = Kitchen
H = Laundry
I = Backyard




A = Front yard
B = Living Area
C = Corridor
D, E = Bedroom
F = Bathroom
G = Kitchen
H = Laundry
I = Backyard

*Figure 15: Floor Plan and Graph Map of the PMCMV Housing Comples in Manaus. Source: Author,2022.*

Despite the initiative of the Federal Government to provide social monitoring after the new dwellers moved to the complex several variables made it difficult for people to adapt to this new style of living in a communal space that does not replicate their prior spatial relations and connections. Some problems highlighted were the understanding of where the public space ends and the private space begins, the resident's acceptance of the new housing configuration, and the remote implantation of the housing, far from the personal and professional ties that they used to have in the neighbourhood where they used to live.

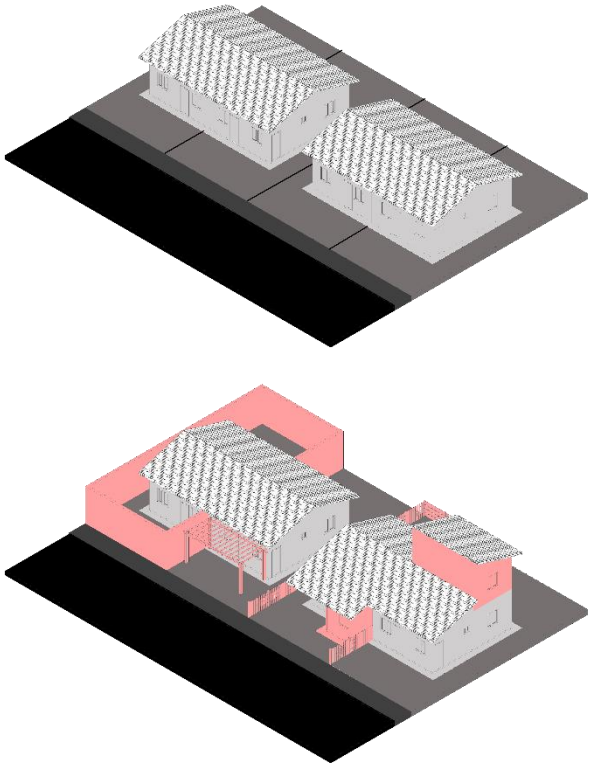


*Figure 16: Before and After Renovation. Source: Author, 2022.*

The consequence of the adaptation process to the new housing was the post-occupancy renovation (Figure 16), as has been already discussed in this chapter, translated as the need for change to achieve personal needs and requirements in their housing. Once again showing the need for a participatory design method, a design game that offers cultural expressive design elements related to the context, and a game that engages and empowers people to express their requirements.

## 3.4. Conclusion

This chapter pointed out important aspects of housing policy, post-occupancy renovation, history, population, and pattern of habitation. Each of these topics contributed to the development and reflection of the design game. For example, the housing policy proved the necessity of implementing a participatory design method that offers mass customization of dwellings to avoid or delay the need for post-occupancy renovation, and to fulfil the user preferences.

The post-occupancy renovation highlighted the need for customization and modularity, for its replicability and affordability to be achieved. Besides, the example of renovation mentioned in that section inspired the program requirement of the game implemented in Manaus. And it showed the need of using discrete Game Pieces during the game, that have multiple dimension options, so the player can decide which one fits their preferences related to the function.

The history, population, and pattern of habitation motivated us to reflect on the objectivity and subjectivity of spatial configurations and therefore that the evaluation process should only be related to objective and measurable criteria, while the subjective criteria will be left to the end-user to assess. It is relevant to mention that beyond evaluating the spatial configuration, the game will be developed to support design and decision-making over a new project.

Other conclusions made were (1) the need of doing previous research and analysis of the context before implementing the game, (2) the creation of a meta-game that highlights the main framework to be followed to adapt the game to its context, and (3) develop shape-grammar that offer culturally expressive design elements related to the context.

All the research is done so far helped in developing design principles for the game, like the following ones:

- End-user participation during the design process.
- Develop a game that engages and empowers the user to express their preferences and needs.
- Develop discrete game pieces that do not limit the user's expression of the configuration of the space.
- Develop discrete game pieces that reflect the non-trivial topography of the site
- Develop a meta-game structure that can be adapted to the context.
- Integration of communal spaces.

# 4. Game Development

The proposed construction game resembles a mix of a board game with Lego pieces that can represent different functions. This game is based on a voxel grid that follows the land topography of the available site, which serves as a gameboard for the functions that the players will be placed on top of. Game pieces with different dimensions will be available for the players to choose and decide the function that they represent. To achieve each game piece and position it, the players need to communicate and discuss their ideas, make trades and commitments between each other, and pay for the pieces. Each participant will start with the same number of coins that they can use to purchase the game piece of their preference or help to achieve another's preference. The design game aims to enable collaboration between end-users, so they can configure their housing space based on their preferences and need.

## 4.1. Design Principles

Design principles were created based on the reflection of the Case Study. These principles were:

- End-user participation during the design process.
- Develop a game that engages and empowers the user to express their preferences and needs.
- Discrete design language.
- Modularity.
- Develop discrete game pieces that do not limit the user's expression of the configuration of the space.

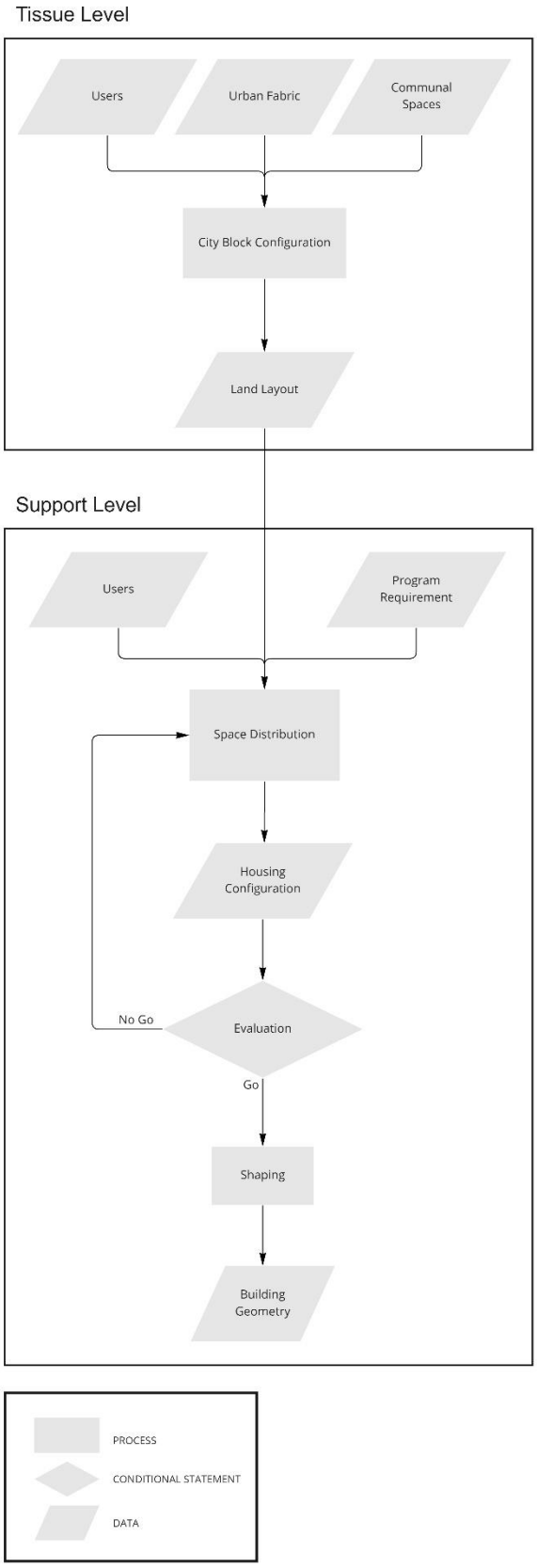



*Figure 17: Flowchart of the Game by Author, 2022.*

- Develop discrete game pieces that reflect the non-trivial topography of the site.
- Develop a meta-game structure that can be adapted to the context.
- Integration of communal spaces.

## 4.2. Game Flow

Acknowledge the concept of Open Building from Habraken (1961), the first step was to categorize the game design into their related level of decision making in the building design. Thus, the levels that this game will be working with are the tissue and the support level (Figure 17). The tissue level of decision-making will be related to the communal spaces, their disposition within the urban fabric and its options. The same will be done to the portion of the land available for the family. After configuring the city block with communal spaces and lands, the game moves forward to the next level of decision making, the support level. The support level works with the configuration of the space within the land, where each family member will have a say during the decision-making process. Both levels work with configuration and connection of spaces, but while the tissue level focus on the macro level and the relation between different families and its background, the tissue level focus on the micro scale and particularities within each of these families. To support the decision-making process game components, rules and framework were set and created.

## 4.3. Game Components

The designing of game components was crucial for engaging the players, understanding the game, and facilitating the decision-making process. Some terminologies are described below for the easy comprehension of this section:

- Game Piece: Lego-like piece that represents space and function.
- Coin: Element used during the game to acquire Game Pieces.
- Boardgame: Represents the land where the housing will be constructed or the site of the city block. Its dimension and topography depending on the constraints of the social housing

program, the urban fabric and the local topography.

- Voxel: Represent a regular three-dimension space.
- Cards: Element that helps in the engagement of the game.
- Grid: Two-dimension grid system
- Tile: The smallest unit of the grid system.

### 4.3.1.Lego and Game Piece

Lego symbolize discrete design language, modularity, and simple and universal programming logic (Chen et al., 2021)[68]. Therefore, using Lego pieces and their proportion to design the Game Pieces was fundamental to achieving some of the design principles. Compatibility between both pieces was crucial to still use regular Lego pieces in the design game. For example, Lego bricks, Lego plates and Lego tiles could be considered as topography, slabs, and roof, respectively during the game. At the same time, it was necessary to design a Game Piece that represents the idea of space, but without constraining the function of the space and the connection between the spaces, so that no limitation was placed on the user's expression of the configuration of their houses and neighbourhood block. Some criteria were considered when designing the Game Pieces:

- Lego compatible.
- Facilitate the visualization of the space inside the Game Pieces.
- The height should be equal to four Lego bricks stacked on top of each other.
- Modular staircase.
- Printable without support, self-standing structure
- Matching openings
- Opening differentiation between doors and windows.

Different inspirations and methods were tested before finding the final form of the Game Pieces. Self-standing compression-only structures, like Gothic, Armenian and Persian architecture were studied, as well as Catmull-Clark subdivision surface modelling, discrete tessellation, and modular approaches were tested (Figure 18). The modular approach inspired by the Muqarnas was the method that best matched the criteria described before (Figure 19).

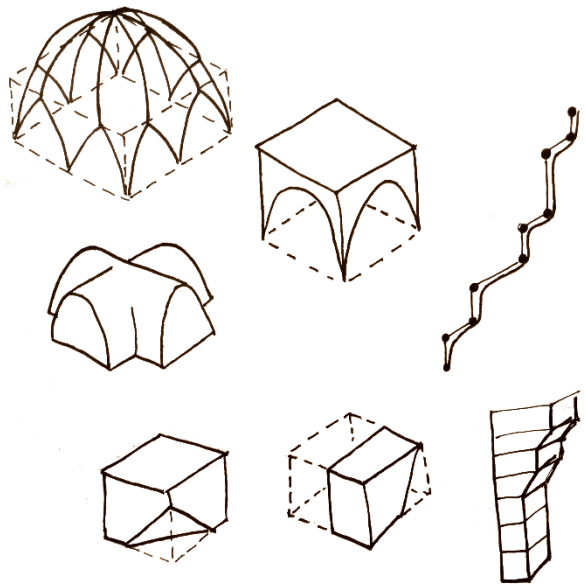


*Figure 18: Sketches by Author, 2022.*

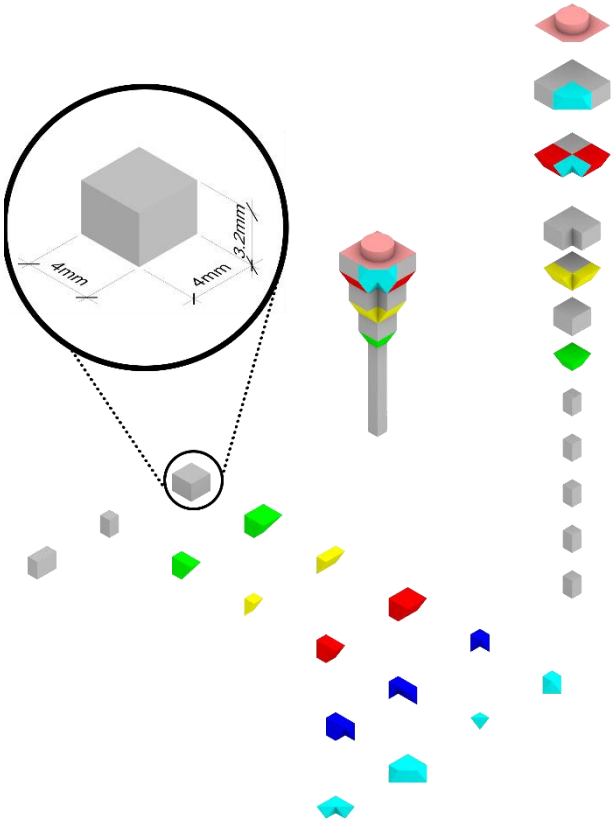



*Figure 19: Modular segmentation inspired by Muqarnas by Author, 2022.*

[68] Chen, Wang, and Chen, "Lego Architecture."

Besides the Game Pieces' shape, its dimension was studied and tested. Although the pieces are a discrete representation of the possible spaces and functions, it was needed to study the potential functionalities that the space could have and the dimension needed for that function, but always having in mind the Lego proportion. So, a program requirement was made based on the local requirements and characteristics, and after it was considered the Building Code of Manaus related to Social Housing to set the minimum dimension needed for each function. In general, functions related to wet areas were the only ones tied to a specific Game Pieces dimension (Figure 20), while the other functions have the autonomy to be represented by more than one Game Piece dimension.

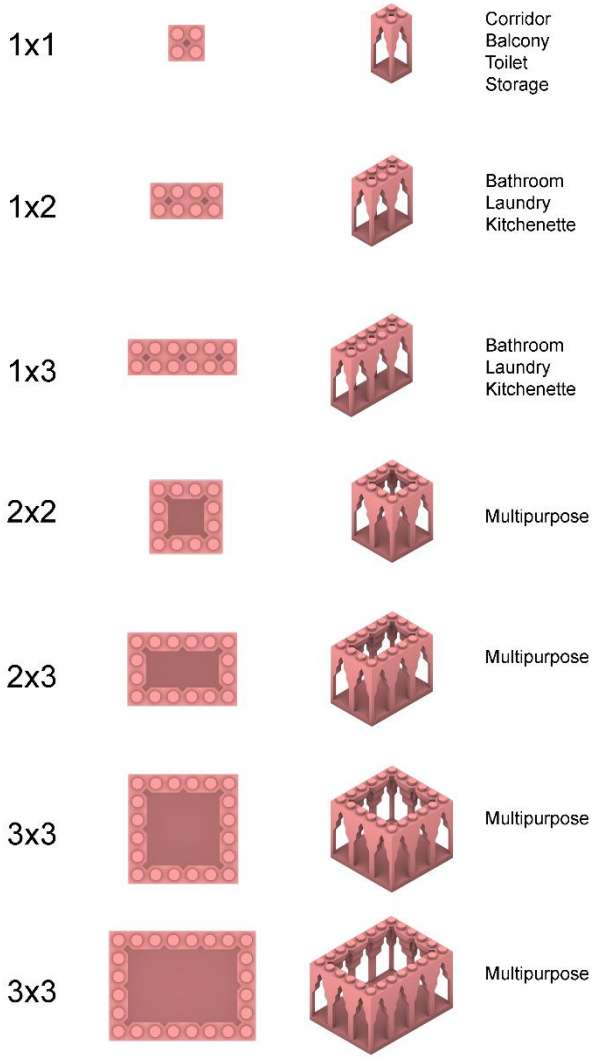



*Figure 20: Game Pieces, By Author, 2022.*

Another relevant Game Piece was the staircase module (Figure 21), which besides creating one large Game Piece that represents the entire staircase needed to move from one floor to another, it was designed as a staircase unit that reaches a smaller height difference of one Lego Brick height (0.96cm). The staircase unit (Figure 22) was inspired by the understanding of the possible relationships that the user can have with non-trivial topography, like the Riverside people which the distance between the ground and the dwelling (stilt house) can vary depending on the topography, the geography and the ebb and flood of the river. Therefore, the staircase, in general, must be modular to facilitate its replicability and applicability.

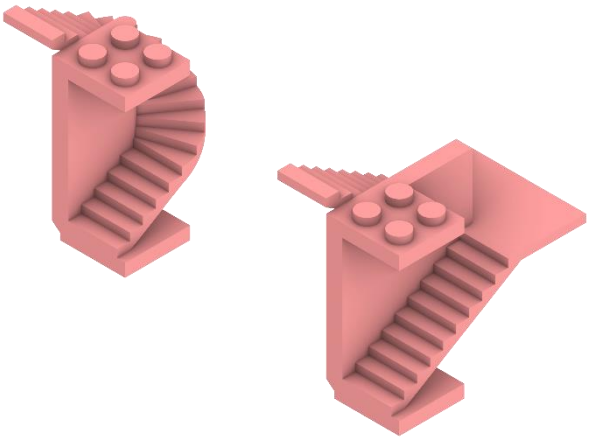


*Figure 21: Staircase Module by Author, 2022.*

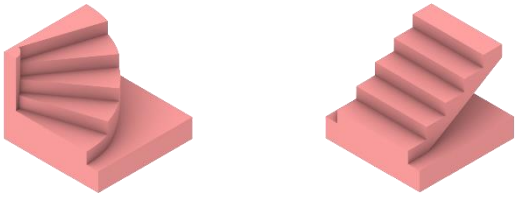


*Figure 22: Stair unit, by Author, 2022.*

The Lego proportion and dimension do not fit economically and spatially to the physical constraints. Exemplifying, one Game Piece of 1.6m x 1.6m x 3.84m (width x length x height) is too big to be considered the smallest space according to the Social Housing requirements of the Building Code of Manaus. Therefore, the Lego proportion had to be scaled down from 1:100 to fit on a 1:87.5 scale. Although the uncommon scale relation, created a voxel dimension of 1.4m x 1.4m x 0.84m (w x l x h) (Figure 23) that matched with the Building Code criteria and the

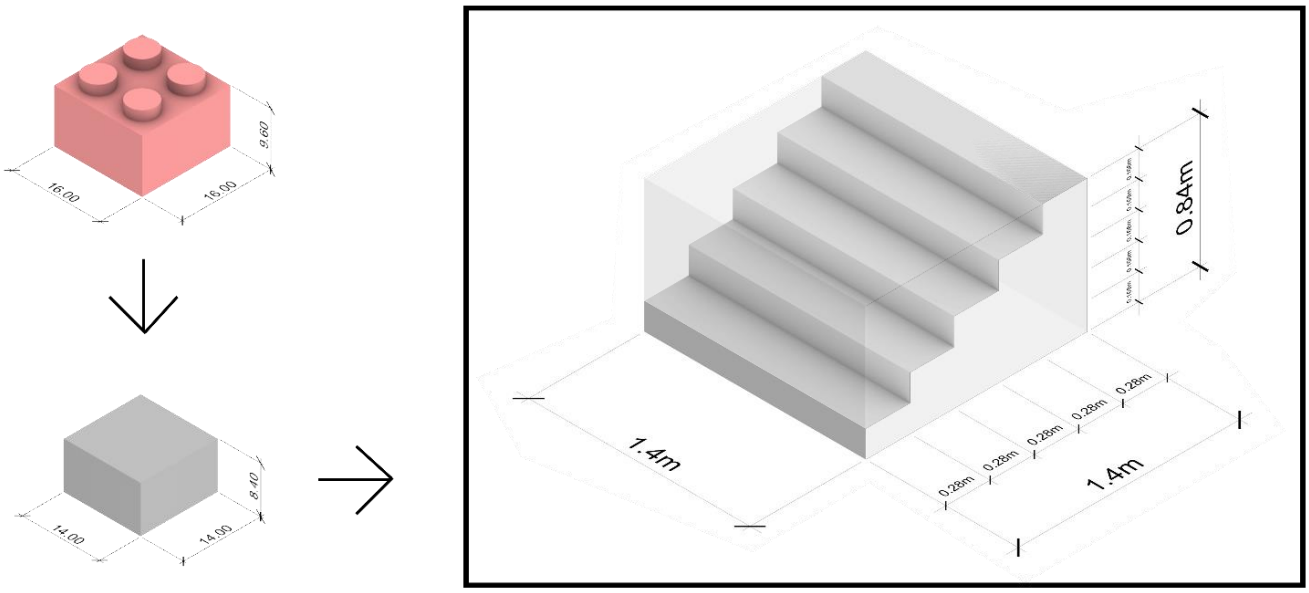



*Figure 23: Lego Brick, Voxel and Stair. by Author, 2022*

tread and riser dimension rules of the Brazilian Norm of Accessibility to buildings (NBR 9050) for vertical circulation:

- Tread (t): 0,28 m ≤ p ≤ 0,32 m e
- Riser (r): 0.16 m ≤ e ≤ 0.18 m;

Reminding the height criteria of four Lego bricks stacked on top of each other, with the proposed voxel dimension the height between the floor is transformed to 3.36m. Which is achieved by using 20 steps, where five steps fit into each voxel, with a riser of 16.8cm and tread of 28cm., creating a modular stair unit system.

The voxel grid was transformed into a two-dimension grid system of 1.4m by 1.4m, and each tile that represents a square of 1.4m by 1.4m could accommodate a tartan grid inside. The tartan grid used a double band of 0.20m each, leaving 1m x 1m internal space within it, considered the smallest spatial dimensional unit of the design (Figure 24). The bands represent different building elements and materials, like walls, openings, and location of columns, giving the user the option to choose during the game process the type of walls and openings, this will be further illustrated in section 4.5 Shape Grammar.

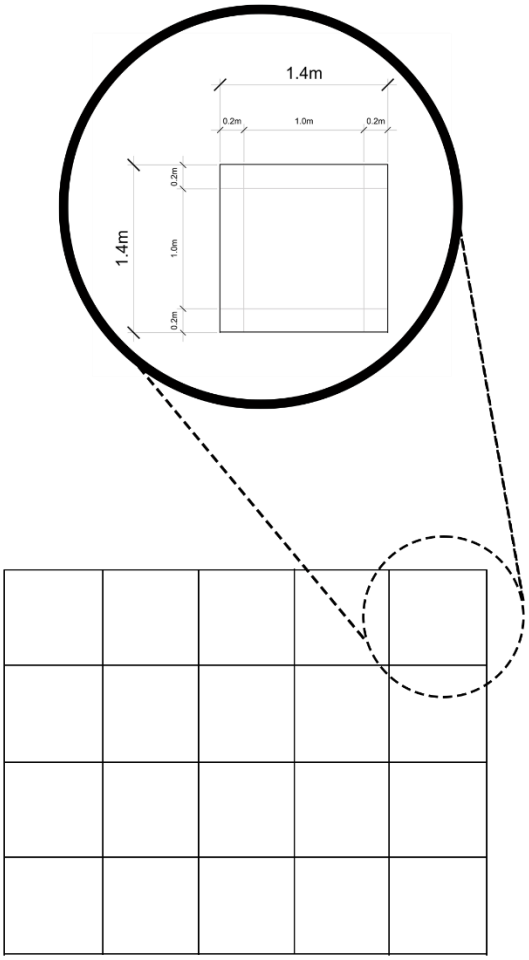



*Figure 24: Tartan Grid and Grid System, by Author, 2022.*

### 4.3.2.Cards

There are Four different types of cards: Common Cards, Spatial Cards, Activity Cards and Evaluation Cards. The Common and Spatial cards act as a play mechanism of the design game to engage the players, they can represent rewards or punishments. Both cards intend to instigate the players to come together as a group and find ways to achieve their goals in the configuration of the space. The Common Cards (Figure 25) influence the resource management of the coins since they dictate if the player loses or wins a coin, and consequently, it influences the purchasing power of the Game Pieces.

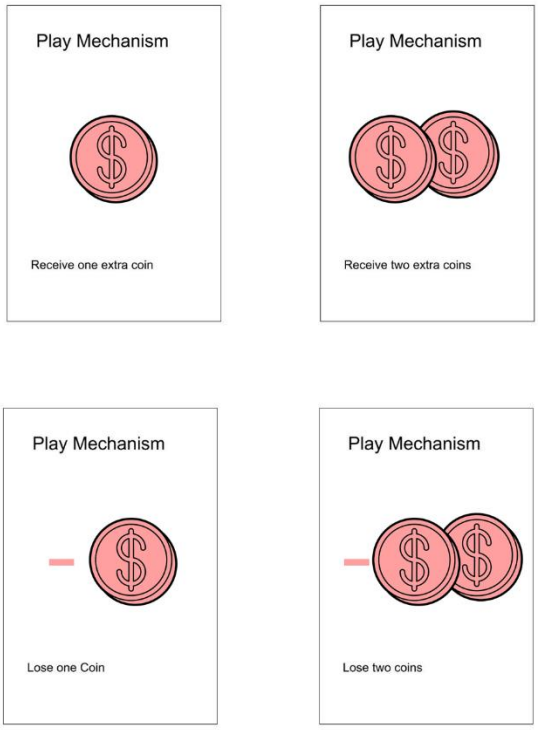



*Figure 25: Common Cards, by Author, 2022.*

Spatial Card affects the spatiality of the design game, with mechanisms that force the player to change the space configuration against or in favour of their desire. Next can be seen all the Spatial Cards available (Figure 26):

- Bulldozer: can remove an entire space module
- Change Position: change the position of a space module on the board, by rotating it or moving it to a different position, as long there is free space to do so.
- Add a multipurpose room of 3x4
    - The player(s) must pay for it, it is compulsory to discuss with the other players where to place it.
- If you have a kitchen change to a kitchenette and vice versa.
- If you have a bathroom change to a toilet and vice versa.
- Reduce one space module of your preference to its smaller version.
    - It is compulsory to discuss with the other players which space module to reduce.
- Increase to a bigger version of one space module of your preference.

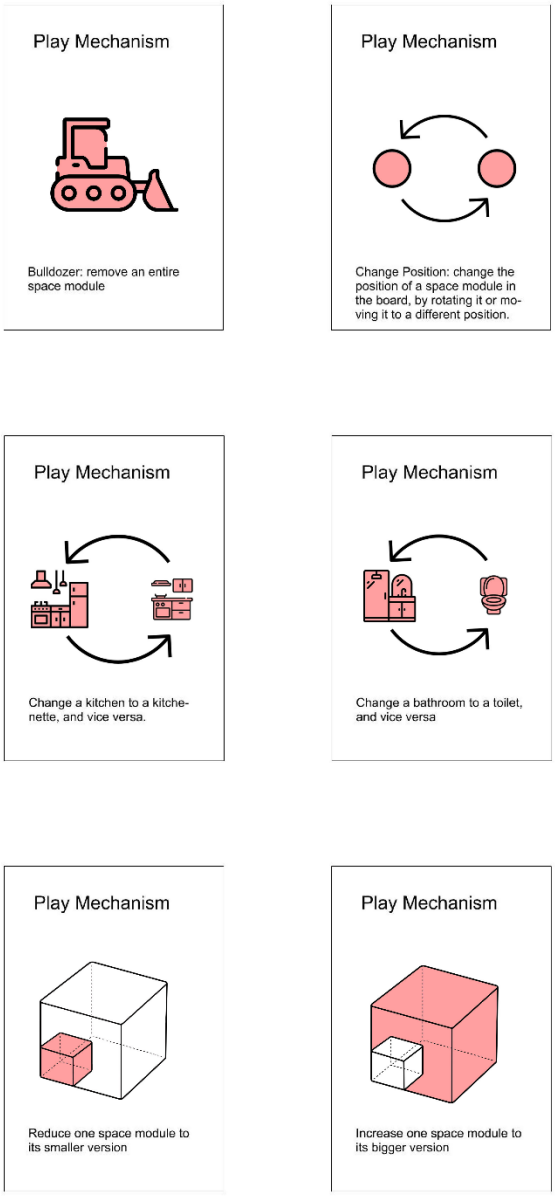



*Figure 26: Spatial Card, by Author, 2022.*

- It is compulsory to discuss with the other players which space module to increase.

The Activity Cards represent functions that can take place in the tissue or support level of the game (Figure 27 and 28). It is an easy way for to players visualize the available functions and build their program requirements. Reminding that the functions will depend on preview research done about the context to understand the common preference and needs of the population, to customize and delimitate the option available. Otherwise, the process of choosing and building their program requirement would take time. Therefore, in the meta-game, this is an element that must be adaptable according to the context.

Some examples of the Activity Cards were based on the Study Case, like the option of having a public swimming pool and small public squares, since this was one of the highlighted patterns that were lost in the transition from the village to the city. Another activity, now related to the support level was the commercial room, which is linked to the fact that low-income families in Brazil tends to have commercial activities inside their dwellings, a post-occupancy renovation highlighted in the study case as well.

Evaluation Cards are inspired by the scoring cards from the Cartographer game. A simple method of making the user to score their configurations by following simple rules described in the card. These cards will be presented and explain further in section 4.6 Evaluation.

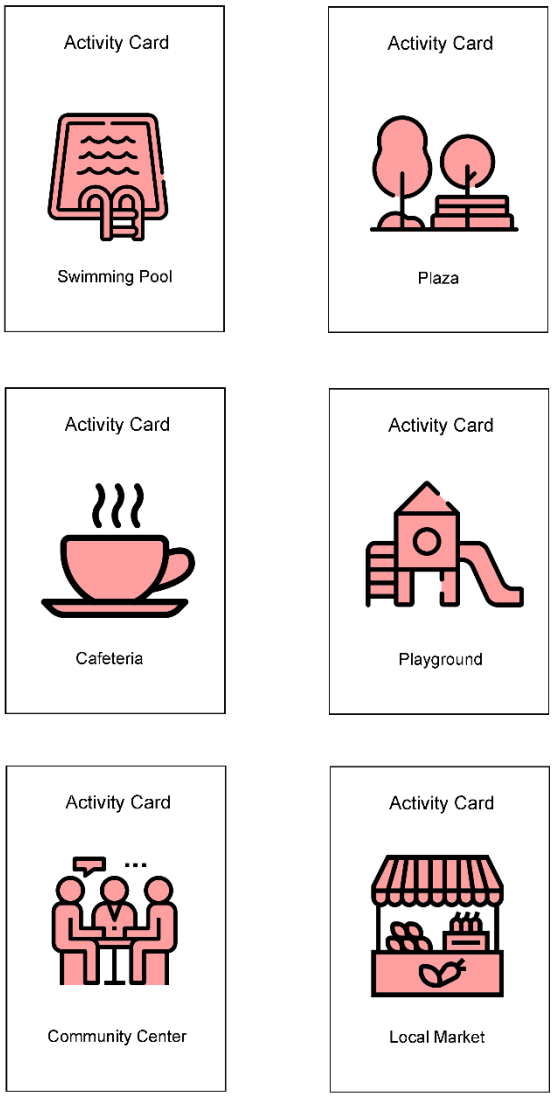



*Figure 27: Example of Activity Cards for Tissue Level by Author, 2022.*

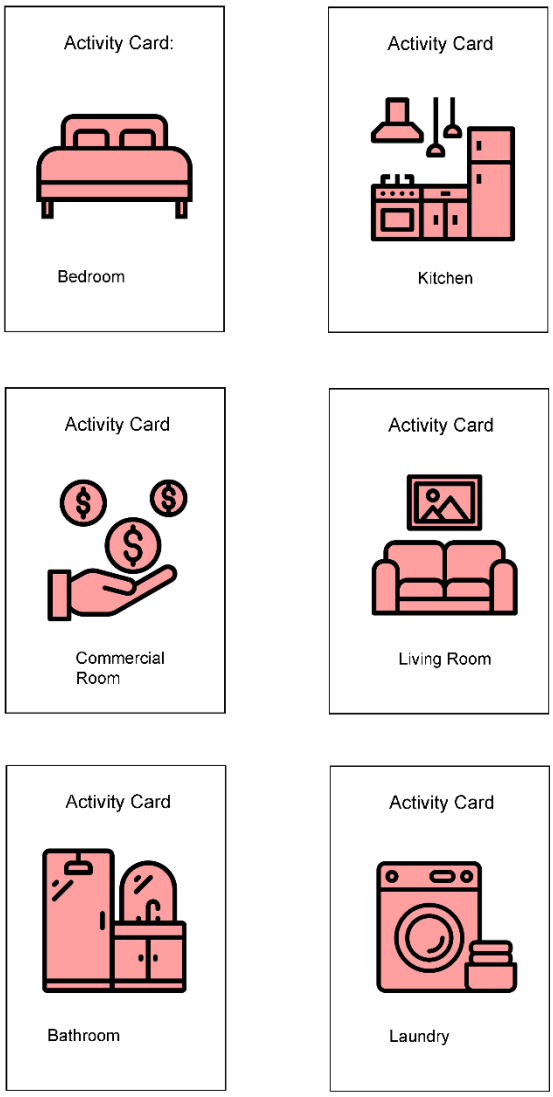



*Figure 28: Example of Activity Cards for Support Level by Author, 2022.*

## 4.4. Game Rules

- Each participant starts with the same number of coins.
- Each round will be led by a different participant, who will choose the game piece of their interest and persuade the other participants to help him/her to get the game piece.
- Each game piece costs a specific amount of coins.
- The players can purchase only one Game Piece per round, but in the case of pieces that are 1x1, the players can purchase up to four at once.
- Only a Spatial Card can be bought, costing 5 coins each.
- The Spatial Card can only be bought when it is your turn in leading the round.
- The bought Spatial Card must be used right after its purchase.
- For each round, the player who is leading must take one card from the pile and follow the instructions of the card.
- The spatial and common cards should always be shuffled together and face down so the player does not know which card they are picking. Whenever a card is picked, the player must use it right away.

## 4.5. Shape Grammar

Three general shape grammars were made. The first shape-grammar was based on recognizing the Game Pieces and giving as output the possible function that the specific Game Piece can contain (Figure 29). Technology such as photogrammetry can be used to recognize and identify the Lego piece.

The second shape grammar regards the function as input and the 2D layout as the output (Figure 30). The 2D drawings represent already the possible position of walls and openings, but it does not specify them yet.

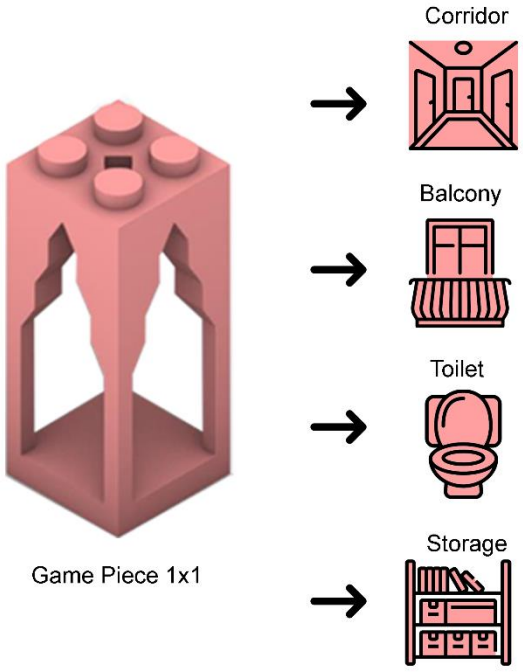



*Figure 29: Game Piece to Function by Author, 2022.*

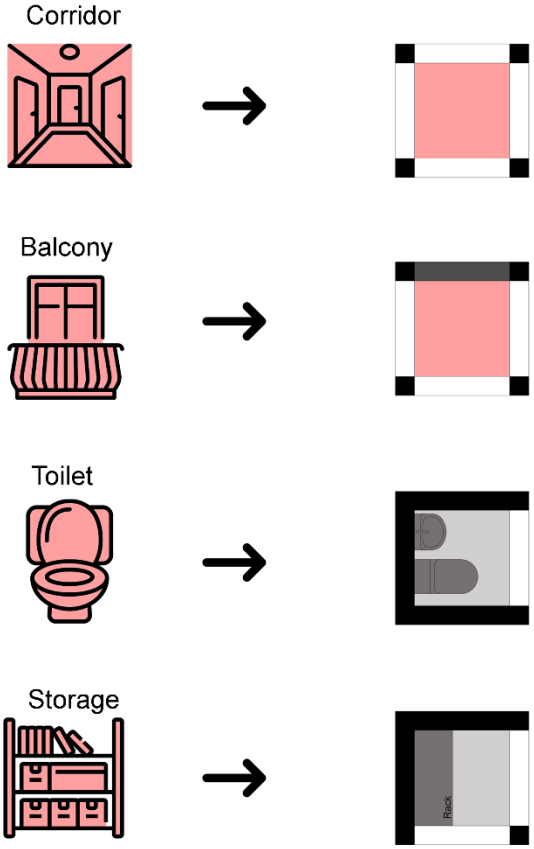



*Figure 30: Function to 2D drawing and Opening by Author, 2022.*

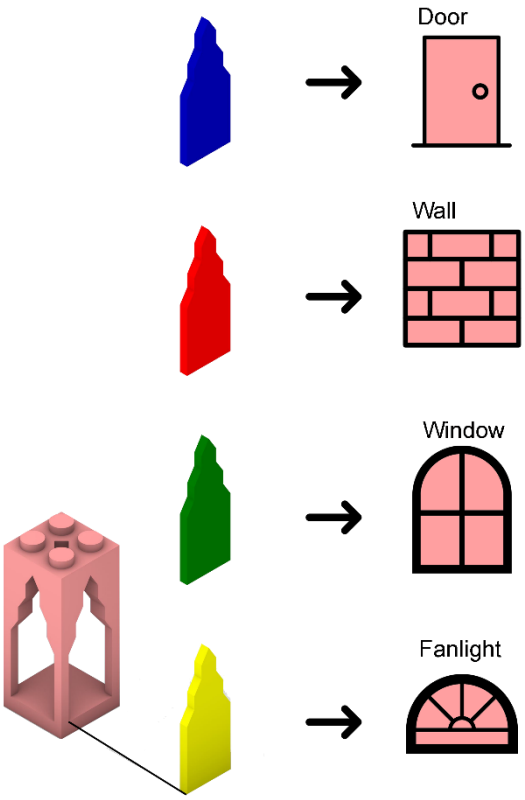



*Figure 31: Colour Grammar, colour to opening by Author, 2022*

The third grammar works on the specification of the openings. So, the plug-in pieces of the Game Pieces will represent different types of openings, this differentiation will be done by Colour grammar (Figure 31).

The next grammar defines the opening to a specific shape, the shape can vary according to some cultural expressions of the context. This example will show some examples of typical elements from the context of Brazil, like the 'cobogós', perforated bricks used to increase the ventilation and natural light inside buildings (Figure 32).

With all the shape generated with the previous Grammars, the last Shape Grammar would be a combination of all the data combined and giving as an output a 3D Model of the space configured. For detailed Shape Grammar see Appendix B.

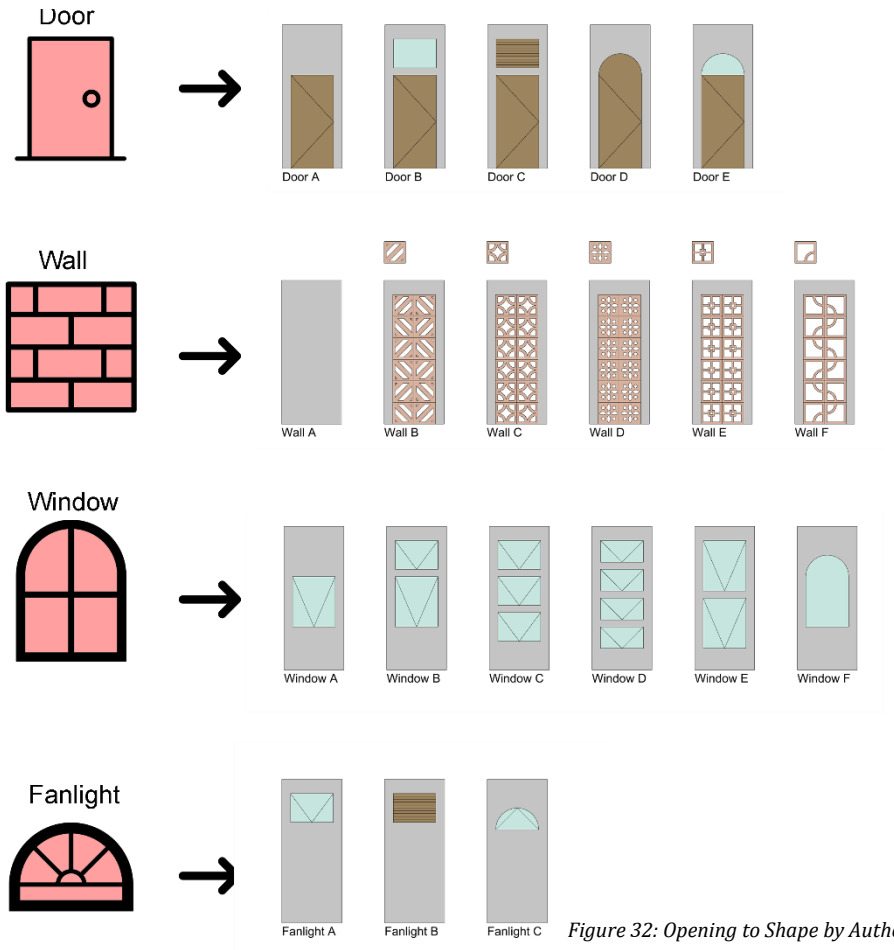



*Figure 32: Opening to Shape by Author, 2022*

## 4.6. Evaluation

The evaluation process checks the spatial quality and validity of the configuration generated by the end-user. Both were inspired by the construction requirements of the 'Urban and Environmental Master Plan of the Municipality of Manaus', which have regulations based on the local climate. The aim of most of the created constraints is to assure natural light and ventilation.

The evaluation will be made manually by the players, by followings step by step the instruction of the Spatial Quality Criteria and the Spatial Validity Criteria. That way by the end of this procedure they will know if their configuration will be procced to the Shaping stage. But in case of an invalid configuration, they will be already aware of what are the criteria that they could improve since they were exposed to them during this stage.

### 4.6.1.Spatial Quality Criteria

The Spatial Quality Criteria is divided into two qualities, one related to the land plot and the other to the building relation. Both must use a scoring mechanism from 0 to 5. A lower score will not veto the design, but the players can choose if they would like to improve the spatial quality scoring of their configuration or not. In case of want to improve, the player will return to the Configuration phase. For them to have a parameter of comparison, the configuration templates that they had access to during the Planning stage will have the corresponding scores for each configuration.

The method implemented for the scoring mechanism in this section is inspired by the Cartographer game, where the players score themselves by using following the instruction of the cards. Therefore, it was created Evaluation Cards as mentioned in the 4.3.2 Cards section. Here it will be explaining further how the constrains of the Context influenced in the design of the Evaluation Cards.

#### 4.6.1.1. Land Plot Constrains

The land plot constraints were based on the building plan code of Manaus, which considers the minimum allowed plot area for social housing to be 125 $m^2$ and the minimum frontage of 5 m. Next, it is the translation from the Building Code of Manaus of the minimum clearance table chart for social housing buildings (Table 2).

*Table 2: Minimum clearance for social housing buildings*

| Regarding the minimum distances from the building: the following distances must be guaranteed: | | | |
|---|---|---|---|
| Number of Floors | Frontal Distance (m) | Lateral Distance (m) | Background Distance (m) |
| 1 | 3 | 0* | 1 |
| 2 | 3 | 0* | 1.5 |
| 3 | 4 | 2 | 2 |
| 4 | 5 | 3 | 2.5 |
| 5 | 5 | 3.5 | 3 |
| * For cases in which there is no opening in the lateral façade, the lateral clearance can be zero.<br>But for cases in which the applicant considers lateral clearances with openings in their design, the lateral clearances for one floor will be 1 m and, for two floors, it will be 1.5 m.<br>Can be assumed one of the lateral distances to be 0 m | | | |

However, for the sake of pushing further the possibilities and variety of the configuration, it was allowed and tested gameboard with smaller dimensions than the one imposed by the code, but still assuring ventilation and natural lighting. The unit distance for the clearance distance was adapted from meters to tiles, to facilitate the evaluation, recalling that one tile is 1.40 by 1.40m. Follows the point mechanism for the Land Plot Constrains (Figure 33):

- Earn 1 point for each empty tile in the plot that is not adjacent to the edge of the plot
- Earn 2 points for each empty tile adjacent to the edge of the plot
- Earn 5 points for each complete row or complete column of empty tiles adjacent to the edge of the plot.
    - If adjacent to those rows or columns there is a complete row or complete column of empty tiles earn 5 points for each of them.
- Earn 3 points for each complete row or complete column of empty tiles that are not on the edge of the plot or adjacent to those that are on the edge of the plot.

- Lose 5 coins for each added floor after the building reaches five stores.

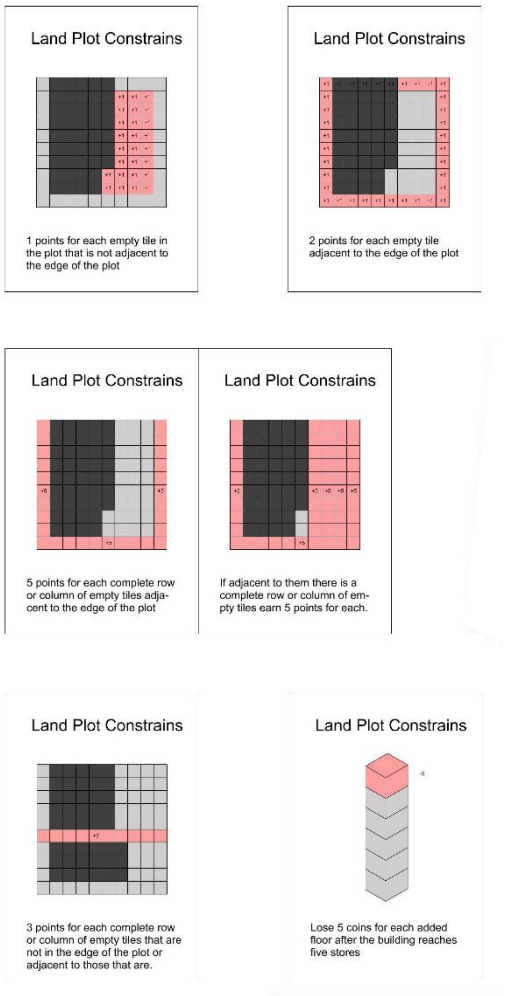



*Figure 33: Evaluation Cards: Land Plot Constrains by Author, 2022.*

### 4.6.1.2. Building Constrains

The criterion for the Building Constraints is more related to the ideal practice of spatial configuration, representing a pattern of the current best guess on how to arrange a physical environment (Christopher Alexander et al., *A Pattern Language*, p. xv). Therefore, even when the configuration does not score, the design is not eliminated. Next is the point mechanism for the Building Constraints (Figure 34):

- Earn 1 point for each wet area adjacent to another wet area.
    - Wet area: toilet, bathroom, kitchen, kitchenette
- Earn 2 points for each wet area placed above another wet area
- Earn 1 point for each commercial module placed facing the street.
- Earn 1 point for each staircase connected to a free passageway
- Earn 3 points for each space module that shares four edges with another space module
- Earn 5 points for each kitchenette space module that shares one edge with a multi-purpose space module.

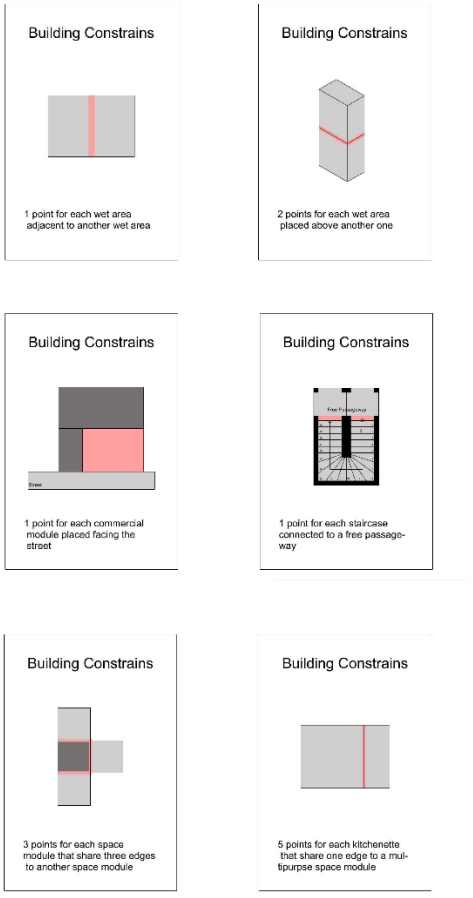



*Figure 34: Evaluation Cards: Building Constrains by Author, 2022.*

## 4.6.2.Spatial Validity Criteria

The spatial validity is based on the go or no-go mechanism since the lack of certain validity criteria will directly turn the configuration invalid. In the case of a non-valid design, the end-user will know directly what should be improved in their design. The spatial validity

mainly assures natural light and ventilation of the building. According to the building code of Manaus, the openings for ventilation and lighting should attend 1/5 of the total area of the room. Therefore, to calculate the number of windows and fanlights necessary for each space module was made the following chart table (Table 3) with all the necessary information.

*Table 3: Opening for Ventilation and Lighting by Author, 2022.*

| OPENINGS FOR VENTILATION AND LIGHTING | | | | |
|---|---|---|---|---|
| Tile | Area of the room | 1/5 of the total area of the room. | Number of windows* | Number of fanlights* |
| 1 x 1 | 1 $m^2$ | 0.2 $m^2$ | - | 1 of any kind |
| 1 x 2 | 2.4 $m^2$ | 0.49 $m^2$ | - | 1 fanlight A or 2 fanlight B |
| 1 x 3 | 3.8 $m^2$ | 0.76 $m^2$ | - | 2 fanlight A or 3 fanlight B |
| 2 x 2 | 5.76 $m^2$ | 1.15 $m^2$ | 1 of any kind | - |
| 2 x 3 | 9.12 $m^2$ | 1.82 $m^2$ | 1 window B/C/D/E or 2 windows A/F / G | - |
| 3 x 3 | 14.44 $m^2$ | 2.89 $m^2$ | 3 windows A or 2 windows B/C/D/E /F/G | - |
| 3 x 4 | 19.76 | 3.95 $m^2$ | 4 windows A or 3 windows B or 2 windows C/D/E | - |
| *According to the average area of the window, how many window or fanlight are necessary to fulfill the requirements. | | | | |

The different sizes options of windows and fanlights had an impact on the quantity of each of them per space module. To simplify the constraints, and speed up the process of the evaluation, the number of windows and fanlights were rounded up or made the average. Finally, the result of the Validity Check can be seen in the following chart table. A similar checklist will be given to the players so they can evaluate by themselves their spatial configuration (Table 4). In case one of the constrains is not followed, meaning marked as "No", the design is invalid and it should be made again by the players, but this time the players would already know what makes their configuration invalid.

*Table 4: Validity Checklist by Author, 2022.*

| **Validity Check** | | | | |
|---|---|---|---|---|
| Only the space modules used in the configuration of the house must be checked as a GO. | | | | |
| Game Piece | Function | Constrains | Yes | No |
| 1 x 1 | Corridor | At least two of the facades must be a free passageway/doors. | | |
| 1 x 1 | Balcony | At least one façade must be a parapet. | | |
| | | At least one façade must be a door or passageway, to give access to the balcony. | | |
| 1 x 1 | Storage | In case of only one tile, the storage must have only one door. | | |
| | | In case of multiple tiles set together, the storage set must have only one door. | | |
| 1 x 1 | Toilet | Must have one fanlight connected to the exterior of the building. | | |
| | | Must have one door. | | |
| 1 x 2 | Laundry | Must have one fanlight connected to the exterior of the building. | | |
| | | Must have one door. | | |
| 1 x 2 | Bathroom | Must have one fanlight connected to the exterior of the building. | | |
| | | Must have one door. | | |
| 1 x 2 | Kitchenette | Must have one fanlight connected to the exterior of the building. | | |
| | | Must connect with a multipurpose room | | |
| 1 x 3 | Bathroom | Must have one fanlight connected to the exterior of the building. | | |
| | | Must have one door. | | |
| 1 x 3 | Kitchenette | Must have one fanlight connected to the exterior of the building. | | |
| | | Must connect with a multipurpose room | | |
| 2 x 2 | Multipurpose | Must have at least one window connected to the exterior of the building. | | |
| | | Must have at least one door / free passageway. | | |
| 2 x 3 | Multipurpose | Must have at least one window connected to the exterior of the building. | | |
| | | Must have at least one door / free passageway. | | |
| 3 x 3 | Multipurpose | Must have at least two windows connected to the exterior of the building. | | |
| | | Must have at least one door / free passageway. | | |
| 3 x 4 | Multipurpose | Must have at least three windows connected to the exterior of the building. | | |
| | | Must have at least one door / free passageway. | | |

### 4.6.3. Conclusion

The Land Plot, Building and the spatial validity criteria assist at a certain level to assure that natural light and ventilation are entering the building. The building-related constraints tackle the connection as well between the space module, accessibility and placing the space module. The spatial validity and the building constraints could be used in the apartment complex for social housing, not only for houses.

Following strictly the Building Plan Code of Manaus would narrow down the housing configuration possibilities, therefore the important of considering, testing and reflecting on different rules that can still assure the ventilation and lighting necessary while allowing more freedom in the configuration possibilities.

## 4.7. Game Framework

The Game Design is divided in five stages, each of them have their specificities:

1st stage, Planning.

- Duration: 10 min.
- Discussion between players, what are their preferences, dislikes, a program of requirements and distribution of the space.
- Activity Cards are introduced in order to player built their program of requirement.
- Game Pieces are introduced. Players try different configuration with the pieces to reach in a draft configuration, so they can move forward for the next stage.
    - The draft configuratino won't be used to set a constrain, this is to let the players try to come up with an idea for their house, and they are free to change it later.
- Create a budget from the draft congifutation. Reminder, each Game Piece has a cost.
- Divide equally the budget among the players.
- Show templates of housing, different models, and distribution, so they can get some inspiration while they are playing this game.

2nd stage, Configuring: Zoning.

- Duration: 15-30 min.
- In order to achieve the configuration from the previous stage, players must pay for each Game Piece using the coins that were distributed among them.
- Play meachanism cards (Common Cards and Spatial Cards) are introduced. They should be shuffled and faced down.
- Each player will lead one round, meaning that the leader of the round is the one who picks a play mechanism card from the deck.
- The leader must discuss with or persuade the other players to help pay for the Game Pieces and where to place it on the gameboard.
- The number of rounds will depend on until when the players achieved the final configuration.
- The Activity Cards should be displayed in front of the players, to help them visualize their program of requirement.

3rd stage, Configuring: Routing.

- Duration: 10min
- Shape Grammar are introduced. Game Pice to Functions, Function to Modular Furniture (or 2D Drawings), and Colour Grammar for the openings.
- Modular Furniture are used by the players as a puzzle to built the inside space of each Game Piece. Helpping them to visualize the flow of people from one space to the other and where should be putted the opnenings.
- Players will specify:
    - Where the openings will be placed
    - Which type of opening

4th stage, Evaluation.

- Duration: 10 min
- Quality Check:
    - Point mechanism.

    - This process does not eliminate the design. But it gives information to the player on how to improve it.
- Validity Check
    - Go/No-Go mechanism
        - All criteria are checked, then is a Go:
            - Players can move to the 5th stage
        - One or more criteria are not checked then is a No Go:
            - Explain and point out what is missing in their configuration to have enough score to achieve a Go.
            - Return to 2nd stage and repeat the process.

5th stage, Shaping.

- Duration: 10 min
- Materialization of the Building Geometry
    - Choose the material of the building
    - Chose the size and type of openings and roof.

# 5. Meta Game

The meta-game is divided into five stages which will order the design decision-making process from abstract to concrete. The stages are Planning, Configuring-Zoning, Configuring Routing, Evaluation and Shaping, each of them has an expected input and output (Figure 35).

These procedures help to abstract and understand the key points of the method being developed and highlight what can be altered in this framework for adaptation to the context. Allowing the participatory design game to adapt to the context in which is being implemented, is to recognize that cultural and social values may differ from society to society and even between individuals in the same society. Therefore, acknowledging that those values play a direct role in spatial configuration.

The meta-game uses a modular system to facilitate the replicability, mass-customization, and flexibility of the configuration and the design. Before moving further to describe each stage, follows some background information from Go-Design (Azadi et. Al, 2021).

> 'Multi-criteria complexity is concerned with balancing static and dynamic/operational qualities that a design is required to provide, such as light, solar energy, etc. The multi-actor complexities stem from the difference in the goals of stakeholders. Finally, the multi-value complexity originates from the uncertainties and ambiguities inherent to human perception and communication, which can be traced in self contradictory preferences, bounded-rationality, miscommunication of goals, and individual-communal good dilemmas as discussed in Game Theory (q.v.(Cunningham, 2018)'

The aim of the meta-game is:

- Adapt the gamified design process to the context in which is being implemented.
- To simulate/replicate local scenarios
- To achieve mass-customization for social housing
- To engage end-user to discuss their ideas on how the housing configuration should be.
- To give the power to the end-user to co-create their housing.
- To help visualize, and consequently understand, what the end user want/need from the housing to satisfy their needs and preference.
- To follow local constructions guidelines
- To generate a drawing of the created building geometry

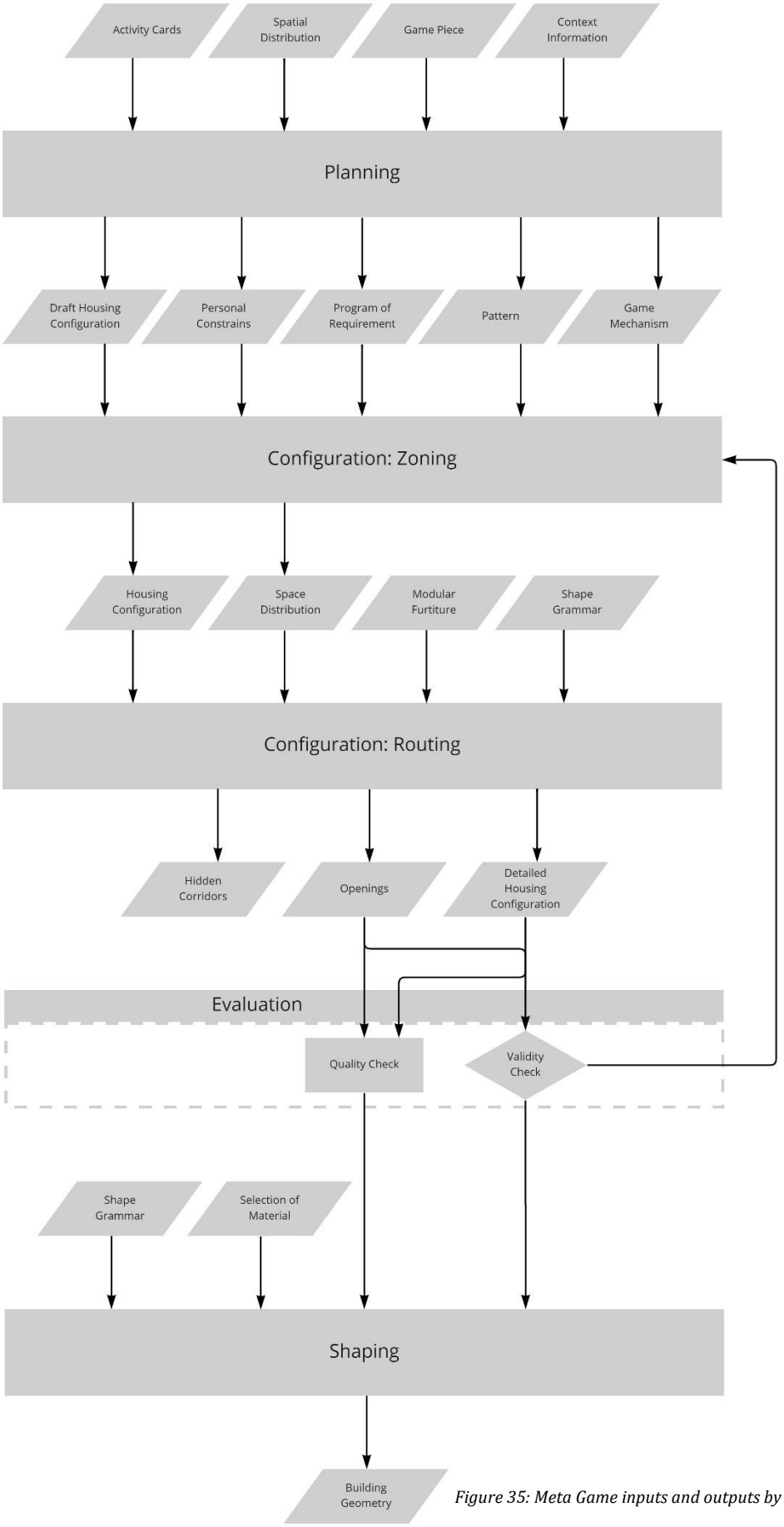



*Figure 35: Meta Game inputs and outputs by Author, 2022.*

## 5.1. Planning

Planning is the first moment where the end-users will express and specify their criteria, preferences, program of requirement, spatial organization, and social logic of the space. This process involves multi-values and multi-criteria complexities. This stage aims to reach spatial specification, spatial relation, and collective design goals. One of the outcomes will be a draft configuration made of Game Pieces that they are going to use as a guide for the next stage of the game.

Input as Activity Cards and Context Information are adapted to the context. The Activity Cards is built accordingly with Space Syntax Analysis and Pattern identification previously done about the context, to find common preferences and needs. For example, in Manaus, the data extracted from the population it was possible to identify patterns that the population were used to have before moving to the city, like Access to Water (25th) and base on that suggest communal spaces like public swimming pool that could keep alive that patterns. The Context Information is related to all the information and analysis gathered about the locality where the game is being applied. Information like population, their backgrounds, cultural identity and other are relevant information that can help the adaptation of the game in any context. The overall inputs and outputs can be seen in Figure 36.

The method for the Planning procedure is the consensus Building suggested by Henry Sanoff (2000), where the players are engaged to discuss and share their opinions, identify common preferences and goals, generate ideas and reaching to a consensus between the users. Another method present in this process is the participatory design which allows active involvement of the end-user in the design decision-making process.

From the structure of the Planning phase described above elements that can be adapted are the options available in the list of functions given to them, for example in some contexts having a room in the house dedicated to a small business (like a seamstress, cafeteria, small grocery store) can be common while in another context it is not. The housing templates shown to the participants can be based on housing configuring that already exists in that context but using the space modules of the game to translate that configuration. The way how the interaction is handled and encouraged between the end-users could be crafted according to the culture of the context. The topological and geometrical aspects of the Lego pieces could be adaptable to generate a better representation of the space from that context.

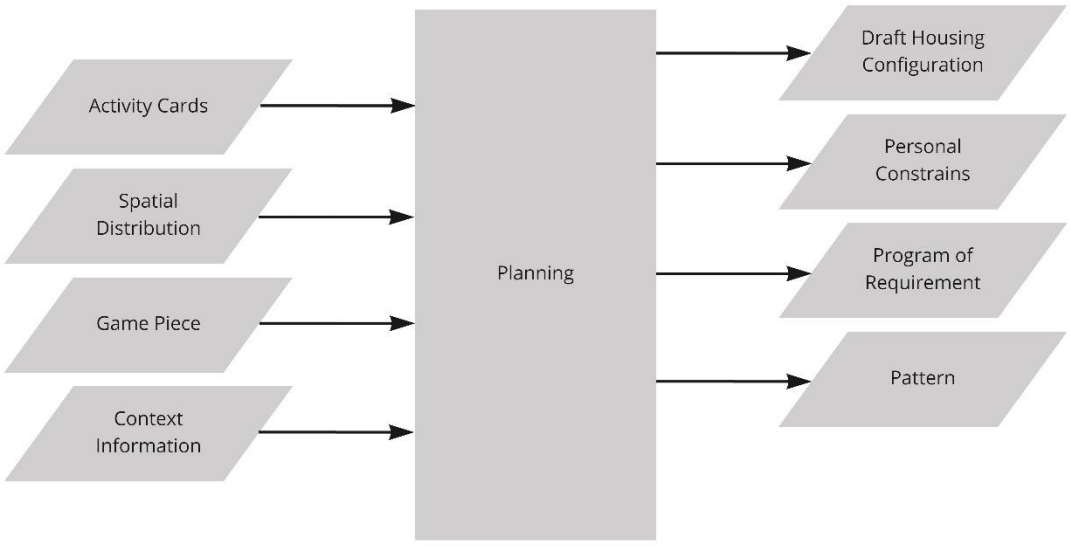



*Figure 36: Planning input and output by Author 2022*

## 5.2. Configuring: Zoning and Routing

The configuring stage works with multi-dimensional and multi-criteria complexities. This process focused on generating a housing configuration from the outcome of the previous step. Configuring is divided into two different phases: Zoning and Routing.

The Zoning phase involves inputs like game mechanisms, draft housing configuration, personal constrains of the users, their social logic of the space, pattern and connection between spaces (Figure 37). The game mechanism is standard to any context, since its goals is to engages players, motivates them to work together, and induces them to discuss and make commitments. Cards of activity used during this stage of the game are adapted to the context, since they translate the possible needs and preferences of the user, based on Context Information from the previous stage. Game pieces represent the space and function, facilitating the users to understand each others ways of connecting space, and the social logic behind.

The second process, Routing, allows the end-user to customize the interior of each space module through a modular system of furniture layout, allowing the visualization of hidden corridors and understanding of the walking flow from one space to another (Figure 38). As part of this procedure, the end-user must specify where the openings will be placed and which type. The shape grammar used in this stage can vary according to the Contex, by considering architectural style and creating option of opening and wall that consider cultural design expression. The modular furniture system should be adapted to the specific context, like the type of furniture, its dimension and distribution within the space.

The Configuring phase uses different methods like gaming, gamification, serious game, and participatory design. The gaming method simulates a real-life situation, highlighting the essential characteristics of the problem and allowing participants to interact with it (Henry Sanoff, 2000 and 1978). While the gamification allows the addition of a game mechanism to a non-game context (Deterding et al., 2011) and and seeks functionality and engagement of the players (Morschheuser et al., 2017). The serious game is described as games for non-entertainment purposes (Deterding et al., 2011), but could still be entertaining (Michael, 2006). The participatory design method allows the active involvement of the end-user in the design decision-making process.

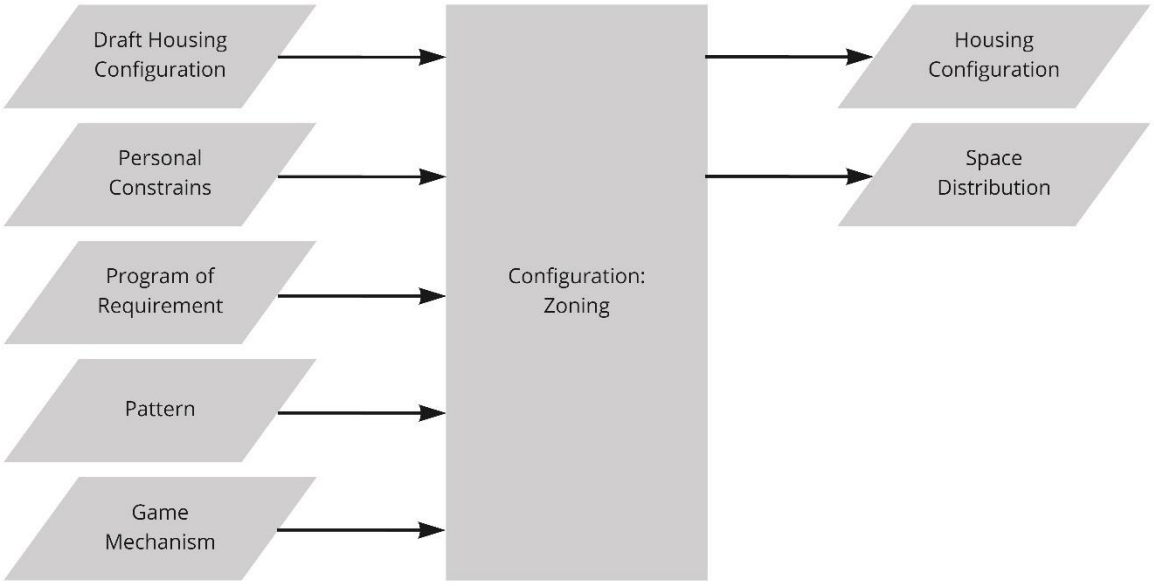



*Figure 37: Zoning input and output by Author, 2022.*

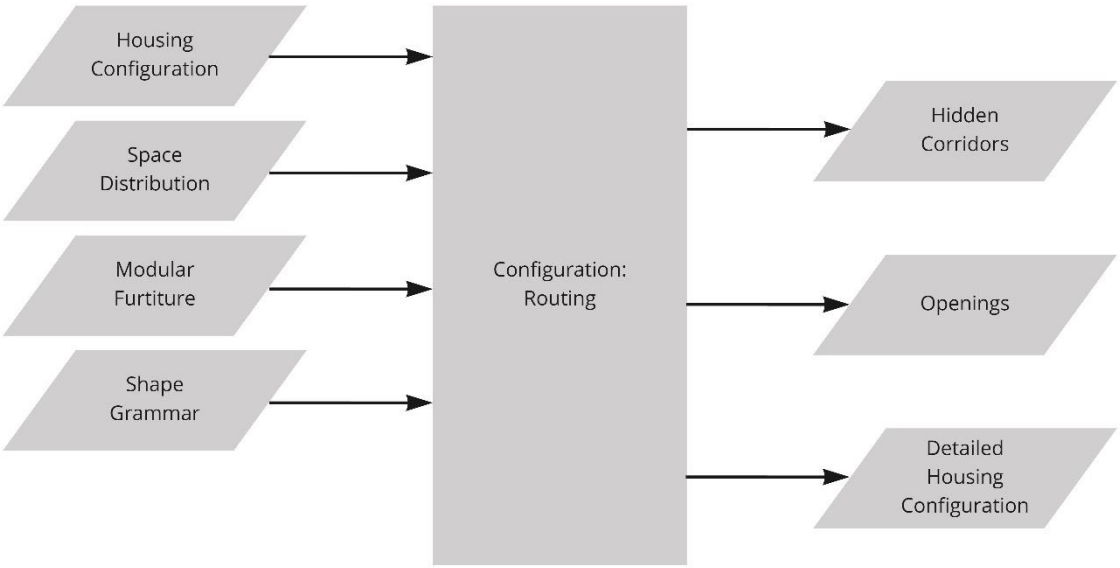



*Figure 38: Routing input and output by Author, 2022.*

## 5.3. Evaluation

The evaluation process checks the spatial quality and validity of the user-generated design. This stage aims to inform if a design is valid or not. In case of being invalid, point out a recommendation to improve the design. The criteria used to evaluate the design should be adjusted to the reality in which is being applied, therfore it should follow Building Code. The outcome of this stage will inform rather the design can proceed to the next step or if it will need to be improved, and for so, return to the Configuring Stage (Figure 39).

The multi-Criteria decision analysis (MCDA) method is a support tool at the stage of evaluating a project and helps frame different types of criteria in various fields of life and science, such as social, economic, environmental, spatial, etc (Ogrodnik, K 2019). Besides, this method helps in the process of scoring the configurations. In this evaluation process, spatial quality criteria and validity criteria will be used in the MCDA methodology.

The formulation of quality criteria can be any, as long it is computable and related to spatiality, for example, daylight, accessibility, visibility, noise, ventilation etc. Therefore, it will depend on the context which type of spatial quality criteria to consider in the evaluation process and their constraints must rely on the local climate, construction requirements and cultural aspects. This part of the evaluation must be point based, the result will not veto the design, it will only show the spatial quality scoring of that configuration. It will be up to the end-user if they want to improve it or not.

The validity check must be based on a go or no-go mechanism since the lack of certain validity criteria will directly turn the configuration invalid. Like the spatial quality criteria, the validity criteria must be based on the climate, construction requirements and/or cultural constraints of the context. Both processes of the evaluation phase, the spatial quality criteria, and the validity criteria can be made manually or computationally.

## 5.4. Shaping

Shaping is the last stage (Figure 38), it concerns the materialization of the building geometry, determining the aesthetics of the design and concretization of the building. Different options will be available so the players can select the type, size, design and position of walls and openings from the wall modules. They will be able to select the type of roof as well, from the roof modules and material. This stage must be crafted to the local architecture and style of where the building is being inserted.

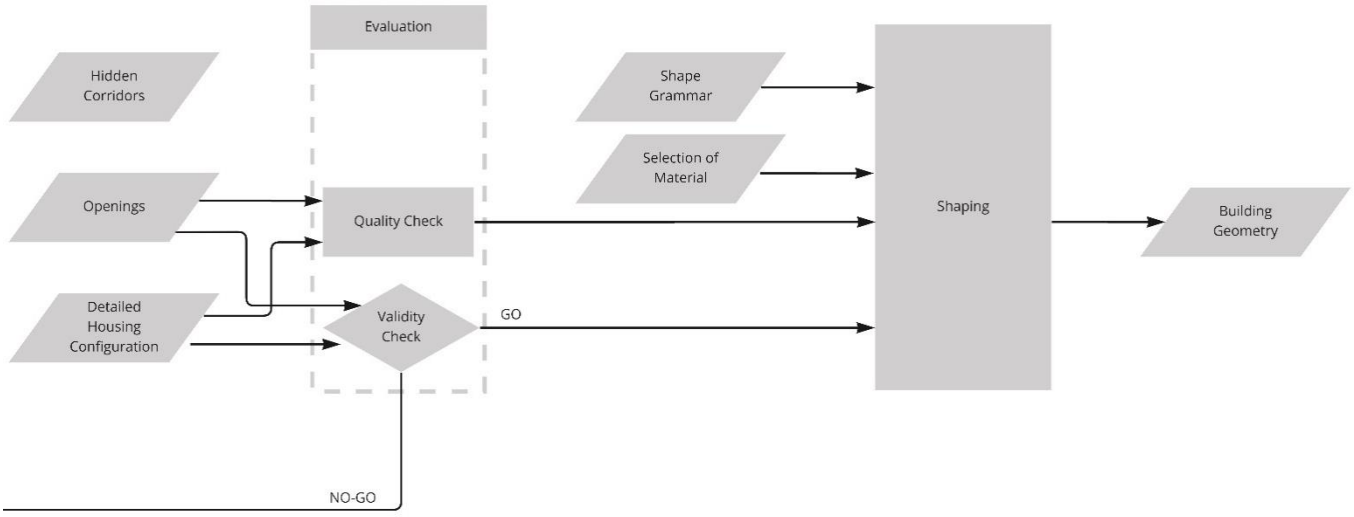



*Figure 39: Evaluation and Shaping input and output by Author, 2022.*

The process of choosing all details of the type, design and size of openings, walls, and the roof is based on the participatory design and consensus-building method. Further, all the details above described together with the outcome of the previous stages, are polygonised to create a geometrical representation of the configuration.

The design of openings, walls and roofs must be adapted to architectural styles and aesthetics of the context, as well as the material options, are given to the end-user. Therefore, crafting options that the end-users can relate to it.

## 5.5. Conclusion

The meta-game framework provided a general formulation of the faced design problem and allows to the design process to be transparent, helping the developer team to identify and reflect what and how should be adapted to the context and helping the end-user to make part of the design process. Each stage has their specificities and contribution for the meta-game.

The Planning phase is the first step towards the concretization of cultural-social values in the space configuration, besides it ensures customizable design. This procedure could be even further developed to allow multi-actors participation. In the Configuring process the engagement and participation of the end-user in the decision-making process of the design is assured. There is no technical limitation for the end-user, since all the technical information are already embedded in the modular system of the space modules. The Evaluation stage secures the formulation of quality and validity criteria for the spatial configuration outcome from the previous steps. And finally, the Shaping process materialize the building geometry.

The framework does not evaluate non-quantifiable quality criteria, especially when related to abstract values. Therefore, is crucial to have the end-user participation in order to them to certify that their cultural-social values are being translated to the housing configuration.

# 6. Test Case

## 6.1. Planning

In this stage players will be using the Game Pieces to create and test configurations that might attend their needs and preference. Discussion among user will be incentivized so they can express their preferences, dislikes, program of requirement (using the Activity Cards) and distribution of the space by using Game Pieces (Figure 40). The outcome of the configuration that they achieve will help to craft a specific budget to this family (Figure 41).

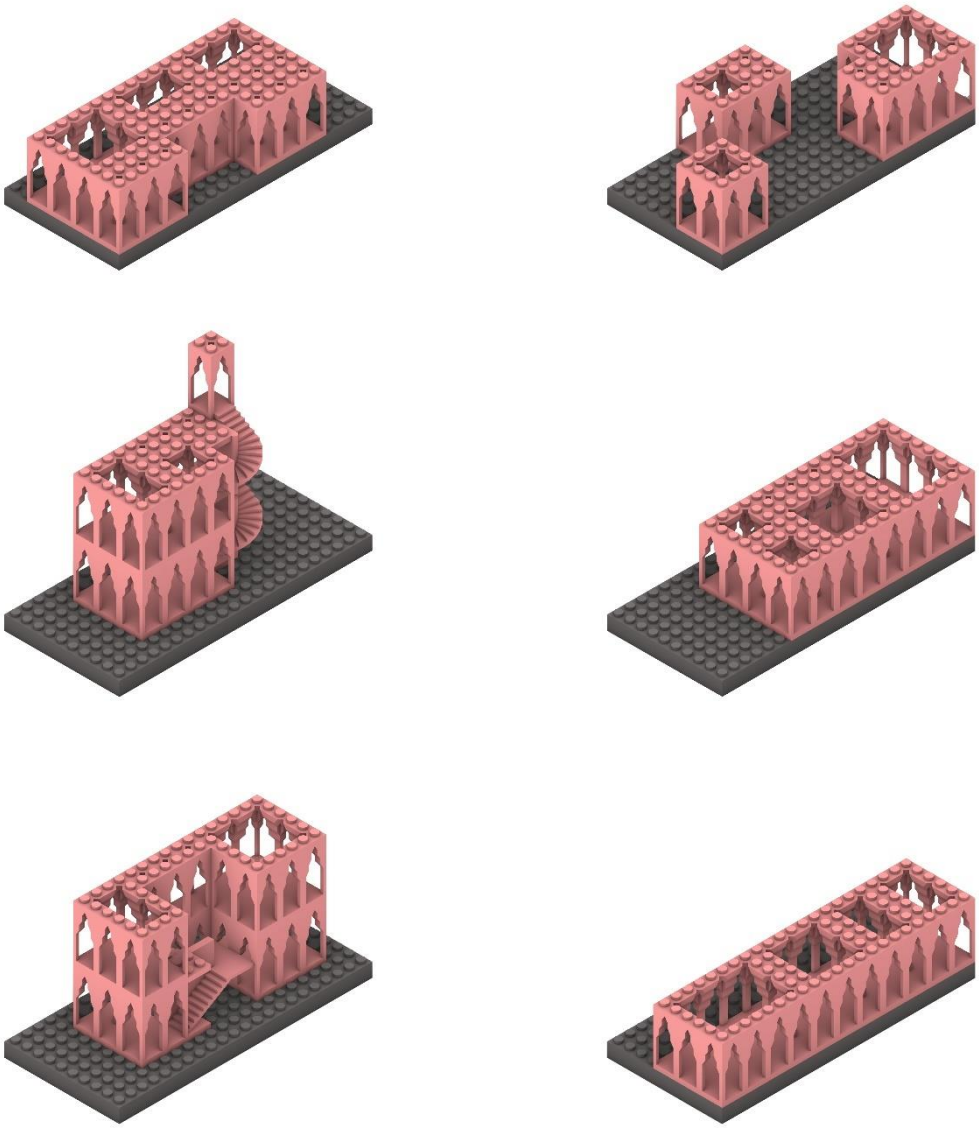


*Figure 40: Planning Stage, trying different configuration by Author 2022.*

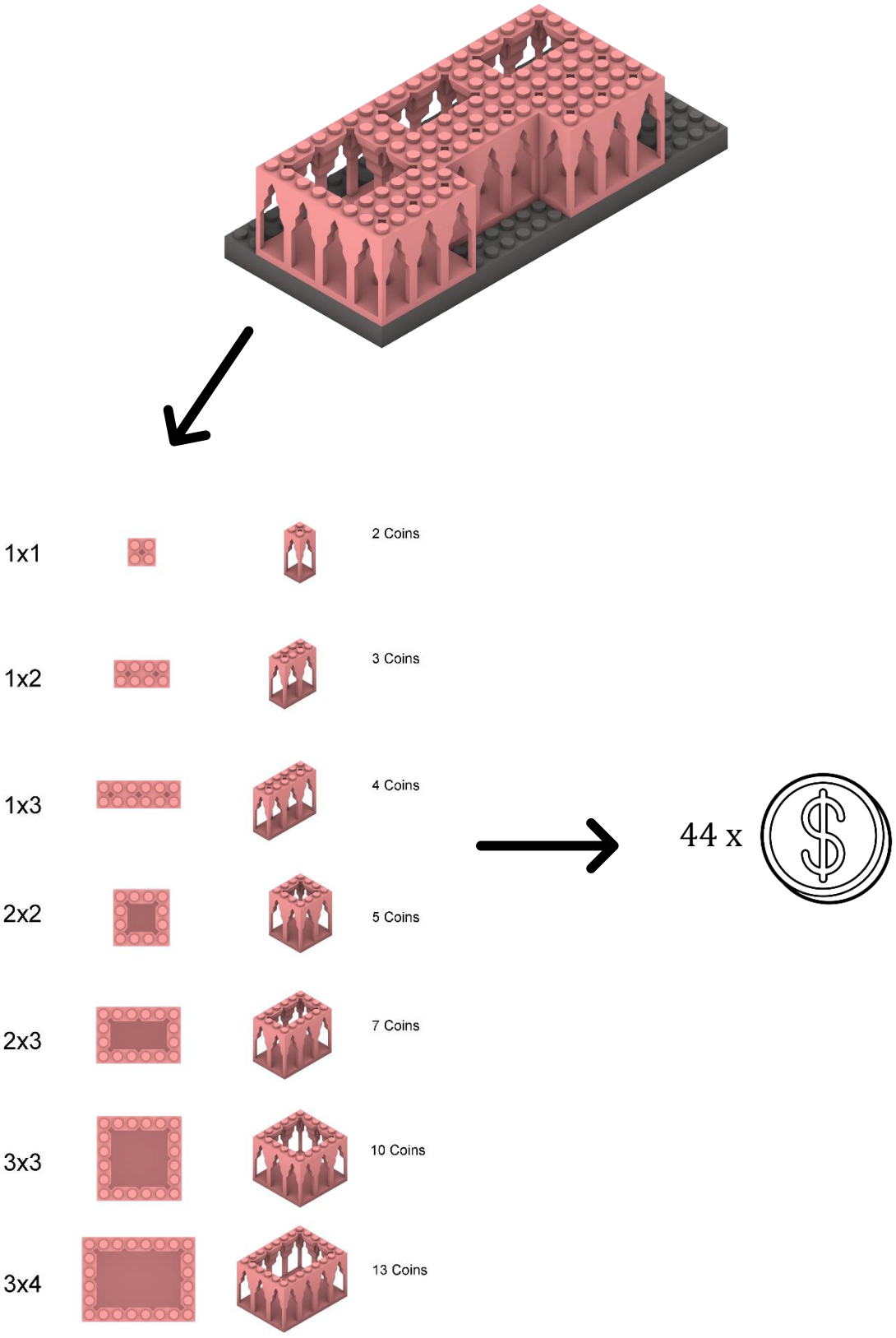
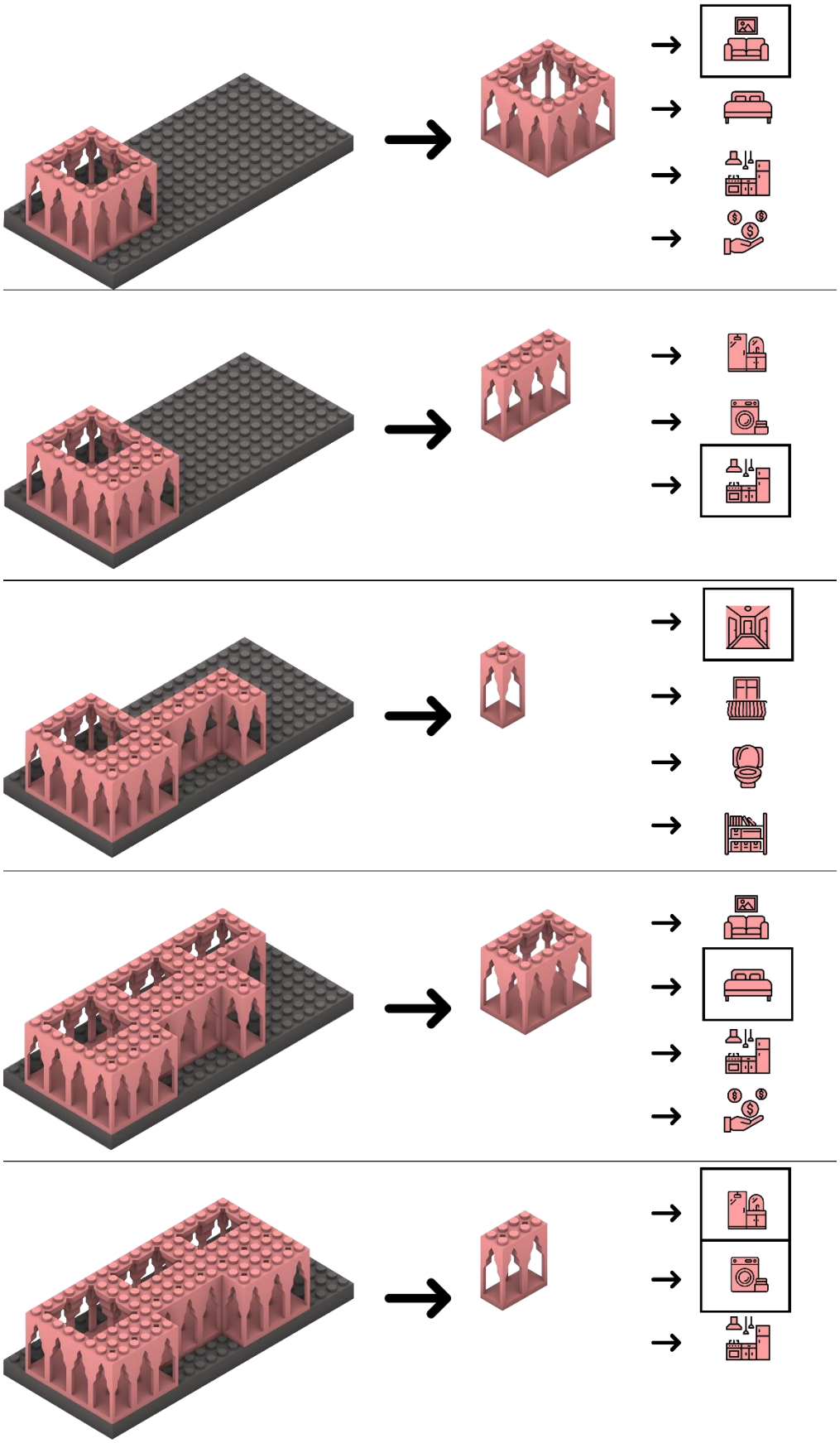
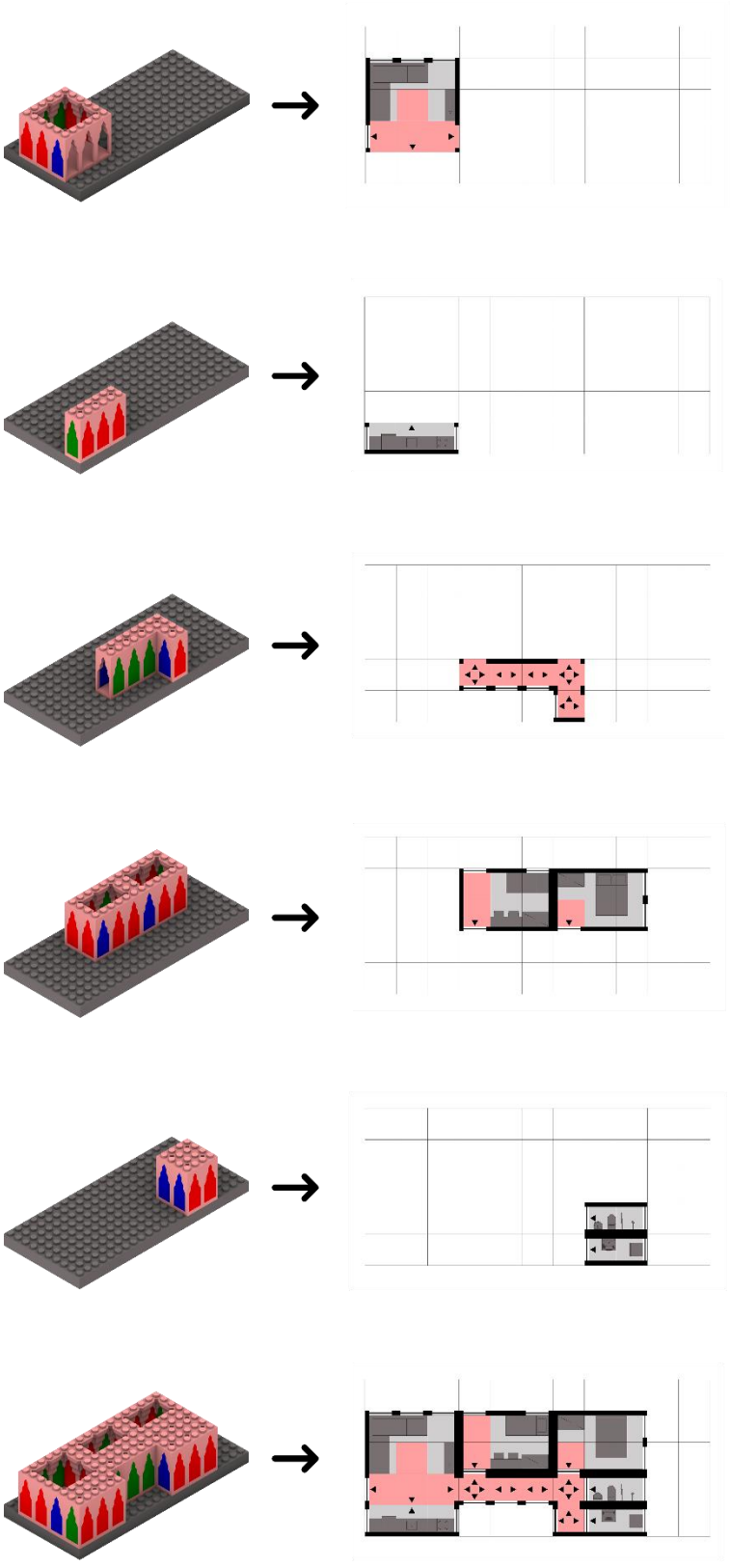



*Figure 41: Creating a budget from the configuration by Author, 2022.*

## 6.2. Zoning



## 6.3. Routing

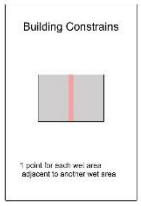


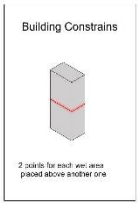
## 6.4. Evaluation

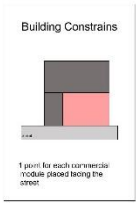
### 6.4.1.Spatial Validity Check

| **Validity Checklist** | | | | | |
|---|---|---|---|---|---|
| Only the space modules used in the configuration of the house must be checked as a GO. | | | | | |
| Piece | Function | Constrains | Go | No-Go | Does not apply |
| 1 x 1 | Corridor | At least two of the facades must be a free passageway/doors. | X | | |
| 1 x 1 | Balcony | At least one façade must be a parapet. | | | X |
| | | At least one façade must be a door or passageway, to give access to the balcony. | | | X |
| 1 x 1 | Storage | In case of only one tile, the storage must have only one door. | | | X |
| | | In case of multiple tiles set together, the storage set must have only one door. | | | X |
| 1 x 1 | Toilet | Must have one fanlight connected to the exterior of the building. | | | X |
| | | Must have one door. | | | X |
| 1 x 2 | Laundry | Must have one fanlight connected to the exterior of the building. | X | | |
| | | Must have one door. | X | | |
| 1 x 2 | Bathroom | Must have one fanlight connected to the exterior of the building. | X | | |
| | | Must have one door. | X | | |
| 1 x 2 | Kitchenette | Must have one fanlight connected to the exterior of the building. | | | X |
| | | Must connect with a multipurpose room | | | X |
| 1 x 3 | Bathroom | Must have one fanlight connected to the exterior of the building. | | | X |
| | | Must have one door. | | | X |
| 1 x 3 | Kitchenette | Must have one fanlight connected to the exterior of the building. | X | | |
| | | Must connect with a multipurpose room | X | | |
| 2 x 2 | Multipurpose | Must have at least one window connected to the exterior of the building. | | | X |
| | | Must have at least one door / free passageway. | | | X |
| 2 x 3 | Multipurpose | Must have at least one window connected to the exterior of the building. | X | | |
| | | Must have at least one door / free passageway. | X | | |
| 3 x 3 | Multipurpose | Must have at least two windows connected to the exterior of the building. | X | | |
| | | Must have at least one door / free passageway. | X | | |
| 3 x 4 | Multipurpose | Must have at least three windows connected to the exterior of the building. | | | X |
| | | Must have at least one door / free passageway. | | | X |

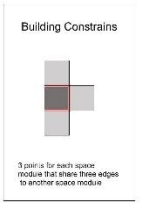
## 6.4.2.Spatial Quality Criteria

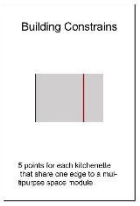


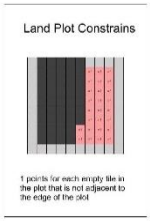



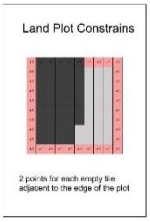



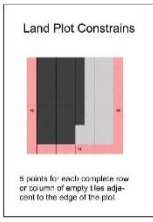


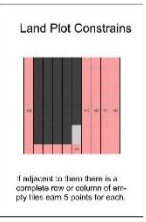


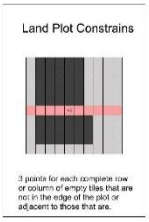



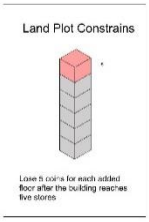



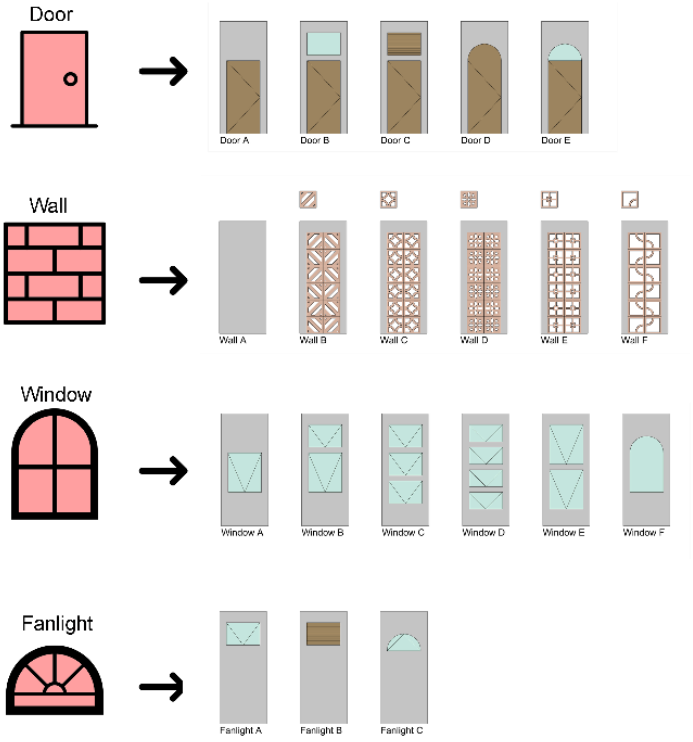



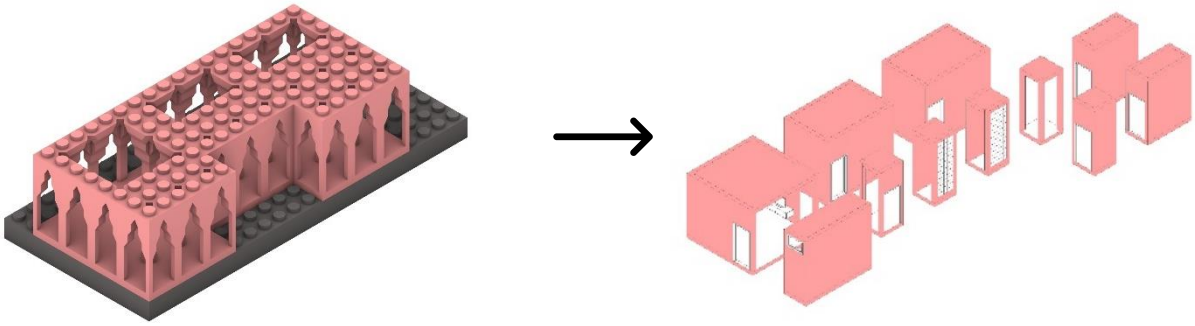



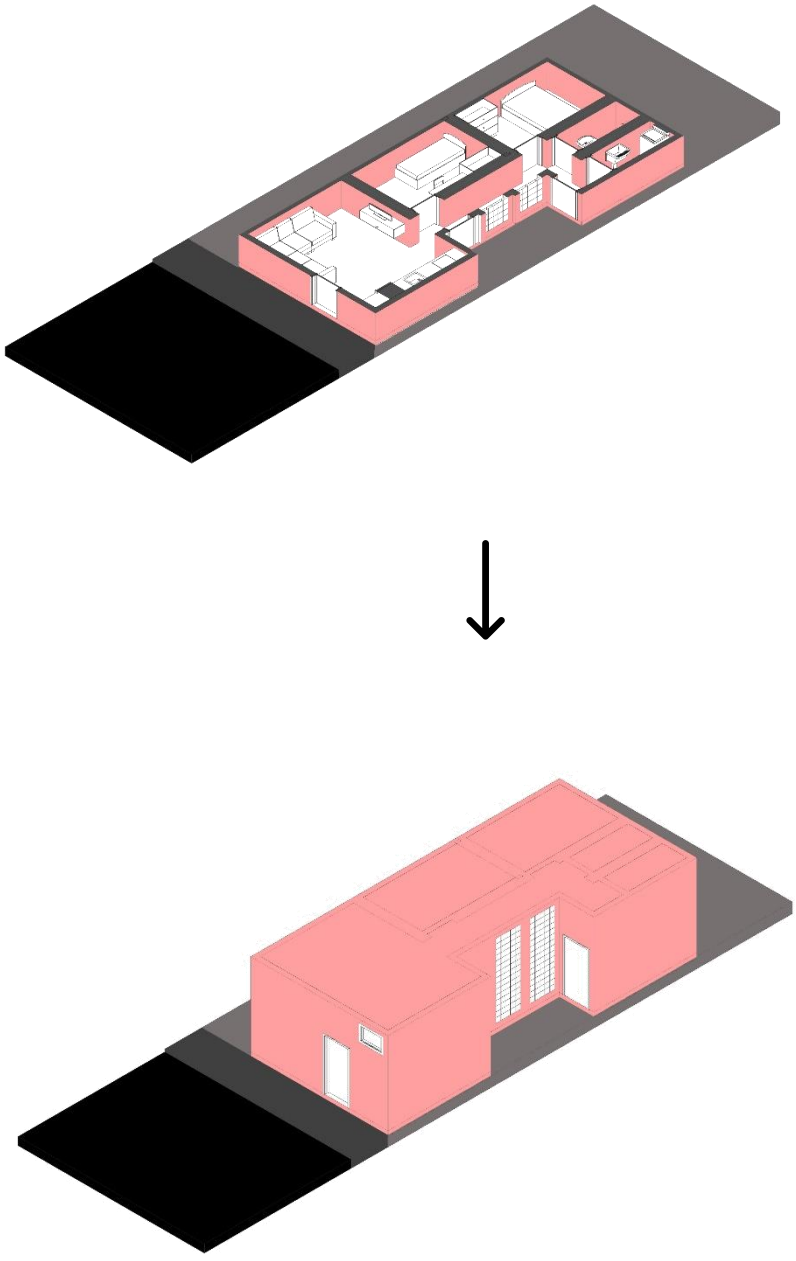




Land Plot Constrains: 56 points
Building Constrains: 10 points

## 6.5. Shaping


Door
Door A
Door B
Door C
Door D
Door E
Wall
Wall A
Wall B
Wall C
Wall D
Wall E
Wall F
Window
Window A
Window B
Window C
Window D
Window E
Window F
Fanlight
Fanlight A
Fanlight B
Fanlight C





# 7. Conclusion

## 7.1. Conclusion

The objective of the research was to create a participatory design game method that can be adjusted to different realities, enabling people to embed their social and cultural values in the design and to take part in the design decision-making process, without the obstacle of technical knowledge.

The main question of the research was how can be allowed future inhabitants to custom design their future affordable homes, in a way that their social and cultural patterns of using the space can prevail. The answer to this question is dependent on the sub-questions made to guide and structure this research. For that, we are going to break down and answer each of them in the following paragraphers.

The affordability and construction cost down while providing customization were reached by standardization and modularity of the elements and giving the possibility to combine them in numerous ways. The discussion of multiple actors in the design process was achieved through game mechanisms that engaged participation and collaboration.

To keep the design process simple and affordable while providing for customization and expression of subjective patterns of using space was attained by gamification, since it can be abstracted the complicated technicalities of the design process and provide for an engaging, expressive, and playful participatory process. And to assure certain levels of quality while allowing for mass customization it was used evaluation of spatial criteria.

The challenge of this thesis was to match the right methods and techniques that would allow social and cultural values to be expressed in the design. Therefore, one of the main complexities of this research was to combine subjective and objective matter to work in balance together and provide a solution that can concretize subjective values into the design. Besides both of those matters might change depending on the context, therefore, to achieve an adaptable game it was necessary to develop a meta-game and highlight what must be changed to be suitable for a particular context. For example, elements like Activity Cards, Shape Grammar and Evaluation are the main topics that must be adapted accordingly to the context.

For these topics to be adjusted it is crucial to have enough context information, about history, population, cultural expression, and space syntax analyse. For instance, through the

research done about Manaus and Population, it was identified patterns of using the space and expressive cultural elements that should be considered during the design, being them related to the communal spaces or housing.

It is relevant to comment that the generalization and simplification made about the population of Manaus were made to outline a process of identifying design principles for the participatory design game. In the future, a more in-depth research and space syntax analyse would help to identify more accurately patterns and possible preferences of a particular population.

When considering multiple different backgrounds in the game, the players would choose from the beginning which option is more related to its culture. And this option would automatically adapt the game to that particular background, presenting activity cards, shape grammar, and a technological framework related to it.

In general, the thesis is an introduction to how a participatory design game can be developed, and what relevant topics must be tackled. Besides, it can be extracted different research topics that could be worked on in parallel to the game to provide a better outcome for it, like space syntax analyse, social and cultural patterns, and shape grammar.

## 7.2. Limitation

A couple of limitations were encountered during the development of this research. The research primarily focuses on the end-user participation in the support level, not considering other types of stakeholders which normally take part in the development of the social housing complex.

Tissue-level participation would require further research at a larger scale of different stakeholders, game rules and play mechanisms. Due to time constraints, only some suggestions for the tissue level of the game were briefly mentioned.

Despite acknowledging the relevance of technological framework, this research did not dive into a systematic recommendation on materialization, structuring and manufacturing of the building.

The generalization and simplification made about the population of Manaus and the space syntax analysis of it might not accurately translate the reality. But that does not negate the outcome reflection made from that data, which was crucial to developing some of the design principles of the game. Finding data on housing and village of Indigenous and Riverside people was challenging since there is a lack of literature available that could provide relevant information for this research.

Certain aspects of the game were not extensively tested and evaluated, like (1) the amount of each card related to the play mechanism (Common Cards and Spatial Cards) that should be put in the deck of cards, (2) the amount of coin given to the dweller that depends on each design, (3) the time for each stage of the game, (4) the evaluation process, (5) the level of engagement and collaboration, and (6) the cost of each Game Piece.

Limitation related to the workshop was identified as well. Ideally, the workshop would be tested with dwellers of the actual PMCMV in Manaus, since this would bring more accurate feedback on the game developed for that context. However, due to geographical distance, this physical game had to be tested in a role-play environment. The role-play workshop made available instruction for each participant to follow their role. However, it was identified that despite the given instruction, each player acted their role influenced by their background, which was different from the one of Manaus.

## 7.3. Reflection

The proposed game can only provide the right mechanism for a particular social and cultural context through (1) end-user participation, (2) context information and (3) adaptation of some of the game development processes, like Activity Cards, Evaluation, and Shape Grammar.

Cultural values and their attributes are subjective matters that can not be evaluated as objective and quantifiable matters. To assure and evaluate if these values are being embedded into the design is necessary for end-user participation in the design decision-making process.

For future work and potential application, this game could be used as: (1) a learning tool to make players gain knowledge about their spatial decision and their effect on the spatial quality and validity or make them understand the quality and validity difference between different contexts, (2) a research tool to identify social and cultural patterns of using the space and its space syntax relation, (3) a computational tool that can generate automatically 2D and 3D drawing, and (4) a game to be used in any other housing development.

### 7.3.1. Relation of the Thesis to the master track and master program

Given the fact that Building Technology is the application and integration of technologies in the building design process and considering that the performance of buildings and the built environments involves both soft (human) and hard (physical) aspects. This research brings the application of computational design methods for the early stages of the design process, creating a method that considers the social and cultural pattern of using space and systematically designs the configuration and shape of the housing.

### 7.3.2. Scientific and Societal relevance:

The societal relevance of this research is the empowerment (and valuation) of people, through their participation in the design and allowing them to reinforce their social and cultural values and preferences in the design. While the scientific relevance is the development of a participatory design game method for the early stage of the design process that considers social and cultural complexities using scientific methods and theories like participatory design, shape grammar, space syntax, discrete architecture, and game design theory.

### 7.3.3. Ethical Issue

Social Housing it's a multicomplex subject that tackles the matter of cost, land, construction material, population, city development plans, stakeholders, affordability, constructability, social housing policies, etc. During the research, the dilemma was on how in-depth each of these topics should be considered. It is unquestionable their importance but for a matter of timeframe the framework lack in considering all those points.

The danger of proposing design solutions reflecting only on our views and preferences is trying to fit one solution to a problem with plural solutions. Design is not neutral and is never a solitary act. Besides, design influence how people behave and live their lives. That is why is important to understand that design is an ethical activity on its own and it is fundamental to consider the complexities of the user, such as its background, pattern of habitation, spatial values, and social logic of the space. The puzzle comes when we want to design and respect complexities that are subjective and abstract or not measurable, therefore, hard to replicate in the design. One of the main dilemmas during this graduation project was how to develop a game that empowers people to express their logic, preferences, and values while considering those aspects in the design process.

The dilemma encountered in potential (future) applications was how should the result of this project be adapted to different locations in the world and still empower the user from that place and respect their backgrounds.

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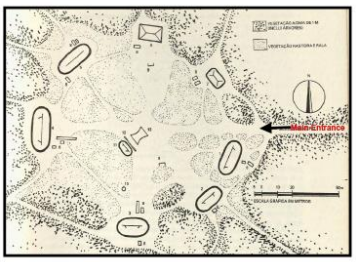
AR40105 - Critical response to Space Syntax

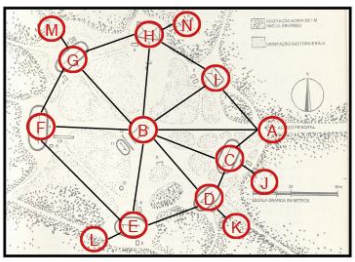
# 9. Appendix

## 9.1. Appendix A

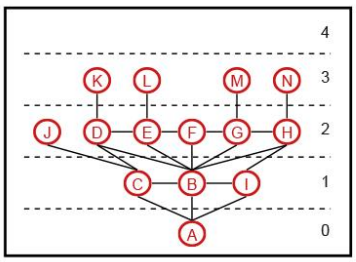
### 9.1.1. Graph Map: Indigenous Village



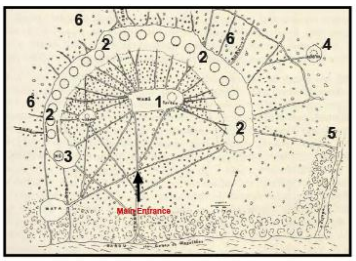
1 to 7 = dwellings
8 = "jirau" (platform used for domestic utensils and fruit dryer or, smoked meat or fish)
9 = goal for soccer game
10 = hawk cage
11= ritual and ceremony house
12 = stripped trunk
13 = grave



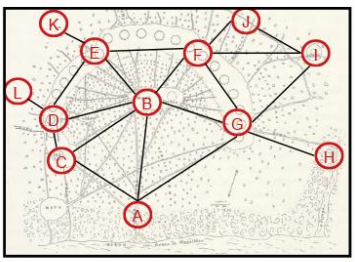

A = Main Entrance
B = Ritual house and Grave
C, D, E, F,G,H, I = Dwellings
J, K, L ,M, N = Jirau



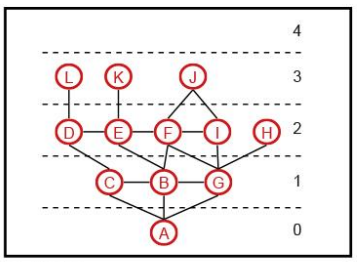

A = Main Entrance
B = Ritual house and Grave
C, D, E, F,G,H, I = Dwellings
J, K, L ,M, N = Jirau



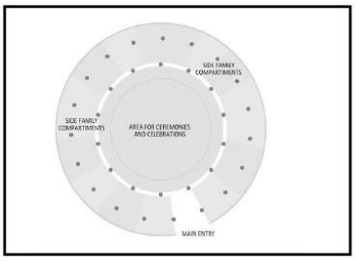

1 = Area for Meeting, Ceremonies and Celebrating
2 = Dwellings
3 = Make up house
4 = Grave
5 = Bath area
6 = Way to vegetable garden

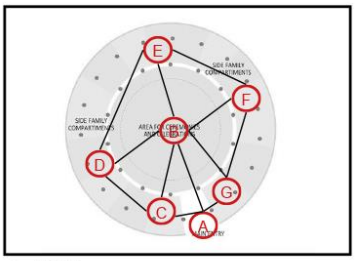



A = Main Entrance
B = Area for Meeting, Ceremonies and Celebrating
C = Make up House
D, E, F,G = Dwellings
H = Grave
I, J, K, L = Way to vegetable garden

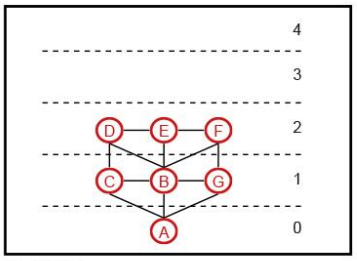



A = Main Entrance
B = Area for Meeting, Ceremonies and Celebrating
C = Make up House
D, E, F,G = Dwellings
H = Grave
I, J, K, L = Way to vegetable garden

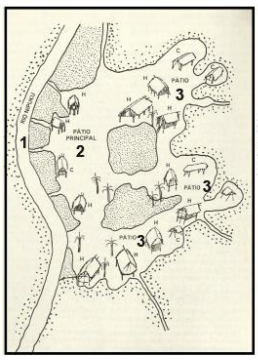


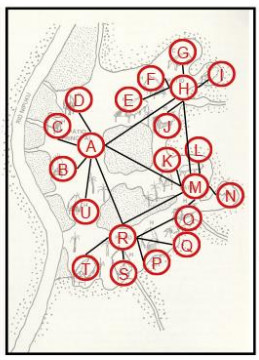

A = Main Entrance
B = Area for Meeting, Ceremonies and Celebrating
C, D, E, F,G = Family Compartments



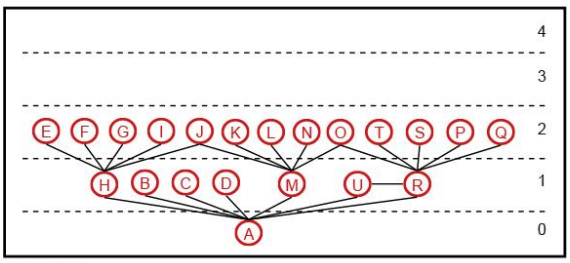

A = Main Entrance
B = Area for Meeting, Ceremonies and Celebrating
C, D, E, F,G = Family Compartments




1 = River
2 = Main Patio
3 = Smaller Patio
H = Dwelling
C = Kitchen

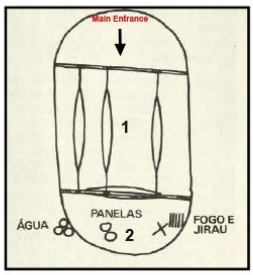



A= Main Patio
B, G, I, L, N, Q = Kitchen
C, D, E, F, J, K, O, P, S, T, U = Dwelling
H, M, R = Smaller Patio

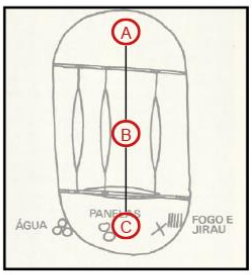



A= Main Patio
B, G, I, L, N, Q = Kitchen
C, D, E, F, J, K, O, P, S, T, U = Dwelling
H, M, R = Smaller Patio

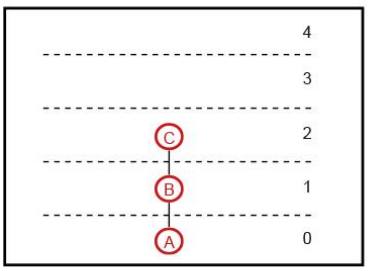
# 9.1.2.Graph Map: Indigenous Dwellings



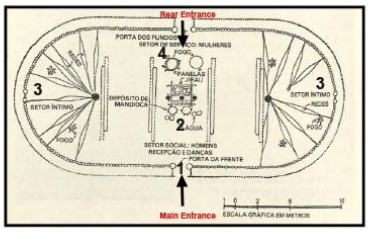

1 = Sleeping area
2 = Cooking area



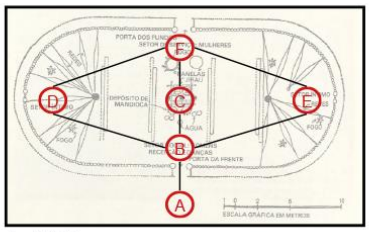

A = Main Entrance
B = Sleeping Area
C = Cooking Area



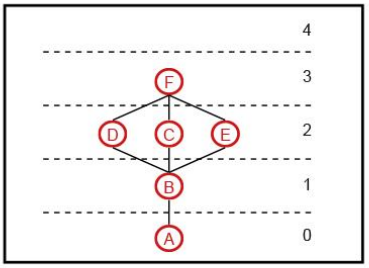

A = Main Entrance
B = Sleeping Area
C = Cooking Area



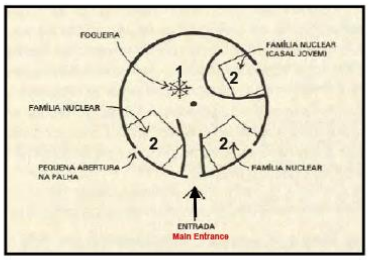

1 = Social sector: Men, reception and dance
2 = Cooking area
3 = Sleeping area
4 = Service sector: Woman



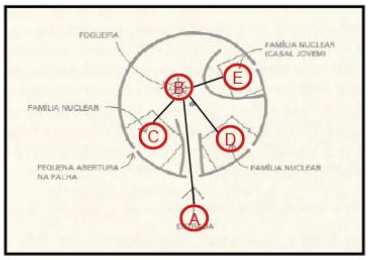

A = Main Entrance
B = Social sector: Men, reception and dance
C = Cooking area
3 = Sleeping area
4 = Service sector: Woman



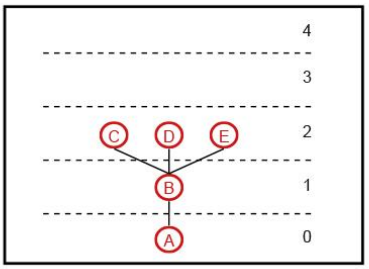

A = Main Entrance
B = Area for Meeting, Ceremonies and Celebrating
C, D, E, F,G = Family Compartiments



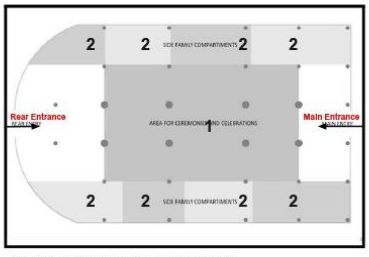

1 = Cooking area
2 = Sleeping area



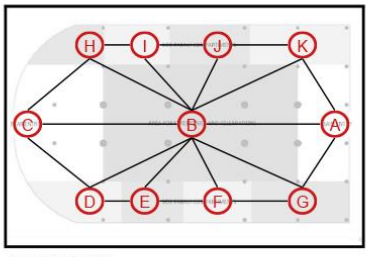

A = Main Entrance
B = Cooking Area
C, D, E = Sleeping Area



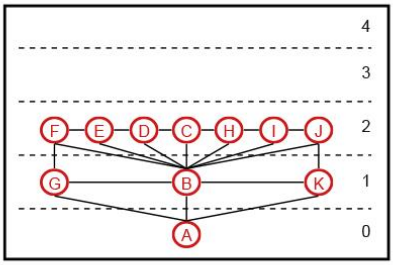

A = Main Entrance
B = Cooking Area
C, D, E = Sleeping Area




1 = Area for Ceremonies and Celebration
2 = Side Family Compartiments (sleeping area for each nuclear family)




A = Main Entrance
B = Area for Ceremonies and Celebration
C = Rear Entrance
D,E,F,G,H,I,J,K= Side Family Compartiments (sleeping area for each nuclear family)

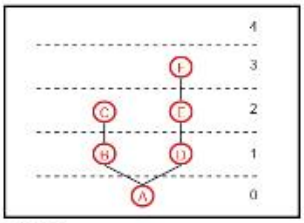



A = Main Entrance
B = Area for Ceremonies and Celebration
C = Rear Entrance
D,E,F,G,H,I,J,K= Side Family Compartiments (sleeping area for each nuclear family)

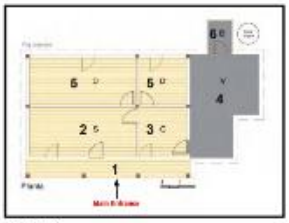
## 9.1.3.Graph Map: Riverside People Dwellings


1 = Veranda
2 = Living Area
3 = Kitchen
4 = Bedroom

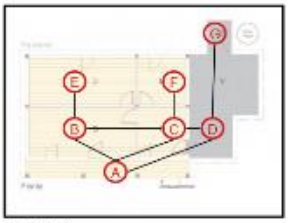

A = Veranda
B = Living Area
C = Kitchen
D, E, F = Bedroom



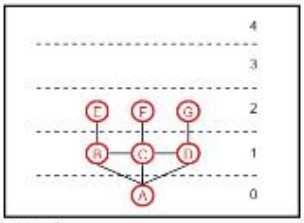

A = Veranda
B = Living Area
C = Kitchen
D, E, F = Bedroom




1 = Veranda
2 = Living Area
3 = Kitchen
4 – Covered Patio
5 = Bedroom
6 = Bathroom

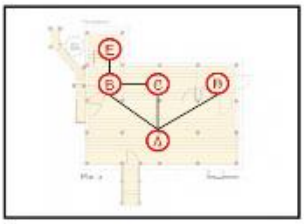



A = Veranda
B = Living Area
C = Kitchen
D – Covered Patio
E, F = Bedroom
G = Bathroom

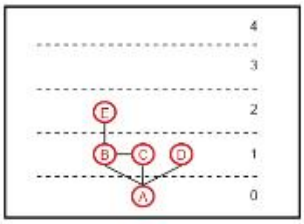



A = Veranda
B = Living Area
C = Kitchen
D – Covered Patio
E, F = Bedroom
G = Bathroom

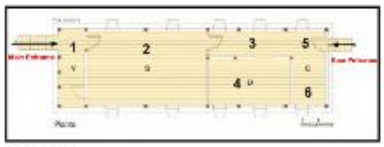

1 – Veranda
2 – Kitchen
3 – Bedroom
4 – Bathroom



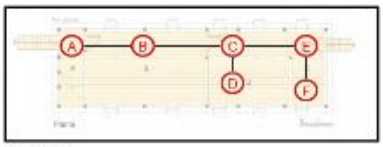

A – Access from the River
B – Access from the Land
C – Veranda
D – Kitchen
E, F – Bedroom
G – Bathroom



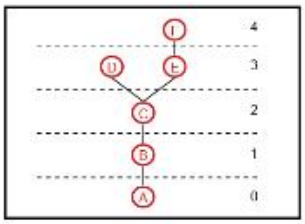

A – Access from the River
B – Access from the Land
C – Veranda
D – Kitchen
E, F – Bedroom
G – Bathroom

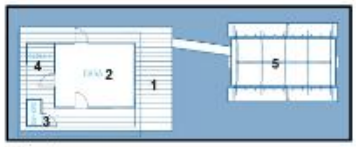



1 – Veranda
2 – Living Area
3 – Corridor
4 – Bedroom
5 – Kitchen
6 – Bathroom

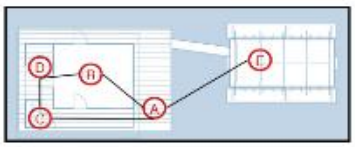



A – Veranda
B – Living Area
C – Corridor
D – Bedroom
E – Kitchen
F – Bathroom

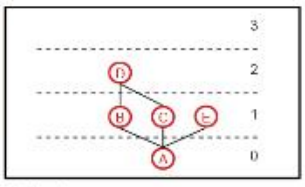



1 = Veranda
2 = Living room and Sleeping area
3 = Bathroom
4 = Kitchen
5 = Vegetable Garden

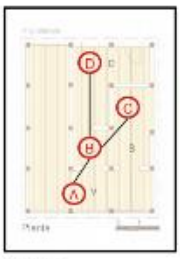



A = Veranda
B = Living room and Sleeping area
C = Bathroom
D = Kitchen
E = Vegetable Garden

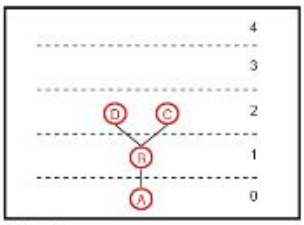



A = Veranda
B = Living Room
C = Kitchen
D = Bedroom


1 – Veranda
2 – Living Room
3 – Kitchen
4 – Bedroom

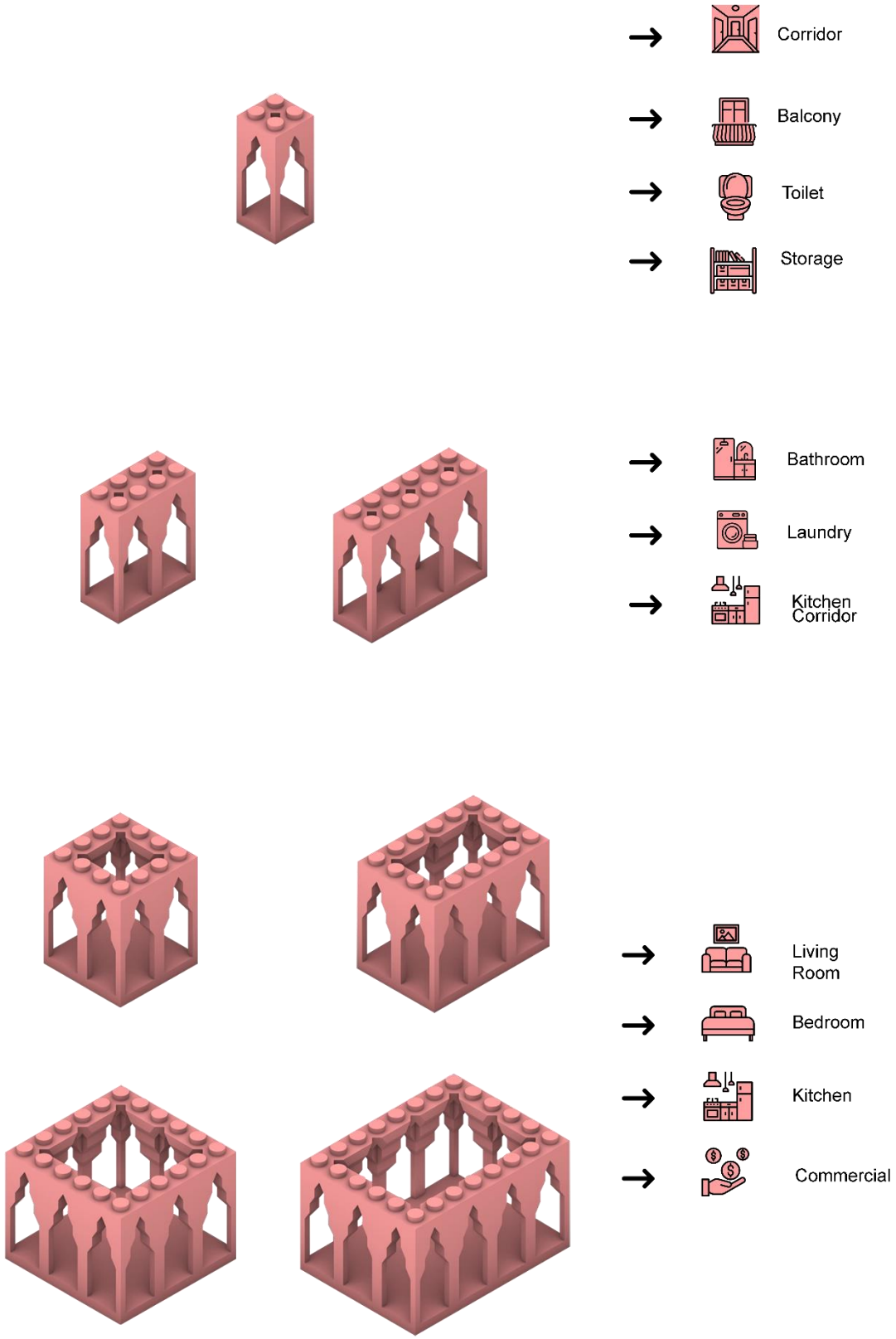



A – Veranda
B – Living Room
C – Kitchen
D – Bedroom

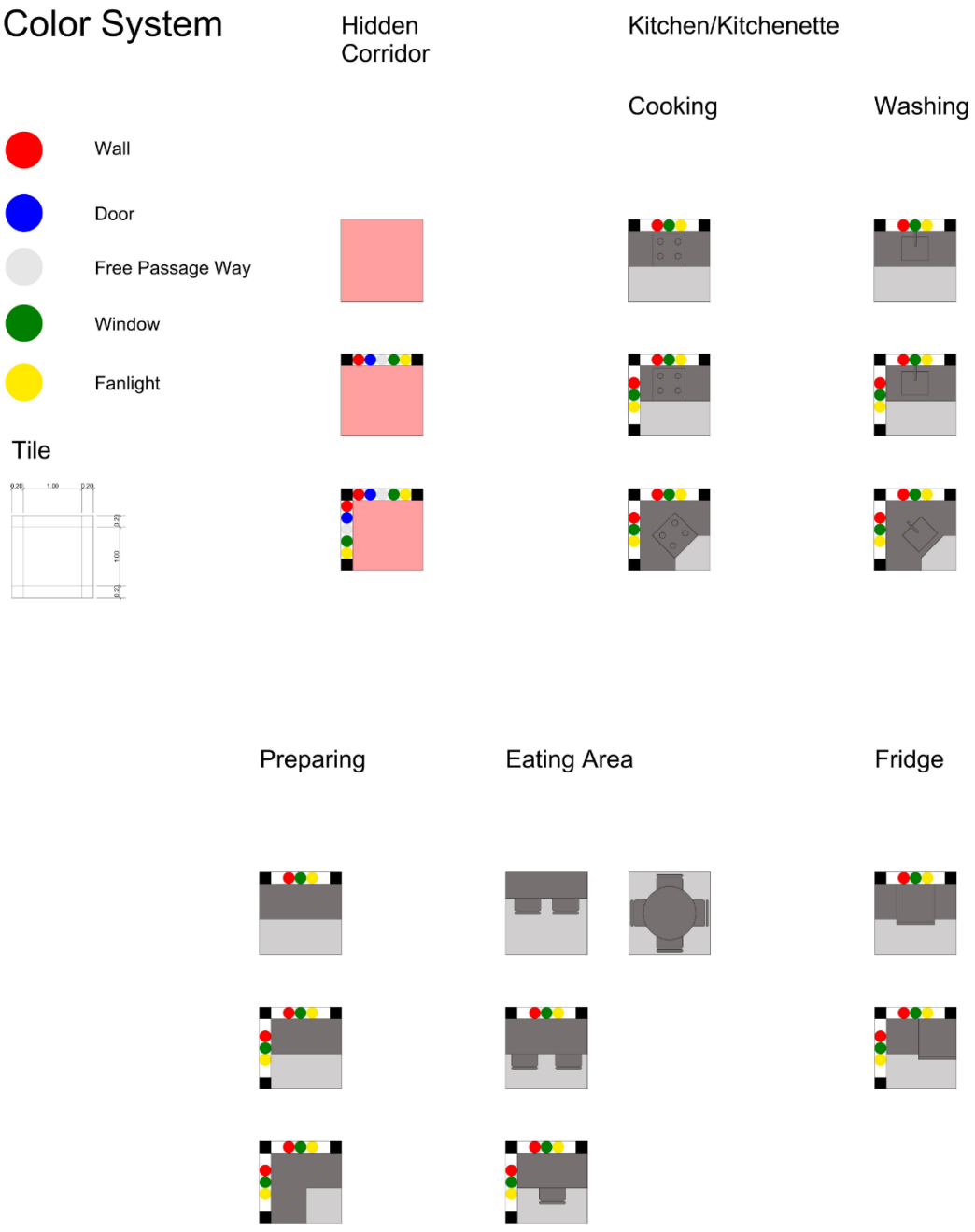



A – Veranda
B – Living Room
C – Kitchen
D – Bedroom

## 9.2. Appendix B: Shape Grammar



## 9.3. Appendix C: Modular Furniture



Bathroom/Toilet

Shower

Toilet

Sink

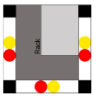
Toilet + Sink

Laundry

Washing Machine

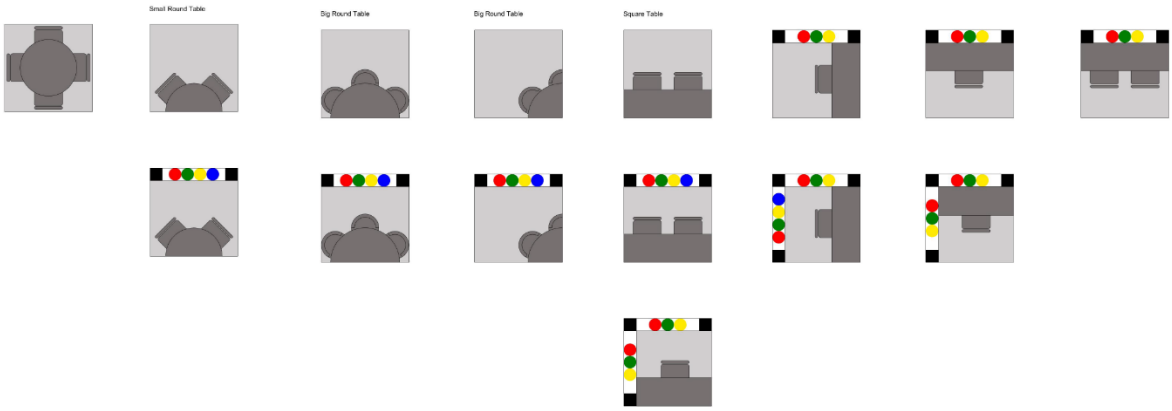
Sink

Storage



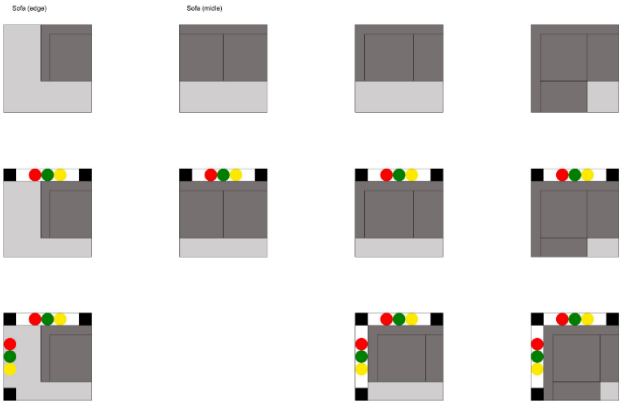
Multipurpose

Eating Area



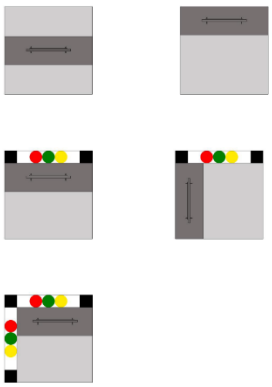

Multipurpose

Sitting Areas



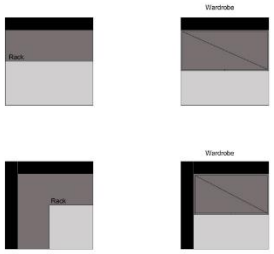

Multipurpose

TV



Multipurpose

Rack/Wardrobe




Multipurpose

Sleeping Area