A CULTURAL, CUSTOMIZABLE AND PREFABRICATED HOUSING GRAMMAR FOR CASABLANCA

by

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ABSTRACT

Proposing an innovative design grammar linking prefabrication, customization and cultural adaptability, this thesis addresses the present day housing deficit and lack of architectural identity in Casablanca, Morocco. The grammar incorporates customization that creates housing units specific to a family's needs, incorporating cultural aspects such as courtyards into the design, and simultaneously allows for the creation of a diverse urban fabric. I first reviewed the existing housing need in Casablanca to date, which includes 400 informal settlements and 98,128 households living in sub-standard conditions. This led to my exploration of prefabrication as a construction method, to my review of historical mass housing precedents in Casablanca, and to my identification of significant cultural typologies of the traditional Moroccan house. With the realization that the current housing market cannot support the current housing deficit, I decided to make a contribution to the system by designing a set of rules or a housing grammar that not only integrates prefabrication for fast construction but also customization to promote user participation and cultural adaptability to respond to local lifestyles. This prefabrication system I designed using light weight factory built modules allows for a fast and efficient way to deliver housing units at affordable prices for Casablanca. Drawing on the existing Moroccan financial housing models, this system will reduce the construction phase by 60%, allows for cost savings of 20%, while offering users the ability to customize in order to address their particular priorities and bringing dignity and practicality to the design of affordable housing. Furthermore, by investigating the courtyard as stacked units, I am exploring a new type of urban typology for low-rise high-density urban courtyard housing for Casablanca.

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I dedicate this thesis to my parents, Rachid Akkar and Naima Mchichi. I would not be here today if it wasn't for your unconditional love. You are both uniquely exceptional people.

INTRODUCTION

INTRODUCTION

"Three things you can depend on in architecture. Every new generation will rediscover the virtues of prefab. Every new generation will rediscover the idea of stacking people up high. And every new generation will rediscover the virtues of subsidized housing to make cities more affordable. Combine all three- a holy trinity of architectural and social ideas." [1]

This thesis proposes affordable housing for Casablanca, Morocco using an innovative design grammar linking prefabrication, customization and cultural adaptability. Casablanca needs to adapt a mass housing scheme that is customizable and constructed using modern day technologies. My thesis will make a contribution to the present day housing deficit and design in Casablanca by specifically addressing problems of customization, adaptation and construction.

Between 2005 and 2007, Casablanca's population increased by 7.5 %. In 2008, there were 400 informal settlements and 98,128 households, (490,640 people) living in sub-standard conditions.[2] The city's slum dwellers makeup the lowest-income group, with unemployment rates as high as 32% and illiteracy rates at 64%. New and existing squatter settlements sprawl all over the city in dense, unsanitary sheds, with no potable water, no waste collection, and no formal address.

Historically, the government and the market have not been able to keep up with the demand for affordable housing. In the past, Casablanca and other cities have created institutional and segregated housing. The slums and the slum-like housing projects have fueled poverty and created alienated communities. The result has been projects not adapting to the needs of the residents and to the city, further aggravating social and urban problems. Furthermore, preliminary studies have demonstrated that ignoring the local population needs only leads to the creation of ghettos.[3] Since 2004, the Moroccan government

1 Pearman, Hugh. "Creative Lego: are prefabricated homes architecture or building?" *Gabion, Retained Writing on Architecture.* 2003.Web. <http://www.hughpearman.com/articles4/creativelego.html>.

2 Baverel, Anne. Best Practices in Slum Improvement: The Case of Casablanca. Development Innovations Group, 2008. Urbis: The Urban Capacity Laboratory. Web.

3 There are numerous examples of affordable and public housing projects that have failed due to the disregard of the local community. Some references are Cite Verticale in Casablanca and Pruitt-Igoe in St. Louis.
Additionally, according to a report written by URBIS, the Villes Sans Bidonsvilles program is at risk because there is very little popular involvement in governmental policies regarding new housing, relocation and slum restructuring. Carliez, Marianne, Franck Daphnis, Fouzi Mourji, and Craig Matasick. *A Rapid Urban Diagnostic and Proposed Intervention Strategy for DIG in Casablanca, Morocco.* 55.Web.

has implemented a country wide housing program, allocating funds and creating agencies that target the eradication of all urban and rural slums by 2012.[4] Globally and over the years, public housing and partially government subsidized housing have been the most exposed to political, economical and demographical influences, and very often used as experiments.

My proposal is a design scheme for affordable housing that is culturally compatible, customizable, and built using a prefabrication construction system. This culturally compatible design is a general typology in regards to the cultural and social context. My design incorporates courtyards, important spaces in the everyday lives of residents. The courtyard has been used for centuries, at different scales, and in different building types. In this proposal, the courtyard is an inner private space open to the sky, transformed and used in an urban setting for a mid-density housing project. I have chosen this typology because it is a multi-functional space that can be used for various functions, becoming a 'different' space every time. The courtyard is also environmentally ideal for Casablanca, as it allows for ventilation and shading during hot summer days and natural light and heat gain for chillier winter seasons. Most importantly, the courtyard is affordable. It is multi-purpose room that eliminates the need for bigger kitchens or larger indoor living rooms. In addition to courtyards, large living spaces with elongated couches, enclosed kitchens, and private sleeping quarters are also culturally important.

Additionally, cstomization is essential as it creates housing units specific to a family's needs and simultaneously allows for the creation of a diverse exterior urban fabric. The method I am using is a design and prefabrication grammar that will generate various design schemes for the floor plans. In this thesis the grammar is a set of rules that, when applied methodically, can generate different prototypes of an archetypical floor plan. The grammar embodies the characteristics of the local buildings, as well as integrating a construction system as part of the design process. The overall scheme is suited to today's culture and urban environment. For example, with the application of these rules, a family can choose the number of bedrooms, the size of their apartment, if they want private spaces or only large common areas, or if they need a core that can be incremental. The interior configuration of the units will

4 The 2012 goal will unlikely be attained.

therefore affect the exterior design of the buildings. Furthermore, since every unit has a different exterior shape; once stacked up, they form a unique and diversified exterior. As opposed to high-rise buildings that have identical floor plans and monotonous exterior façades, this scheme gives everyone a choice, and benefits the urban city. Furthermore, by investigating the courtyard as stacked units, I am exploring a new type of urban typology for low-rise high-density urban courtyard housing for Casablanca.

The customizable housing scheme will allow families to voice their needs and will be offering them more than a traditionally standardized affordable housing project. Customization of housing is a time and design intensive process that is a luxury afforded only by the middle and upper income groups.[5] Habraken wrote that the "[The lower class] demanded for themselves the rights enjoyed by the middle and upper class [in housing].[6] Additionally, giving people that right will offer equality and lead to more stability in a country.

Therefore, by putting in place a system that generates customizable options without extra design time (and extra expenses), customization becomes attainable by all income groups. To optimize the design grammar, it would be best put to use if scripted into a computer program that will generate the housing floor plans instantaneously. However, a manual application (as in this thesis) of the design grammar is still possible, but requires a bit more time.

This academic work is implemented through a construction system of prefabrication. The prefabrication system allows for a fast and efficient way to deliver housing projects at affordable prices. This system will largely reduce the construction phase, resulting in a fast delivery of housing units, and eliminating the need for transportation and storage of raw materials to sites.[7] The supply of new housing in Casablanca, using traditional construction methods added 93,000 units to the housing stock in 2006. However, with the existing housing deficit, and the need for additional housing, together totaling 120,000 [8] units

5 Please refer to the interview in the appendix with Dennis Michaud of Blu Homes. Mr.Michaud points out that there are added design fees involved with customization.
6 Habraken, N. J. *Supports, an Alternative to Mass Housing.* 41. London: Architectural Press,1972.Print.

7 Casablanca has a backlog of housing units, but also needs new housing for incoming migrants and a growing population. Approximtely 25% of Casablanca's population is under 15 years old and 9% are over 60 years old.
8 Baverel, Anne. Best Practices in Slum Improvement: The Case of Casablanca. Development Innovations Group, 2008. Urbis: The Urban Capacity Laboratory. Web.

that year, there was still a shortage of 23,000 units,[9] making this prefabrication construction method a viable solution.

I have chosen a prefabrication system that is factory built, multi-trade, and modular.[10] These modules are built in a controlled factory environment, increasing productivity and worker safety, and minimizing material waste, before being shipped and assembled on site. Additionally, this thesis explores a design and prefabrication system, made up of one or more modules that are assembled to create a larger space. This system will be useful for private and semi-public developers building mass housing complexes as well as independent families that would like to incrementally build their site and serviced plots.[11]

The structure of this thesis is in three parts. Part 1: Historical context, is a historical framework and analysis within (A) historical housing precedents in Casablanca and why they failed, (B) The cultural context in Casablanca and how it can be incorporated in the thesis grammar to prevent the failure of future housing projects and (C) a review of customization theories and projects and how they can be used in the housing grammar. Part 2: Present Context, is the analysis of the current housing market in Casablanca and (A) the existing housing models and why they are likely to fail, (B) Prefabrication systems and why they should be used in the present day market to avoid its failure, (C) The constraints of prefabrication and (D) an approximated comparative cost between traditional construction and prefabrication. Part 3: An Innovative Design Grammar Linking Culture, Customization, and Prefabrication In Casablanca, is the introduction to the housing grammar. This section includes (A) the design housing grammar, and (B) Layout diagrams in forms of tree diagrams and catalogues, and (C) architectural drawings for the housing grammar.

9 As of today there is still a significant shortage of housing stock deficiency. I was however, not able to obtain exact numbers for 2010.
10 An example of this prefabrication system is the Portuguese factory Pavicentro
11 Please refer to Part 2, A: Housing Background and Funding for more information

FIG I: AERIAL PHOTO OF CASABLANCA,1914

FIG II: AERIAL PHOTO OF CASABLANCA, 2011,
CIRCLE AROUND 1914 CITY

FIG III: MAP OF CASABLANCA, 1900

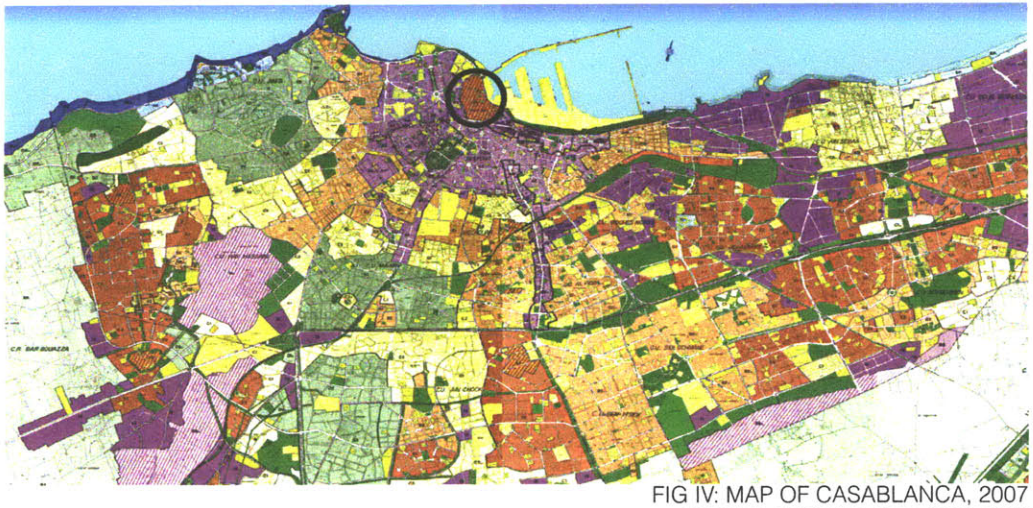


FIG IV: MAP OF CASABLANCA, 2007
CIRCLE AROUND THE 1900 CITY

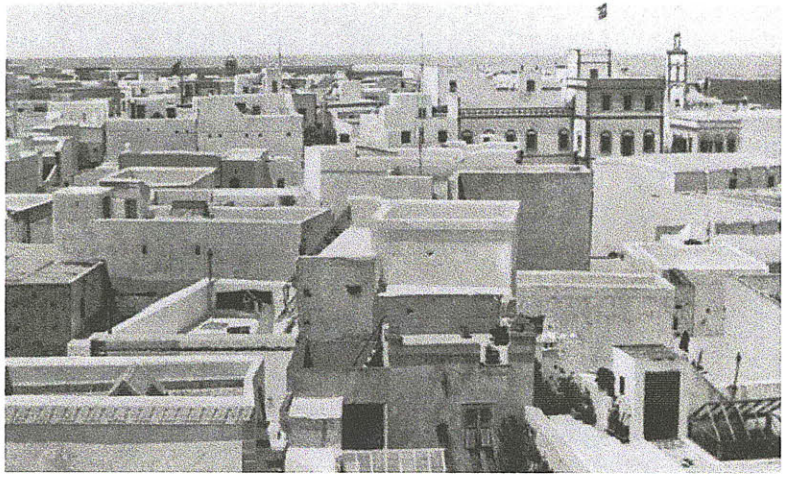


FIG V: PHOTOGRAPH OF THE MEDINA OF CASABLANCA, 1907

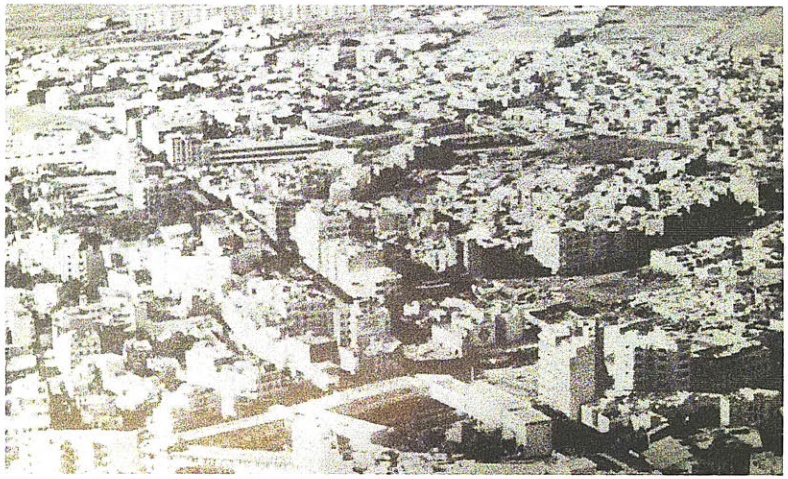


FIG VI: PHOTOGRAPH OF CASABLANCA, 1950'S

FIG VII: PHOTOGRAPH OF CASABLANCA, 2000'S

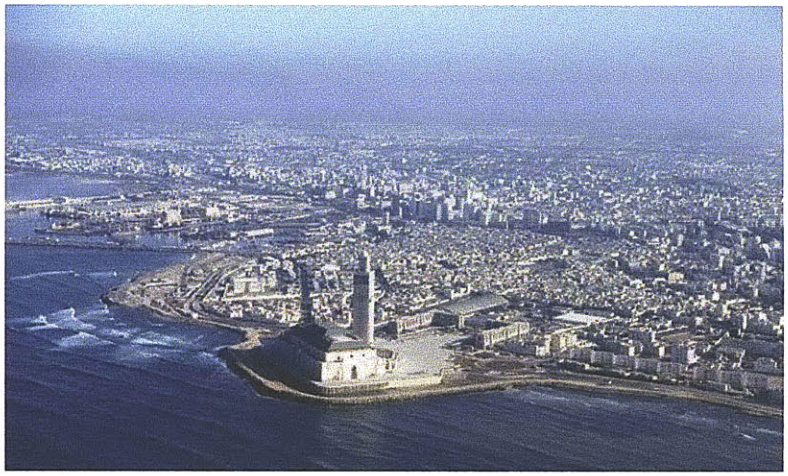


FIG VIII: PHOTOGRAPH OF CASABLANCA, 2000'S

FIG VIIII: A SHANTYTOWN IN CASABLANCA

FIG X: A SHANTYTOWN IN CASABLANCA

FIG XI: PHOTOGRAPH OF HIGH-INCOME NEIGHBORHOOD ADJACENT TO SHANTYTOWN IN FIG X

FIG XII: MIDDLE-INCOME NEIGHBORHOOD ADJACENT TO SHANTYTOWN IN FIG X

PART 1: HISTORICAL CONTEXT

A- MASS HOUSING PRECEDENTS IN CASABLANCA AND WHY THEY FAILED

B- CULTURAL ADAPTABILITY FOR CASABLANCA AND ITS USE FOR SUCCESSFUL HOUSING PROJECT

C- CUSTOMIZATION THEORIES AND PROJECTS AND THEIR USE IN THE GRAMMAR

PART 1

A- MASS AFFORDABLE HOUSING PRESEDENTS IN CASABLANCA

In the past 50 years, Morocco has implemented two main public housing initiatives. The first one was initiated in the 1950's during the French protectorate (1912-56). The need for affordable housing came about when Casablanca became a prominent economic center and thousands of migrant workers arrived in search of work. Since there weren't any existing housing facilities to accommodate the influx of people, the French administration launched the construction of mass housing projects. The projects commissioned and built were at a massive scale, segregated and unsuccessful in the long term. These projects were inherently paternalistic and racist. The architects and planners involved in the design and construction of these projects claimed that they 'analyzed' the way in which rural Moroccans lived and applied their analysis to the design of the new housing. However, the cultural conclusions were very platonic and they did not truly understand the concepts of Moroccan living. For example, they made assumptions that Moroccans like communal living and therefore could share communal kitchens, bathrooms, and patios. Gèrard Blanchère, a civil engineer working in Algeria in the 1960's, wrote:

"If we are not careful, we will end up churning out hopelessly ugly and featureless developments. We already have some outstanding examples of what should not be built, notably the Carrières Centrales project in Casablanca, where rows and rows of grimly identical houses stretch out as far as the eye can see." [1]

Michel Ecochard, a French architect and urban planner was one of the first to initiate mass housing in Casablanca during the French protectorate. Ecochards' plan was to create satellite cities around Casablanca for 30,000 people.[2] One of the first projects that he worked on was the Carrières Centrales complex. The architects and planners involved decided that they would not use the narrow shape of the traditional living room and instead applied square shapes within a 6 meter by 8 meter plan. The result was more than 100 mass standardized and identical units built for the

1 Cohen, Jean-Louis, and Monique Eleb. Casablanca: Colonial Myths and Architectural Ventures. 326. New York: Monacelli Press, 2002. Print.
2 Cohen, Jean-Louis, and Monique Eleb. Casablanca: Colonial Myths and Architectural Ventures. 326. New York: Monacelli Press, 2002. Print.

Carrières Centrales project.

Additionally, when the housing projects were not sufficient to house all the people of the bidonsvilles, or shantytowns, Delaroziere, a town planner, proposed to re-house 9,500 shantytown sheds in standard two-room dwellings with communal public toilets and kitchens.[3] Furthermore, when a Moroccan participant involved in the International Union of Architects wanted to comment on the unfortunate attitude the French had towards the bidonsvilles situation, Ecochard said that "[a] Muslim should not be offered the opportunity to initiate debate on the bidonsvilles."[4] This shows the extremely twisted and racist mentality of Ecochard and his fellow colleagues, which would consequently only lead to disastrous housing projects.

Moreover, during that same time arrived a group of young European architects, several of them disciples of Le Corbusier, all excited by the tabula rasa Casablanca was offering them. They saw Casablanca as an ideal city to perform their design

3 Cohen, Jean-Louis, and Monique Eleb. Casablanca: Colonial Myths and Architectural Ventures. New York: Monacelli Press, 2002. Print.

4 Cohen, Jean-Louis, and Monique Eleb. Casablanca: Colonial Myths and Architectural Ventures. 330. New York: Monacelli Press, 2002.Print.

FIG 1.1: SHANTYTOWN IN CASABLANCA,1950'S

FIG 1.2: AERIAL PHOTO OF CARRIÈRES CENTRALES MASS HOUSING PROJECT,1955

experiments. The result was a series of high-rise functionalist slabs that incorporated few cultural elements. [5]

"There was a clear shift if attitude of the colonial authorities in the provision of housing in the 1950's. Attempts were made to house the local population in blocks of flats. Le Corbusier's former followers George Candilis, Shadrach Woods and Vladimir Bodiansky began working for the firm ATBAT (Atelier des Basttiseur). Five storey apartment blocks were introduced with a two-storey balcony called a suspended garden, reminiscent of Le Corbu immeubles villas." [6]

The three architects mentioned in the quote above, Candilis, Wood and Bodiansky designed buildings mainly for the Carrières Centrales complex. At that time, other European architects considered their designs innovative. However the projects they designed were mass standardized high-density housing projects that reflected the same misconceptions the French had in regards to Moroccan lifestyles. Once again, they assumed that the tenants came from the countryside and would want 'communal living' type

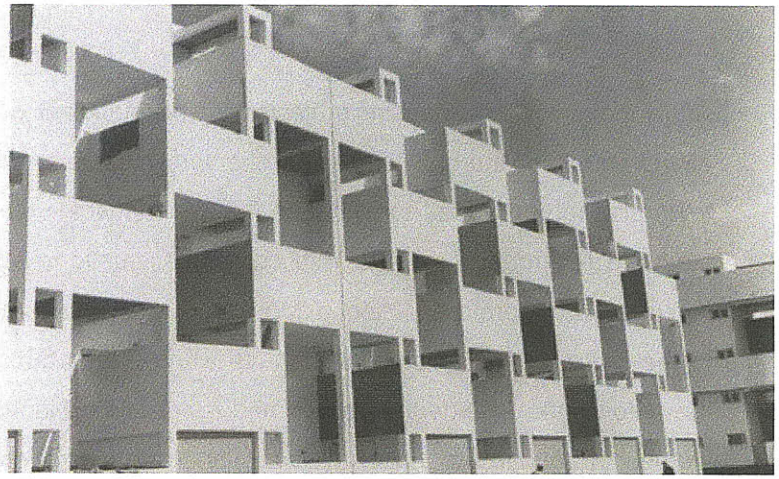


FIG 1.3: COLLECTIVE HOUSING PROJECT BY CANDILIS, CASABLANCA, 1952

FIG1.4: CARRIÈRES CENTRALES COMPLEX, CASABLANCA, 1952

5 Cohen, Jean-Louis, and Monique Eleb. Casablanca: Colonial Myths and Architectural Ventures. New York: Monacelli Press, 2002. Print.

6 Sibley, Magda. "The Courtyard House of North African Medinas." Courtyard Housing: Past, Present and Future. Ed. Brian Edwards. Abingdon, England; New York: Taylor & Francis, 2006. Print.

of dwellings. Furthermore, subsequent projects built during that time frame also reflected the previous ideas. For example, the 200-unit housing project Sidi Othman, designed by the architect Jean Hentsch, included individual family units consisting of only two rooms only, and sharing a patio and kitchen with adjacent dwellings.[7]

Overall, the mass housing projects built during the French protectorate failed primarily because they were 1) Standardized and 2) Discriminatorily un-cultural.

Therefore, in this thesis, I am making cultural adaptation and customization an essential aspect of the housing grammar. However, I am not being nostalgic about the past ways of living in Morocco, instead I am making the grammar reflect the daily living activities, making it about practicality and functionality. The next two sections will describe in further detail the cultural adaptability and customization research undertaken for the housing grammar.

FIG 1.5: AERIAL PHOTO OF THE MEDINA OF CASABLANCA

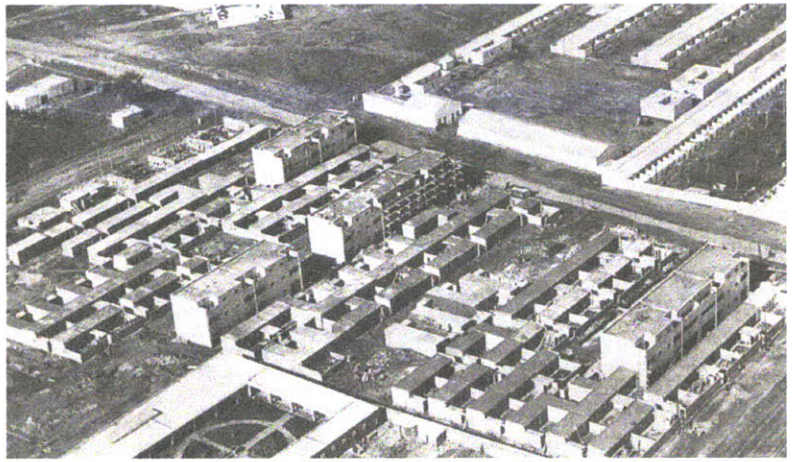


FIG 1.6: SIDI OTHMAN HOUSING COMPLEX BY HINEN, CASABLANCA, 1954

7 Cohen, Jean-Louis, and Monique Eleb. Casablanca: Colonial Myths and Architectural Ventures. New York: Monacelli Press, 2002. Print.

PART 1

B- CULTURAL ADAPTABILITY FOR CASABLANCA AND WHY IT SHOULD BE USED IN AFFORDABLE HOUSING

When we want to connect to our cultural tradition we must study in depth the building types this tradition maintained for many centuries. We must study them,not in a way historians would do, but from a designers' point of view.[1]

By understanding the typology of a house, we can derive from it recognizable rules that give it its architectural identity. I grew up in Morocco, but I still found it valuable to study traditional homes there in order to understand the underlying values and architectural spaces of the traditional house. Habraken writes, "We want to learn from our cultural heritage, not to deny present day realities, but to establish a continuity between tradition and renewal."[2] We should therefore be able to change the way traditional housing structures are built, depending on what is the most meaningful in that context.

In this thesis, I appropriate important elements from the typology of the traditional Moroccan home and use them to develop my housing grammar. Nevertheless, I change the building system from earth or on-site construction to factory built modular units. In accordance with Habrakens' writings, as designers and builders, we can apply variations and transformations to house types as long as we understand the principal inherent qualities that form them. This is especially true for Casablanca. I do not want to replicate the traditional Moroccan medina house, or propose single storey individual units but instead accommodate the daily activities within an adapted urban typology.

The traditional Moroccan house consists of long and slender rooms usually on all four sides, surrounding a central courtyard. The house for the most part is between one to three stories high. The central courtyard serves several purposes depending on the family. It can be a private space, exclusively available to the

1 Habraken, N. John. "Type as A Social Agreement". 3. Asian Congress of Architects. Seoul. 1988. Print.

2 Habraken, N. John. "Type as A Social Agreement". 3. Asian Congress of Architects. Seoul. 1988. Print.

family, or a public space used as an entertaining area for dinners, weddings, ceremonies, etc. The courtyard has become an urban typology for many countries in North Africa and the Middle East for centuries. It is a "...sustainable form of housing that has existed for thousands of years and in various geographical regions. It is particularly responsive to the development contemporary of low-rise high-density urban housing."[3] However, in most urban areas, the courtyard is 'endangered' because of the high demand and price of real estate. Nevertheless, the courtyard remains valuable because it offers a private open space in the middle of the city. Being surrounded by walls, it can be completely disconnected from the outside world, but also has the ability to connect with interior spaces, allowing them to extend into it.

FIG 1.7: COURTYARD HOUSES BY ZEVACO, AGADIR, 1964

FIG 1.8: COURTYARD HOUSES BY ZEVACO, AGADIR, 1964

The courtyard has indeed changed throughout the centuries, through its migration from rural or urban, and from denser urban areas to even denser urban areas. From form to function, architects have attempted to reuse the courtyard in urban settings. For example, the Courtyard Housing project designed by the architect Francois Zevaco in Agadir, the courtyard has

3 Sibley, Magda. "The Courtyard House of North African Medinas." Courtyard Housing: Past, Present and Future. Ed. Brian Edwards. Abingdon, England; New York: Taylor & Francis, 2006. Print.

been adapted and is placed in a corner of the lot and not in the center. Thus, there is a "...strong need to increase public and decision makers' awareness if the unexplored potential of such a house form through experimental and innovative contemporary projects." [4]

Spatially, the courtyard is also an organizing element within the dwelling.[5] The courtyard, "flexible and affordable, offers a supportive social arrangement."[6] In this thesis, the courtyard does indeed serve different functions (play area for children, extended living space, green space, cooking area), and acts as an organizational element. It is placed first in the design grammar, and the other spaces are positioned around it. The second space that is customarily placed adjacent to the courtyard is the kitchen. Since cooking and cuisine are important aspects of the Moroccan culture, it is important to have air ventilation and evacuation to an

4 Sibley, Magda. "The Courtyard House of North African Medinas." Courtyard Housing: Past, Present and Future. Ed. Brian Edwards. Abingdon, England; New York: Taylor & Francis, 2006. Print.

5 Sarkis, Hashim. "One Thousand Courtyards: Observations on the Courtyard as Recurring Design Element." The Courtyard House: From Cultural Reference to Universal Relevance. Ed. Nasser O. Rabbat. Farnham, Surrey, England: Ashgate Publishing, 2010. 188-202.Print.

6 Goethert, Reinhard. "More than a Pattern: The Contribution of the Courtyard House in the Developing World." The Courtyard House: From Cultural Reference to Universal Relevance.Ed. Nasser O. Rabbat. Farnham, Surrey, England: Ashgate Publishing, 2010. 173-187. Print.

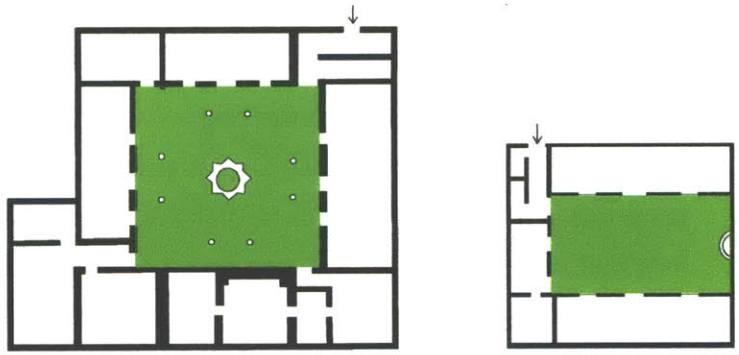


FIG 1.9: COURTYARD HOUSING FLOOR PLAN, CASABLANCA

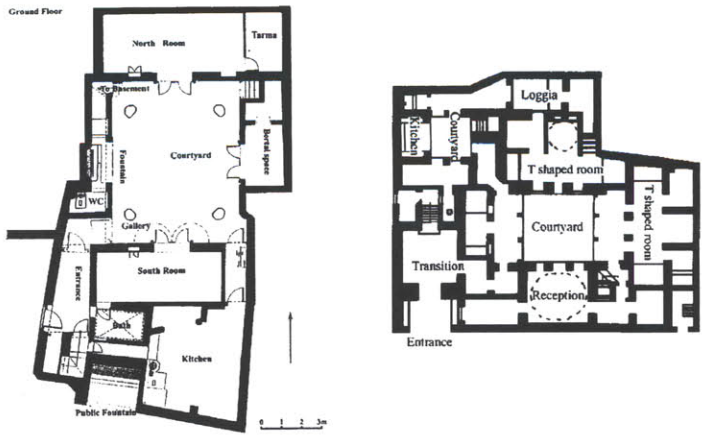


FIG 1.10: COURTYARD HOUSING FLOOR PLAN, FEZ

open space. Additionally, extended cooking needs can also lapse into the courtyard space.

Furthermore, grouping courtyard dwellings in vertical aggregation or in horizontal allocations, allows for a sustainable approach to space use in urban densities. Stacking and aggregating housing units that contain courtyards makes sense because traditional Moroccan medina homes are usually 9 meters to 18 meters high (with the average courtyard being 11.5 meters high)[7], the equivalent to a three-storey apartment building. Therefore having courtyards elevated in an urban setting is an appropriate solution.

Additionally, the courtyard has health benefits since it enables interior cross ventilation a controlled amount of sunlight and shade when needed. Furthermore, by investigating the courtyard as stacked units, I am exploring a new type of urban typology for low-rise high-density urban courtyard housing for Casablanca.

In addition to the courtyard, the living room in a traditional Moroccan house is extremely important. "In the traditional house type the relationship between space and function is more sophisticated." [8] This idea is valid for the Moroccan house as well. In a traditional affordable housing dwelling, spaces are not given specific functions. The traditional Moroccan living room is an essential space in a house, often serving as a multipurpose room, used as a living space, dining space and sleeping space. The Moroccan living room derives its identity from its shape and form,

7 Sibley, Magda. "The Courtyard House of North African Medinas." Courtyard Housing: Past, Present and Future. Ed. Brian Edwards. Abingdon, England; New York: Taylor & Francis, 2006. Print.

8 Habraken, N. John. "Type as A Social Agreement." 11cv. Asian Congress of Architects. Seoul.1988. Print.

FIG 1.11: COURTYARD HOUSE

FIG 1.12: LIVING ROOM IN A LOW-INCOME HOUSE

FIG 1.13: LIVING/SLEEPING ROOM, LOW-INCOME HOUSE

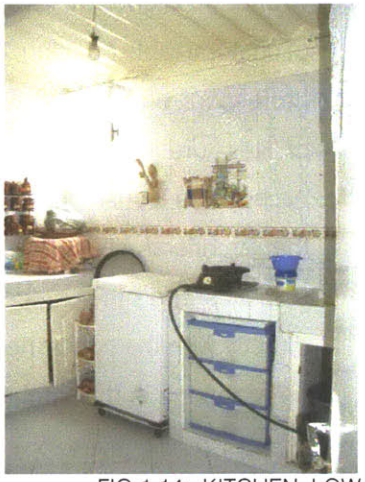


FIG 1.14: KITCHEN, LOW-INCOME HOUSE

as well as its hierarchal location between the public and private spheres. The important aspects of the room include elongated couches along the walls, as well as a round table for dining.

Thus, this existing context calls for a housing grammar, or design rules that respond to these needs and opportunities presented in Part II of this thesis. The next chapter moves from the past housing projects to review present housing models to show that prefabrication is the missing component in Casablanca.

PART 1

C- CUSTOMIZATION THEORIES AND PROJECTS AND WHY THEY SHOULD BE USED IN AFFORDABLE HOUSING

"A man who creates his environment is in harmony with himself"
John Habraken[1]

My interest in customization is based on the theory that flexibility, and customization) within architecture should be something that architects, planners and builders should use as an integral part of the professional practice. Customization should allow for individual expression and a diverse city landscape. In the field of mass housing, the exclusion of the end user is considered efficient and cooperation between the user and architect is un-thinkable, on the assumption that mass housing should not disadvantage the human identity or the urban fabric. In the next section, I will review projects that have dealt with this issue.

Housing has been a problem since the beginning of urban life, and the concept of mass housing goes back to Roman times. Within mass housing, addressing customization has been a dilemma architects have faced for centuries. "How does one design for the mass-man or the anonymous client who refuses to be considered anonymous, a number, or a faceless entry in a statistical survey?"[2], wrote Eric Dluhosch. Two of the leading thinkers and propagators of customizable housing, Eric Dluhosch and John Habraken, both professors emeritus at MIT, have written a substantial amount of literature on the topic. In an essay titled "The Role of the Architect in Housing Design: Old and New", Eric Dluhosch writes that architects should not design housing based on anonymous statistics and other precedents, but instead they should consult directly with the concerned user groups. Another interesting point he mentions is that architects should understand that designing

1 Habraken, N. J. Supports, an Alternative to Mass Housing.39.London: Architectural Press, 1972.Print.

2 Dluhosch, Eric. "The Role of the Architect in Housing Design: Old and New." A|Z ITU Journal of the Faculty of Architecture 3.1/2 (2006): 6. Web.

mass housing is process driven, and that they should transform the way they practice and think about architecture.[3] In a similar train of thought, a recent review of the book *Flexible Housing* written by Habraken, questions the field of architecture and the method in which architects have dealt with and continue to deal with customizable housing. He writes: "[Flexibility]... Is it simply a social service some of us feel morally bound to pursue, or does it imply a new and challenging kind of architecture?"[4]

There are several schools of thought when it comes to the customization of housing, and of course different notions on the degrees of possible customization. I will be discussing three different approaches to customization that are relevant to my thesis. The first deals with customization at the interior scale (also referred to as flexibility); the second is the supports and infill system, and the third approach is modular customization. I am using both the interior customization and supports and infill approaches discussed below as precedents, drawing from them what I find most valuable and applicable to the Moroccan context.

3 Dluhosch, Eric. "The Role of the Architect in Housing Design: Old and New." A|Z ITU Journal of the Faculty of Architecture 3.1/2 (2006): 23. Web.

4 Habraken, N. John. "Design for Flexibility." Building Research and Information 36.3 (2008): 290-296. Web.

The flexible and customizable housing discourse began in the 1920's with the rising need for affordable worker housing. It continued to develop with prefabrication technologies of the 1930's. It was assumed at that time that prefabrication techniques would not only be used for mass production but also for the creation of flexible and customizable housing. Since the 1920's, architects such as Le Corbusier, Mies Van der Rohe, Walter Gropius, and William Wurster (amongst many) preached the use of flexible and industrialized housing. Walter Gropius compared a house to a car, imagining a house with standardized individual elements that can be assembled together to create shrinkable and expandable customizable solutions. He envisioned people composing their house based on their individual taste.[5]

The notion of interior flexibility emerged early in the twentieth century when the need for worker mass housing and limited space became apparent. This occurred simultaneously with the minimalist and modernist architectural ideals of the time.[6] More than one hundred years later, this approach is still used.

5 Gropius discusses mainly single-family homes, and not the customization of multi-family dwellings

6 One of the first explicit examples of interior customization in Europe was Auguste Perret's Rue Franklin, in Paris in 1903.

To accommodate the customization of interiors architects design long-span concrete structures or frame based constructions to eliminate the need for interior columns and walls. The tenants can then arrange their interior spaces, delineating them with moveable and non-structural partition walls.

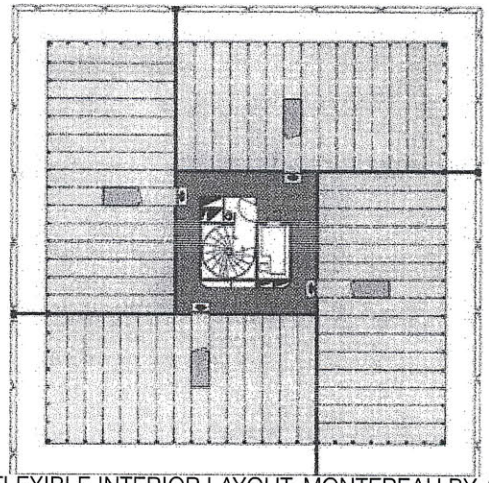


FIG 1.15: FLEXIBLE INTERIOR LAYOUT, MONTEREAU BY ARSENE-HENRY, FRANCE, 1971

An example of flexible housing is the Montereau apartment building in France, designed in 1971 by the architecture firm Arsène-Henry. The building structure is long-span concrete floors that create an unrestricted floor space. The occupants of the units could then subdivide their individual spaces to their liking. The residents of this building were involved in the initial design, resulting in thirty-seven unique apartment layouts.[7] Unfortunately, this building with its box like exterior, does not address the issue of customization of the facade.

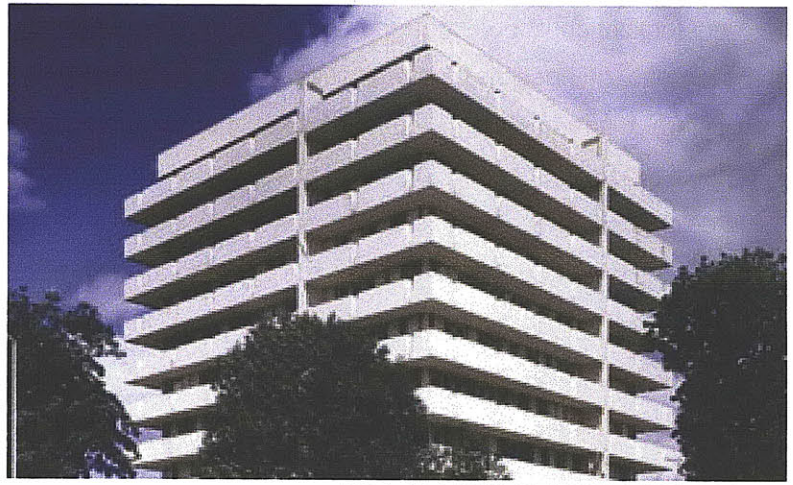


FIG 1.16: MONTEREAU EXTERIOR FACADE

Another example of a building that incorporates interior flexibility in the design is the Greenwich Millennium Village in London, completed in 2001 by the architecture firm Proctor. There are one

7 "Montereau | Les Frères Arsène-Henry." Flexible Housing.Web. <http://www.afewthoughts.co.uk/flexiblehousing/house.php?house=49>.

189 units that have been designed to accommodate the lifestyles of the residents. Similarly to the previous example, the units could be transformed into a one bedroom, two bedrooms, or an open loft plan using moveable walls. [8]

A third and more recent housing project that allows the tenants to make interior modifications to their units is built right here in Cambridge. AbodeZ on Broadway, developed by AbodeZ development, allows tenants to choose their interior layouts (with fixed locations for kitchens and bathrooms). Once again, interior partition walls make this possible. Similar to the other projects referenced, AbodeZ on Broadway works within an already built exterior shell.[9]

The primary focus of flexible housing according to Jill, Schneider and Till (authors of the book *Flexible Housing*), is on the design of generic spaces that are modest and that can tolerate change. The buildings should be convertible over time so that they can be used

8 Schneider, Tatjana, and Jeremy Till. Flexible Housing. 1st ed. Amsterdam; Boston: Architectural Press, an imprint of Elsevier, 2007. Print.

9 Reference the appendix interview with Ling Yi, Chief integrator and founder of AbodeZ.

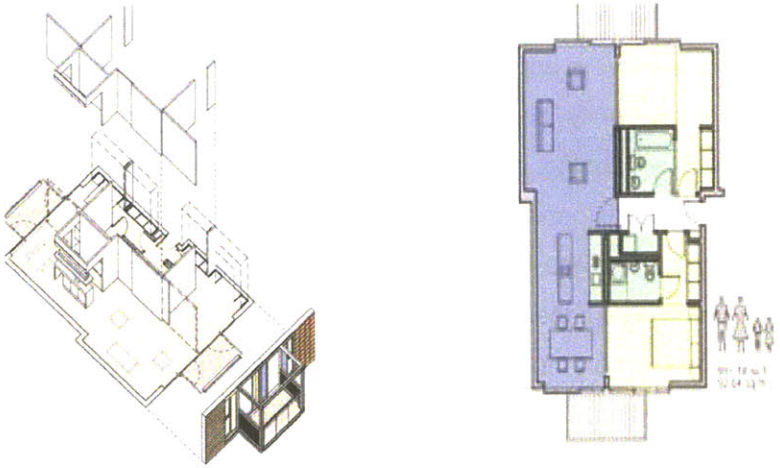


FIG 1.17: FLEXIBLE INTERIOR LAYOUT, GREENWICH MILLENIUM VILLAGE, LONDON, 2001

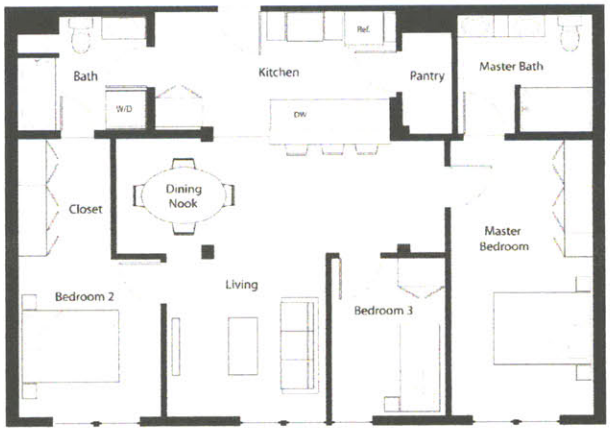


FIG 1.18: FLEXIBLE INTERIOR LAYOUT, ABODEZ ON BROADWAY, CAMBRIDGE, 2010

for other purposes. [10] However, to my knowledge housing projects deal with the opposite situation. Warehouses, churches, schools, single-family homes, etc... are being transformed into multi-family housing, and not vice versa. When is a housing complex ever transformed into a factory or a church? So even though I appreciate the idea of a transformable generic space, I am not quite sure if there are any valid precedents to sustain this theory. Furthermore, for the regions of the world with a growing working population, there will still be a need for housing for decades to come.[11]

Furthermore, another issue regarding the customization theories put forward by the architects discussed earlier is that the idea of an exterior customization is not thoroughly investigated by many of them. These architects have been talking about the idea of flexibility and personalized homes, but rarely do they explore the idea of exterior customization.

This leads me to the second approach to customization, that of support and infill. In his book *Supports, an Alternative to Mass Housing*, John Habraken explicitly investigates the ideals of the urban city, its landscapes and its characteristics. Habraken believes that other solutions to mass housing are possible than what has historically been designed. He writes that the relationship between man and dwelling must become more direct, and that if homes are incapable of growing or changing, they will become unlivable. So to counteract this, he recommends building 'superstructures' throughout the city that will act as a support system. Once this support system (the structural system) is in place, it can be infilled with housing units. My understanding of this approach is that the support system transfers the traditional street level plot of land to an elevated plot of land, two or three stories high.[12]

An example of the support and infill system is the Diagoon houses designed by Herman Hertzberger in 1972, located in Delf, Netherlands. The design provided a structural skeleton or frame that the users then filled in with internal and external spaces.[13]

10 Schneider, Tatjana, and Jeremy Till. Flexible Housing. 1st ed. Amsterdam; Boston: Architectural Press, an imprint of Elsevier, 2007. Print.

11 Morocco is a developing country that has nineteen and a half million people under the age of sixty, and four and half million under the age of fifteen. The country is not in a position to be transforming the housing stock into anything else but additional housing. However, residents have largely evacuated the new 'old' city of Casablanca that was built during the French protectorate, and offices now occupy the apartment buildings.

12 Habraken, N. J. Supports, an Alternative to Mass Housing.7. London: Architectural Press, 1972.Print.

13 "Diagoon Houses | Architectuurstudio Herman Hertzberger." Flexible Housing. Web. <http://www.afewthoughts.co.uk/flexiblehousing/house.php?house=48&number=

However unlike the supports and infill concept described by Habraken, Diagoon houses are single-family homes.

As much as the support and infill concept is interesting, it involves significant site work as well as responsive building codes. However I did want to review the supports and infill system because it allows for exterior and interior customization. The third type of customization is that of customizable modules. A very renowned example of a customized modular project is Habitat 67 in Montreal, Canada, designed by Moshe Safdie.

Additionally, creating a sense of ownership within affordable housing will help resolve both architectural and economic problems. Research has shown that housing is not a priority for people who cannot afford it. Instead, educating their children and feeding their families is more important.[14] Therefore when market

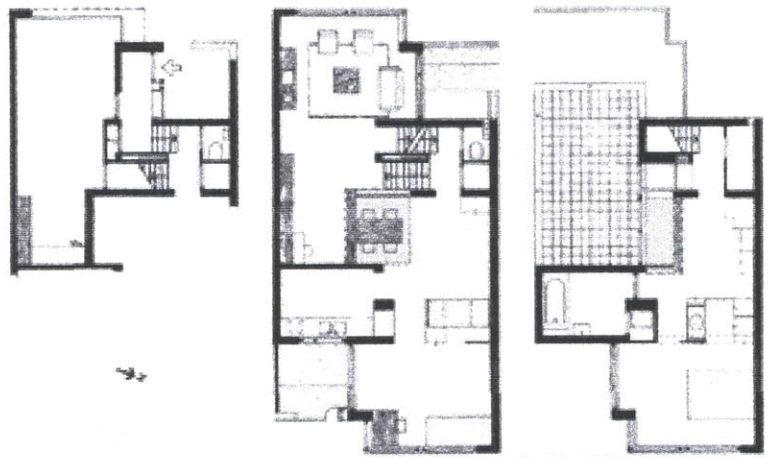


FIG 1.19: SUPPORTS AND INFILL, DIAGOON HOUSE BY HERTZBERGER, NETHERLANDS, 1972

FIG 1.20: SUPPORTS AND INFILL, RATHENOW, GERMANY BY KEIM+ SILL

&total=&action=&data=&order=&dir=&message=&messagead=>.
14 Turner, John F. C. "Housing Priorities, Settlement Patterns, and Urban Development in Modernizing Countries." AIP Journal (November 1968): 354-363. Web.
Goethert, Reinhard, and Nabeel Hamdi. Making Microplans: A Community-Based Process in Design and Development. London: IT, 1988. Print.

priced housing is made available to low-income housing tenants at a subsidized and very interesting price, what often happens is that they end up selling their units at market price to make a profit, and then go back to living in slums. Thus, housing should not be speculative since the end goal is to eradicate squatter settlements. By combining internal flexibility and exterior individuality, end users will have a sense of ownership and will not be as eager to sell their dwellings.

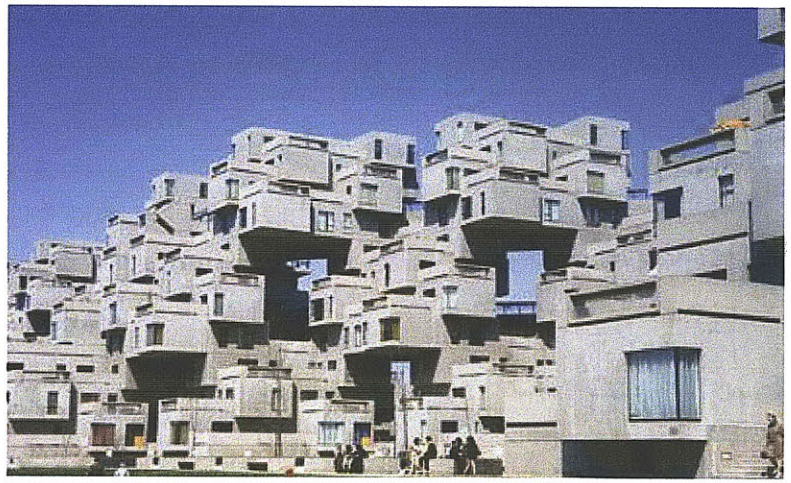


FIG 1.21: CUSTOMIZABLE MODULES, HABITAT 67, BY MOSHE SAFDIE, CANADA

In this thesis, the grammar proposed provides the end user with a proxy to make a contribution to the final design. When only the interior is flexible, then the exterior still looks like mass standardized housing. This is what I am trying to avoid. Flexibility should be possible both in the interior scale, by moving doors, folding furniture, and in the flexibility in exterior of the building.[15]

The way I decided to use customization was to allow the user a choice in the layout of the bedrooms, in the location of the courtyard and in the size of the overall unit. This is possible because the

15 Customization and flexibility are especially important aspects of this grammar since it is inherent in the Moroccan culture. Most rooms are multifunctional- they can act as a living room, a T.V room, a dining room, and at night that same space transformed into a sleeping areas.

prefabrication system allows the use of non-structural partition walls. These partition walls are then placed to accommodate the needs of the residents. However, it is important to point out that Morocco has very strict building codes when it comes to government subsidized affordable housing. An apartment has to have at least one master bedroom and one secondary bedroom, in addition to a living room, kitchen and bathroom.

In general, customization and user involvement is criticized for being costly, having technical flaws, needing an architect rather than an end user to make the final decisions. Some research also shows that a 'trained' architect would not have designed the floor plans that were designed by the users. Furthermore, for customization to work properly, the legal and financial systems need to adapt to it.[16] However, I believe that if given the right tools, architects as well as developers will truly consider the option of customization.

16 Habraken, N. John. "Design for Flexibility." Building Research and Information 36.3 (2008): 290-296. Web.

PART 2: PRESENT CONTEXT

A- HOUSING BACKGROUND AND FUNDING

B- PREFABRICATION SYSTEMS AND TECHNOLOGIES AND THEIR USE IN THE PRESENT CONTEXT

C - TRANSPORTATION AND OTHER PREFABRICATION CONSTRAINTS

D- COMPARATIVE COSTS: TRADITIONAL BUILDING VS. PREFABRICATION

PART 2

A- HOUSING BACKGROUND AND FUNDING

The Kingdom of Morocco has a population of approximately thirty million people, and more than half of the population lives in an urban setting. There is an increasing need for affordable housing throughout the country. Only 83%of urban households have access to clean water, and 89% percent have access to electricity.[1] Further proof of the need for affordable housing is the country's $4,900 per capita GDP.[2]

In 2004, the Moroccan government launched a national slum and squatter settlement abolition program, named *Villes Sans Bidonsvilles* (Cities Without Slums) as part of a larger program called the *Initial Initiative for Human Development. Villes sans Bidonsvilles* (VSB) is scheduled to complete by the end of 2012[3]. This program aims at providing housing for 290,000 households throughout the country that are currently living in sub-standard conditions. The program targets 83 cities across the country for slum eradication. The estimated cost of this program is $3.4 billion, of which 40% comes from a state subsidy.[4] The VSB program includes a slum eradication, renovation of existing housing in addition to construction of new housing. The program focuses on restructuring of existing housing[5], upgrading sites and services of squatter housing[6], and the construction of new housing.[7]

However, the economic capital of the country, Dar El Beida, also known as Casablanca, has the most urgent and challenging issues. Greater Casablanca, which includes the city's suburbs and peripheries, has 6.5 million residents. The inner city has an estimated 4 million residents, with about 98, 000 households living

1 This means that 2,500,000 million people do not have access to clean water, and 1,650,000 people don't have access to electricity.

2 Central Intelligence Agency. "The World Factbook. Africa: Morocco." Central Intelligence Agency. The work of a nation. The center of intelligence. 04/28/2011 2011.Web. <https://www-cia-gov.libproxy.mit.edu:9443/library/publications/the-world-factbook/geos/mo.html>.

3 This seems very unlikely at this point. Eradicating all slums in Morocco in the next eight months is probably not achievable and the scheduled end date will be pushed back.

4 Baverel, Anne. *Best Practices in Slum Improvement: The Case of Casablanca.* Development Innovations Group, 2008. *Urbis: The Urban Capacity Laboratory.* Web.

5 This housing includes homes in the old medinas', or the areas of the original city, that need to be structurally reinforced to comply with current building codes. However, in some cases where the housing is unsalvageable, the residents are given newly built housing units.

6 In this case, squatted land is given to the current residents. Land parcels are upgraded to fire code regulations, and serviced with water, electricity and sewage systems.

7 The construction of new housing is the focus of this thesis.

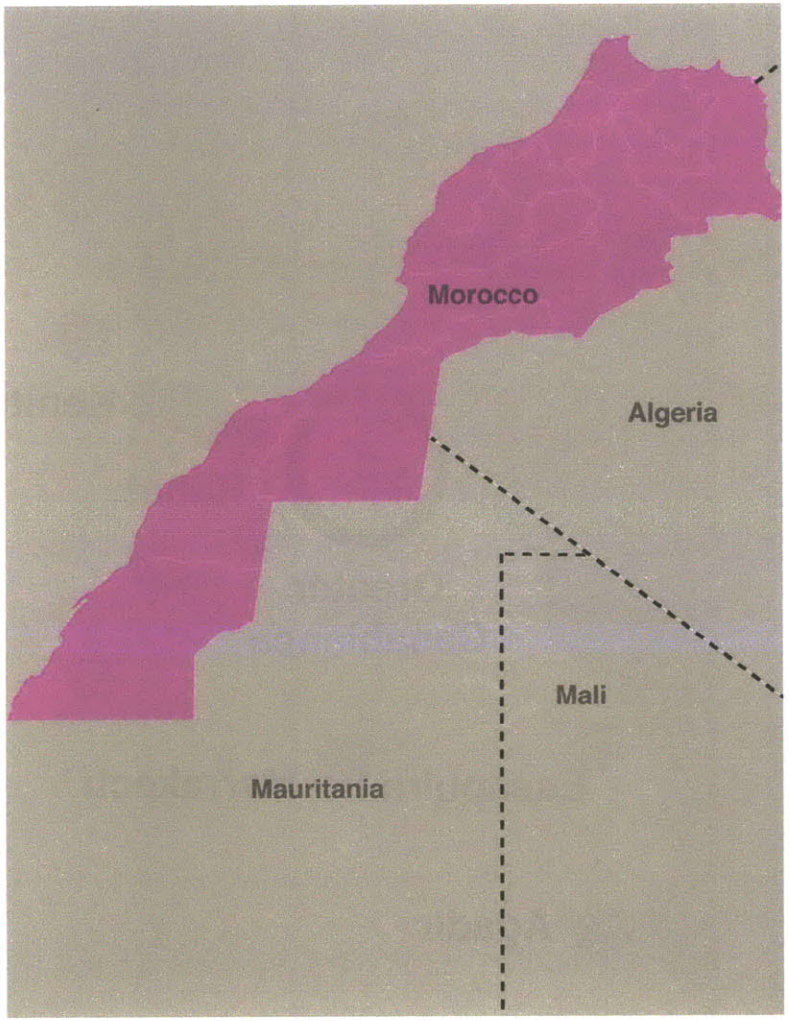


FIG 2.1: MAP OF MOROCCO

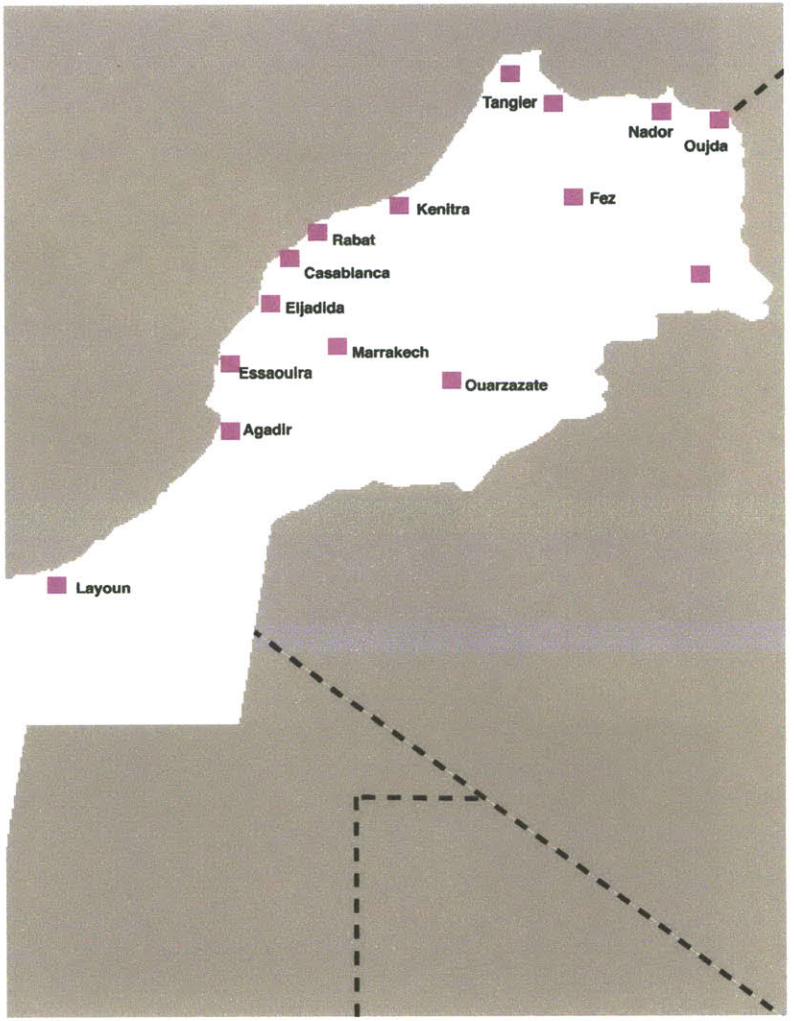


FIG 2.2: MAP OF MAIN URBAN CITIES IN MOROCCO

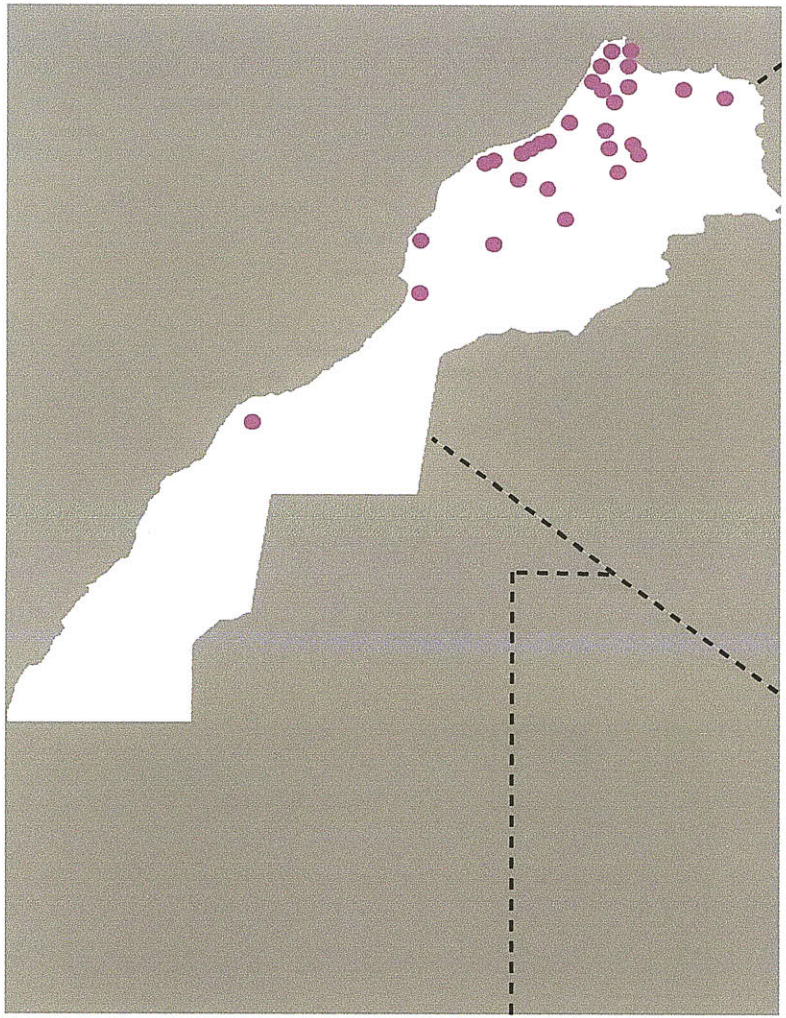


FIG 2.3: MAP OF THE MAIN CITIES TARGETED BY THE VSB INITIATIVE

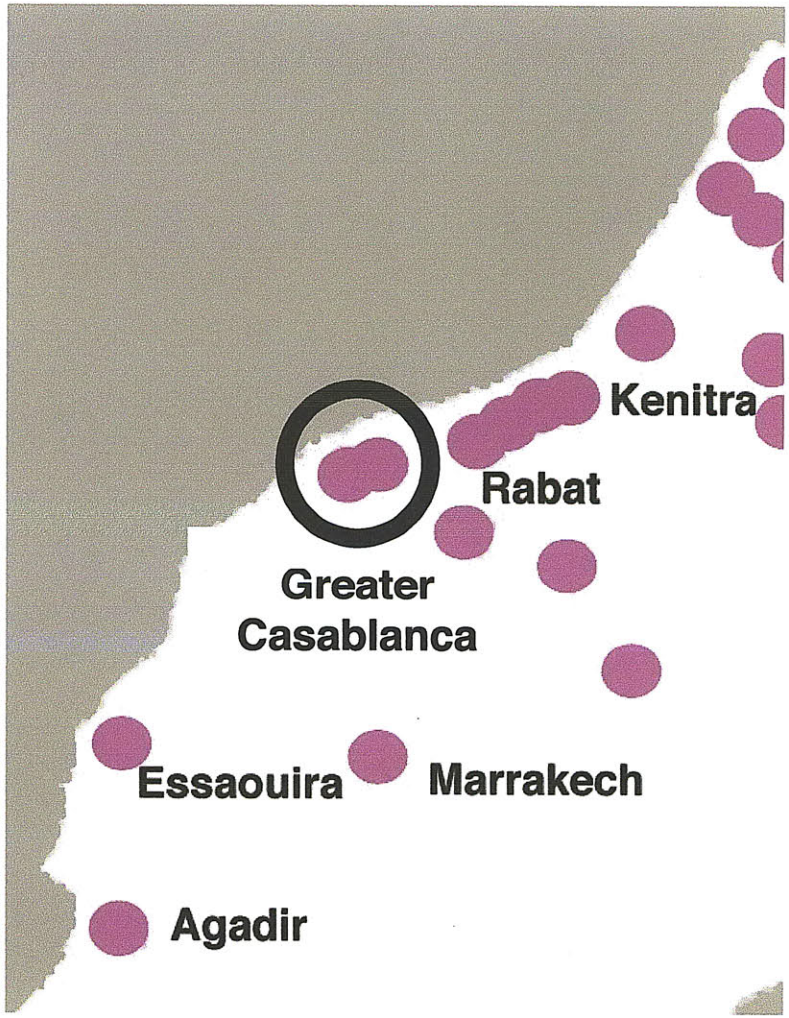


FIG 2.4: LOCATION OF GREATER CASABLANCA WITHIN MOROCCO

in unsanitary conditions, without any access to water, sanitation, (legal) electricity, and other basic needs.[8] In Casablanca alone, the government has planned an investment of $1 billion. [9]

As part of the VSB program the city is using services from both private and semi-public developers (Holding Al Omrane, Idmaj Sakan) to help build new housing for the urban poor. According to a recent census, and in accordance with the three point

8 Baverel, Anne. *Best Practices in Slum Improvement: The Case of Casablanca.* Development Innovations Group, 2008. *Urbis: The Urban Capacity Laboratory.* Web.
9 Baverel, Anne. *Best Practices in Slum Improvement: The Case of Casablanca.* Development Innovations Group, 2008. *Urbis: The Urban Capacity Laboratory.* Web.

FIG 2.5: FIGUREGROUND SHOWING DENSITY OF SHANTYTOWN

FIG 2.6: SHANTYTOWN IN CASABLANCA

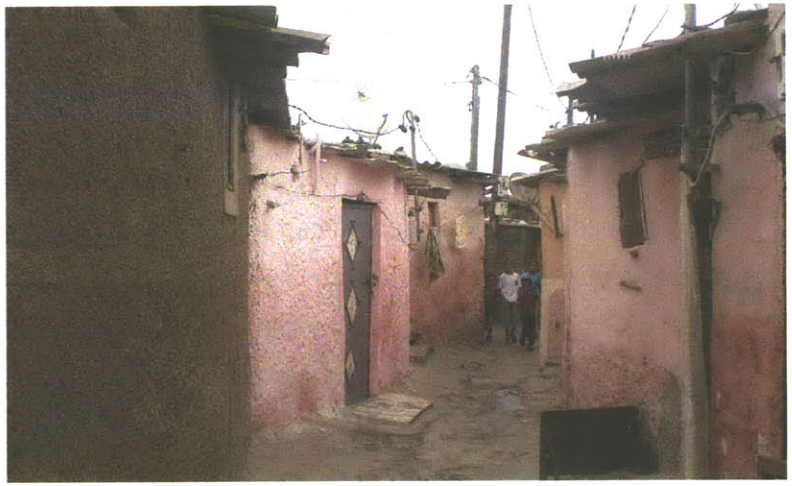


FIG 2.7: URBAN SETTLEMENT IN CASABLANCA

housing plan, 27,000 households in Casablanca are to be given new housing, 31,000 will be relocated to serviced lots, and the remaining salvageable housing will be upgraded and connected to services.

According to a report written by URBIS, the VSB is "one of the worlds best urban poverty alleviation program"[10], but it is at risk because there is very little popular involvement in governmental policies regarding new housing, relocation and slum restructuring.[11]

In addition to setting national goals for the removal of all slums in the country, the government created financial and development models to sustain the growth of the VSB program. The main financial model put in place is FOGARIM, a guarantee fund for mortgages for low or seasonal income groups, administered through local banks and guaranteed by a government fund, the Caise Centrale de Garantie, under the Ministry of Finance at a 70% risk. Local banks such as Credit Immobilier et Hotelier (CIH), Crédit Populaire du Maroc, Banque Marocaine du Commerce

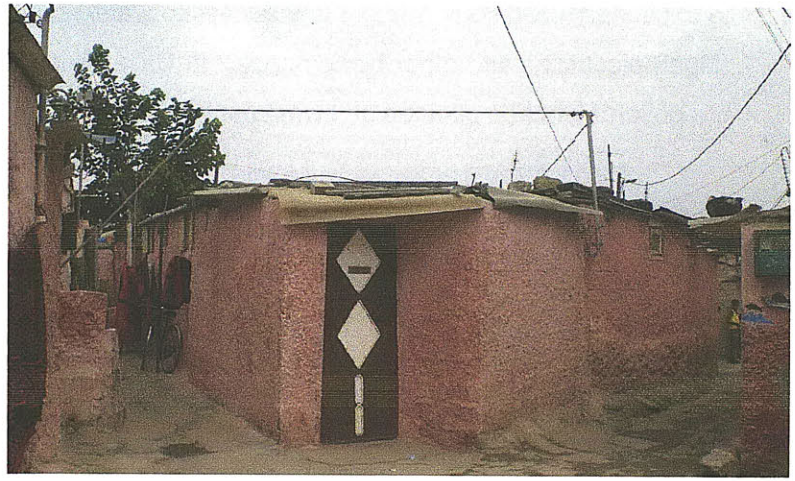


FIG 2.8: SALVAGEABLE HOUSING TO BE UPGRADED

FIG 2.9: NEWLY BUILT GOVERNMENT SUBSIDIZED HOUSING

10 Carliez, Marianne, Franck Daphnis, Fouzi Mourji, and Craig Matasick. *A Rapid Urban Diagnostic and Proposed Intervention Strategy for DIG in Casablanca, Morocco.* 55. Web.

11 This thesis project tackles the issue of lack of resident participation by providing customizable housing options, and participation in the design and planning phases.

Exterieur, (BMCE) and Attijari Wafa have provided more than 97% of the loans.[12]

FOGARIM allows residents without resources to access bank loans and other housing finances by providing 100% of the mortgage at a rate of 4-9% of the purchase price of the housing unit (a maximum of $23,000), over a twenty-five year period (this is also dependent on age). FOGARIM, which provides an opportunity for low-income residents to purchase a home, is available only to first time homebuyers who cant provide evidence of a guaranteed income.[13] According to maghrebia.com, the main beneficiaries of the loan are traders (41%), street merchants (23%), traditional manufacturers (16%), taxi drivers (4.2%), housemaids (3.7%), and artisans (3.3%).[14]

When it was launched, FOGARIM was not as successful as predicted, because it did not properly target low-income residents. Those it intended to help did not know how to access this loan, and most of the time were intimidated by the fact that they had to go to a bank or other financial institutions where they had never been before and that only operated during certain business hours. [15] These problems were overcome after the involvement of micro finance institutions (MFI's) and non-profit organizations. These organizations started an outreach initiative to educate and provide information for the low-income residents and slum dwellers. Local offices were set up within the slums and low-income neighborhoods to help people understand the system and apply for loans. Certain non-profit organizations were also trusted by the banks to run the background check on the residents applying for the loan.

Since its creation in 2005, more people have been made aware of FOGARIM, and between 207 and 2008, there was a 15% increase in approved bank loans. By August 2008, approximately 200,000

12 Belhaj, Imane. "Morocco's FOGARIM Fund Benefits Aspiring Homeowners." *Maghrebia*. 09/04/2008 .2008. Web. <http://www.magharebia.com/cocoon/awi/xhtml1/en_GB/features/awi/features/2008/09/10/feature-02>.

13 "FOGARIM" Guarantee Fund for mortgages for low or seasonal income groups." Web. <http://www.finances.gov.ma/portal/page?_pageid=93,17878110&_dad=portal&_schema=PORTAL>.

14 Belhaj, Imane. "Morocco's FOGARIM Fund Benefits Aspiring Homeowners." *Maghrebia* 09/04/2008 2008Web. <http://www.magharebia.com/cocoon/awi/xhtml1/en_GB/features/awi/features/2008/09/10/feature-02>.

15 Most low-income residents and slum dwellers are illiterate and were not properly educated on this newly set up loan system.

people had benefited from the FOGARIM loan.[16] As of 2007, the bank BMCE had made 24,000 loans, and used the guarantee fund for only twenty-four defaults (after 9 months of nonpayment, which is a very low 1% default rate). However, FOGARIM is still inaccessible to one fifth of the urban poor who cannot afford the monthly payments.

Additionally, to further encourage the construction of affordable housing, the government provides credit and tax incentives to private and semi-public developers who build affordable housing and sell it below $23,000. These developers are exempt from the Value Added Tax (VAT), and are exempt from a zero percent appreciation of the real estate.[17] It is also estimated that so far, the Moroccan government provided 9,000 hectares of land to developers for the construction of affordable housing.

However, even with all the subsidies available, the housing market is unable to keep up with the demands. The supply of new housing in Casablanca, using traditional construction methods added 93,000 units to the housing stock in 2006. The existing housing deficit, and the need for additional housing, together totaled 120,000 [18] units that year, resulting in a shortage of 23,000 units. [19] In this situation prefabrication construction becomes the only solution possible to avoid the failure of the Villes Sans Bidonsvilles program.

The following section discusses the different prefabrication methods and their applicability.

16 CMC. "Over 200,000 Benefit from FOGARIM Fund." *Morocco Business News.* 08/28/2008. 2008. Web. <http://www.moroccobusinessnews.com/content/ArticlePrint.asp?idr=20&id=358>.

17 There are other tax and credit incentives for sub-contractors and service providers, such as water and electricity companies. Carliez, Marianne, Franck Daphnis, Fouzi Mourji, and Craig Matasick. *A Rapid Urban Diagnostic and Proposed Intervention Strategy for DIG in Casablanca, Morocco.* Web.

18 Baverel, Anne. Best Practices in Slum Improvement: The Case of Casablanca. Development Innovations Group, 2008. Urbis: The Urban Capacity Laboratory. Web.

19 As of today there is still a significant shortage of housing stock deficiency. I was however, not able to obtain exact numbers for 2010.

PART 2

B- PREFABRICATION SYSTEMS AND THEIR APPLICABILITY IN THE PRESENT CONTEXT

"In construction, cost reduction can only be achieved by reducing either quality or area (m2). To lower the overall price, construction needs to shift from on site to standardized industrial systems."[1]

The construction industry is one that is extremely anchored in traditions that have been passed down since humans started building. Today the traditional construction industry continues to be complicated and inefficient. First of all, architects are minimally involved in site construction and are usually limited to design development. Structural and mechanical engineers have no say in the design, only becoming involved when its time to incorporate structure and building systems. Contractors then have to build something which they weren't a part of creating, and they frequently hire subcontractors for plumbing, electric and all other mechanical systems. Detail components (windows, doors, kitchens etc...) are ordered from different manufacturers and come from different locations. Finally, all these various components and service providers arrive at the construction site to assemble the final product in open-air locations with types of environmental constraints (rain, snow, heat etc...). Overall, there is an extensive lack of communication between all the different parties involved, leading to unbuildable designs, over-structured systems, construction mistakes, material waste, and unproductive time. However, with factory prefabrication and the current available technologies such as three-dimensional programs and CadCam software, we can visualize an end product and use machines to fabricate it. Factory prefabrication has evolved since its conception. Today, prefab integrates current architectural and building innovations to produce high quality design and architecture.

In my opinion, prefabrication as a construction method should be used to produce low-cost high-density projects.[2] Today, prefab is defined as the construction of parts of a building or of an entire

1 Dluhosch, Eric. "The Role of the Architect in Housing Design: Old and New." A|Z ITU Journal of the Faculty of Architecture 3.1/2 (2006): 11. Web

2 Since it first started, prefabrication has been the target of a lot of experimentation across the world.

building in a factory setting. Once the building elements have been built they are shipped and assembled on the final construction site. John Habraken states the benefits of prefabrication clearly: "The idea of prefabrication rests on the idea that work can be produced more simply and quickly in the workshop than on the site. Working conditions are more favorable; they are not subject to the weather, and if large numbers of prefabricated dwellings are required, machine production has a great advantage in that most of the work can be done in the same place." [3]

Housing prefabrication has been stigmatized since its development in the early 20th century. From the start it was known as cheap and standardized. This unfortunate stigma has hindered users from implementing prefabricated housing, especially in urban settings. From a historical perspective prefab has been used during social, economical and political crises. In the early 1900's in the Unites States, companies like Aladdin Readi-Cut Houses started offering prefabricated kit homes that consisted of precut components. The entire house could be ordered via catalogue. Another company, Sears, would also deliver these kit homes by mail to the owners who would then assemble them.[4] From then on, architects as well as contractors became interested in experimenting with technologies and materials in regards to prefabrication.[5]

In Europe, after the devastations of World War I, France, Britain, and Germany (amongst other countries) welcomed prefabrication techniques as a cost and time saving method that would help them rebuild their countries.[6] After World War II in the United States, architects, planners and reformers had the possibility to venture into real life exploration in innovative design and prefabrication construction methods. Catherine Bauer wrote in 1942 that "[The War] is giving us a vast laboratory experience with experimental building methods and prefabrication, with large scale community planning, with rental management and upkeep, and with streamlined production process."[7] During and after WWII, the US built

3 Habraken, N. J. Supports, an Alternative to Mass Housing.51. London: Architectural Press, 1972.Print.

4 These were one of the first examples of component homes.

5 Arieff, Allison, and Bryan Burkhart. Prefab. 1st ed. Salt Lake City: Gibbs Smith, 2002. Print.
Smith, Ryan E. Prefab Architecture: A Guide to Modular Design and Construction. Hoboken, N.J.: John Wiley & Sons, 2010. Print.

6 Arieff, Allison, and Bryan Burkhart. Prefab. 1st ed. Salt Lake City: Gibbs Smith, 2002. Print.
Smith, Ryan E. Prefab Architecture: A Guide to Modular Design and Construction. Hoboken, N.J.: John Wiley & Sons, 2010. Print.

7 Wurster, Catherine Bauer. "Wartime housing in defense areas." Architect & engineer 151. (1942): 33-35. Print.

vast prefabricated estates for war workers.

One example is Carquinez Heights in Vallejo, California, designed by William Wurster and commissioned by the Federal Works Agency. Carquinez Heights was built to house the 20,000 employees of the Mare Island Navy Yard.[8] The project involved 1677 housing units, all identical in plan and in materials. These units were designed to be demountable and prefabricated. Using the prefabrication system, the houses were built on a modular basis and sections of the house were built as needed, and numbered. This made the delivery as well as the assembly of the units quick and efficient.[9] Due to the mass housing construction of cheap and standardized worker housing during WW1 and WW2, the image of prefab suffered and still suffers today from this stereotypical idea that prefab is uncustomizable and inflexible.

Today prefabrication, which is still used in housing, hospital and hotel design[10] can be categorized into four groups: component, panel, module, and complete buildings.[11] Each one of these groups comprises different levels of off-site and on-site construction. The

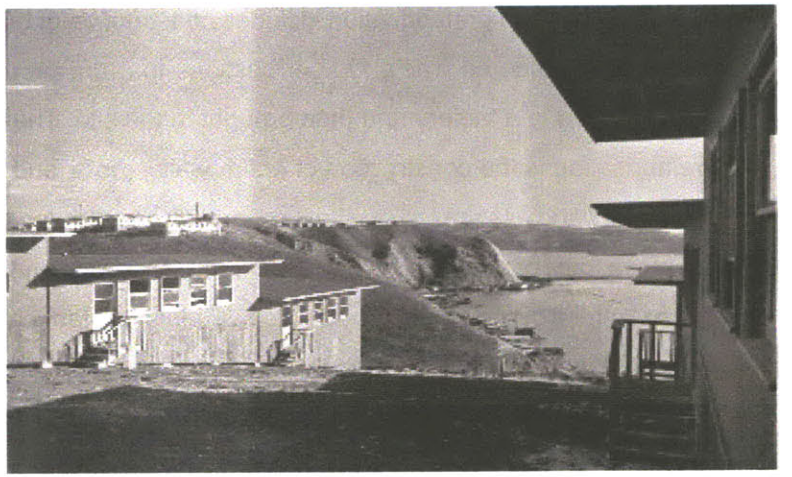
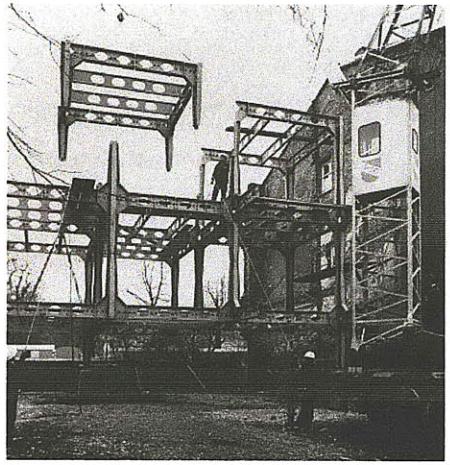


FIG 2.10: PREFABRICATED STANDARDIZED HOUSING , CARQUINEZ HEIGHTS, CALIFORNIA , 1941

8 "Low-cost houses." Architectural forum 75. (1941): 211-242. Print.
9 "America Builds." California arts & architecture 58. (1941): 35-41.Print.
10 In a recently built hospital project using pre-fabrication, it was estimated that four to six months were gained in schedule. This was done through the minimization of construction time and a 20% reduction in labor costs.
11 Bell, Pamela. "Kiwi Prefab." Concrete December 2010/January 2011.Web.

component-based prefabrication includes construction of building components such as wall and floor sections that are produced, cut and sized in a factory and then brought to the site. The panel prefabrication is the construction of entire walls, roofs, and floors in a factory and assembled on site. Le Corbusier's Dom-Ino house in France, built of reinforced concrete walls and floors, is one of the first examples of panelized construction. Modular prefabrication is the construction of an entire building in modules that are then assembled to create the overall building and its structure. The last genre of prefabrication is the construction of an entire building in a factory, which is then anchored to a foundation on site. [12]



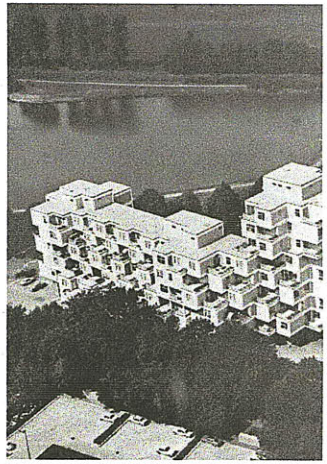


FIG 2.11: COMPONENT PREFABRICATION

There are numerous benefits to prefabrication. Prefab allows for an efficient production since a majority of the building elements are constructed in one location and overseen by designated professionals; The factory environment is controlled and hence the construction is not dependent on weather and other and other external factors; The final product if of higher quality due to the efficiency of the system, and there is added worker safety because of the controlled factory environment. Finally, factory production is less expensive than on-site construction mainly for the following

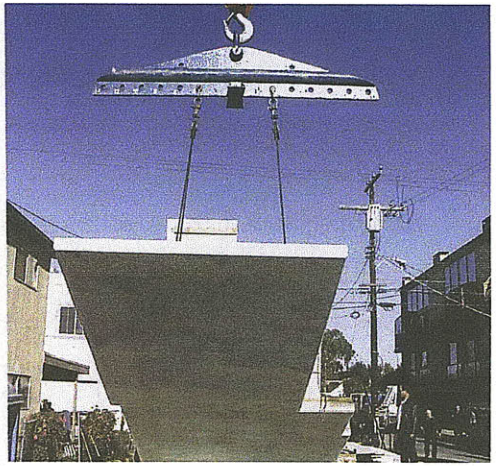


FIG 2.12: PANEL PREFABRICATION

12 This last method only possible for smaller buildings such as single-family homes.

reasons: first, there is less material waste because of fewer inaccuracies and miscalculations (onsite construction has been estimated to waste about 40% of raw materials): second there are less labor costs involved because factory workers do not need to be as skilled as on-site construction workers: and third, there is a 60% reduction in construction time resulting in significantly fewer payments on bank loans, bonds and construction insurance.[13] Additionally, when constructing in an urban context such as Casablanca, prefabrication mobility and quick on-site assembly are an immense advantage.

FIG 2.13: MODULAR PREFABRICATION

Prefabrication is also a sustainable alternative to on site production because it involves less material waste and reduced raw material transportation, contributing to lower CO2 emissions, and producing environmentally friendly buildings. Furthermore, to make prefabrication even more effective, the design has to be generated simultaneously with the building system. By doing so, the prefabrication system allows for greater flexibility, and a generation of customizable floor plans.

FIG 2.14: CoMPLETE BUILDING PREFABRICATION

13 Smith, Ryan E. Prefab Architecture: A Guide to Modular Design and Construction. Hoboken, N.J.: John Wiley & Sons, 2010. Print.

For this thesis, I wanted a system that would minimize on-site construction and overall production time. Thus, the modular prefab system is the best fit for this thesis. The other systems discussed earlier in this section require supplementary site construction work and therefore increasing time and cost. In addition, the modules need to be made of structural lightweight concrete that can be purchased through local companies.[14]

After completing the analysis on cultural adaptation, customization and prefabrication I set up a set of rules that have inspired the housing grammar. Since the modules are made of structural lightweight concrete, there are no additional structural requirements involved; the structural system is inherent in the prefabrication system. The modules are then completely finished in the factory, including the mechanical systems, kitchens, flooring and paint. The modules are transported to the construction site and attached to one another to form the apartment units, and aggregated to form a building. From an urban standpoint, new densities can be created in a very short period of time by aggregating the prefabricated modules. In the case of Casablanca, where there is a high housing need in a dense urban setting, this system will offer the possibility of absorbing some of that deficit.

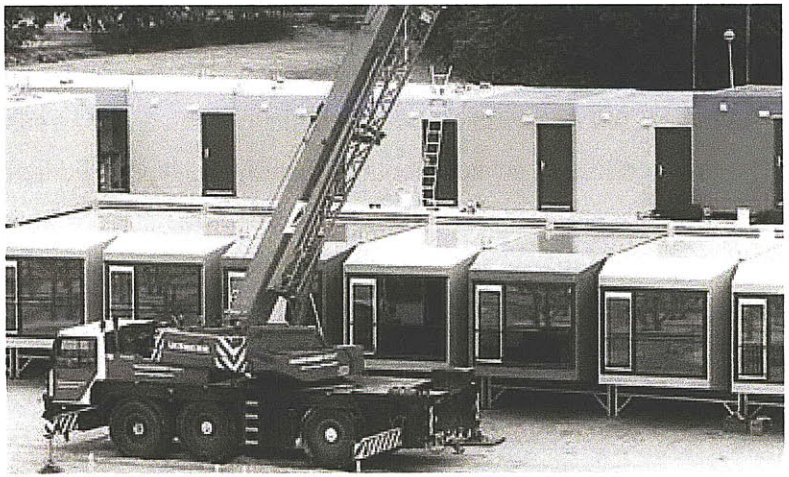


FIG 2.15: PREFABRICATED MODULES PLACED ON SITE WITH A CRANE

14 The use of structural steel is not an affordable option because it is an expensive raw material and needs to be imported from other countries.

PART 2

C- TRANSPORTATION AND OTHER PREFABRICATION CONSTRAINTS

Nevertheless, when envisioning prefabrication as a construction system, several factors such as road systems, transportation and building codes need to be taken into consideration.[15] There is an existing highway system in Morocco that connects the city of Tangier in the northwestern tip, to the city of Agadir along the southwestern coast. This makes it possible for the modular units to be delivered on trucks to the cities along the highway route. [16]

The truck size has to be a standard semi truck or single unit truck to facilitate navigation inside the city. For this project, I have chosen to work with a standard semi-truck that can separately hold a 9-meter by 4.5-meter module, in addition to a smaller module of 6.3 meters by 4.5 meters (these two modules become

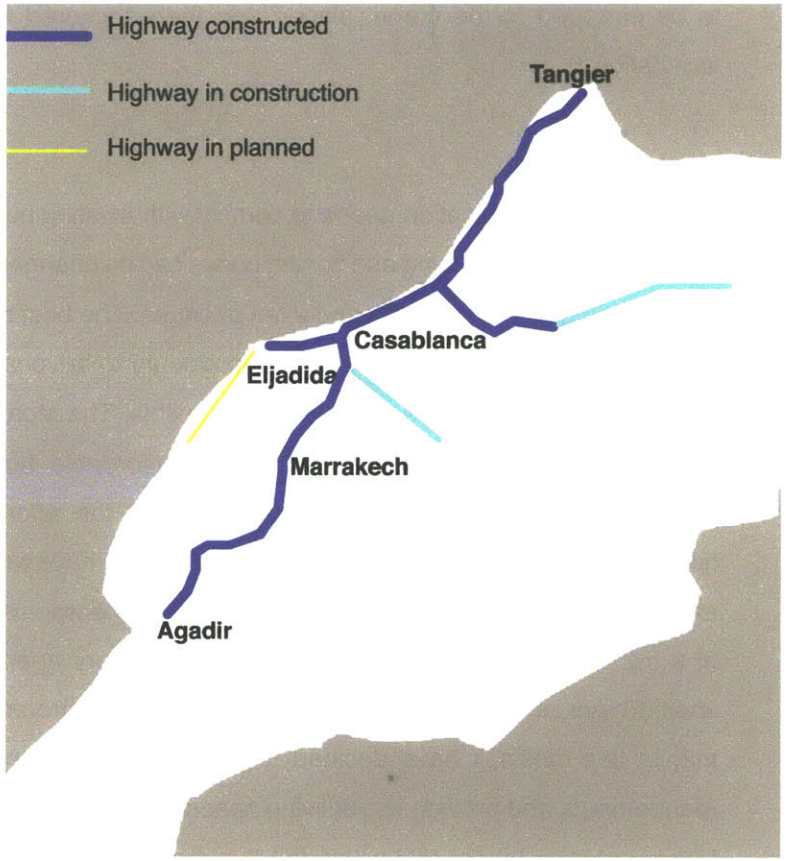


FIG 2.16: MAP OF HIGHWAYS IN MOROCCO

15 Littell, Matt et al. Prefab City. Master's Research Studio at Northeastern University, 2010. Web
Smith, Ryan E. Prefab Architecture: A Guide to Modular Design and Construction. Hoboken, N.J.: John Wiley & Sons, 2010. Print.

16 Other transportation systems such as rail and water vessels are also possible if needed. Since I am using Casablanca as a case study for this thesis, high way transportation is the most efficient method. Nevertheless, if this thesis prototype needs to be applied elsewhere in Morocco where there are no highways, one can envision using the other transportation methods.

the basis of the design system that integrates the prefabrication and customization). Furthermore, the site needs to accommodate cranes for the stacking and assembly of the modules, which need to be strapped to the crane, placed and then anchored to the foundation.[17]

Additionally, prefabrication needs to comply with existing building and zoning codes. Building and zoning codes can be changed with time but it usually takes years and even decades. The best option is to work with the existing context but to also try to advocate for building codes that can be adaptable and flexible. The Moroccan building codes for government subsidized affordable housing projects are rather rigid. The codes state that the affordable housing units have to be between 50 m2 - 100 m2, have to have at least one living room of 12 m2 and at least two bedrooms, one of 9 m2 and the second of 7 m2. Additionally, every apartment should have at least one kitchen of 5 m2 and a bathroom of 2 m2. In this thesis, I have decided to go beyond the minimum requirements and provide larger living spaces. In order to do this, I have set up a 90 cm grid within the two module types allowing

17 Littell, Matt et al. Prefab City. Master's Research Studio at Northeastern University, 2010. Web

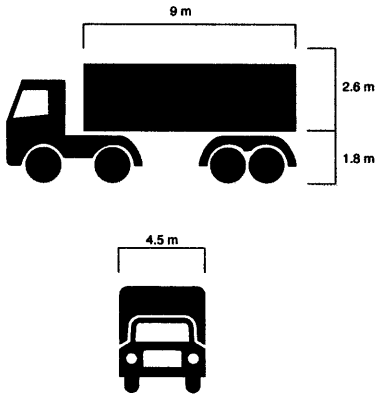


FIG 2.17: TRUCK SIZE USED TO TRANSPORT THE MODULES

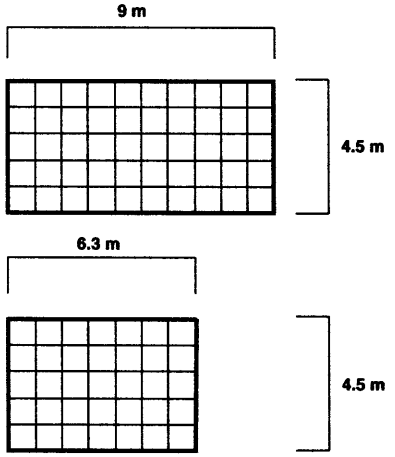


FIG 2.18: MODULE SIZES USED FOR THE HOUSING GRAMMAR

for adequate room and hallway sizing.

The two modules can be used together or separately. For example, two 9 m by 4.5 m modules can be connected to form apartment type 1 consisting, of 81 m2, or one 9 m by 4.5 m module can be attached to a 6.3 m be 4.5 m module to form apartment type 2, consisting of 69 m2.

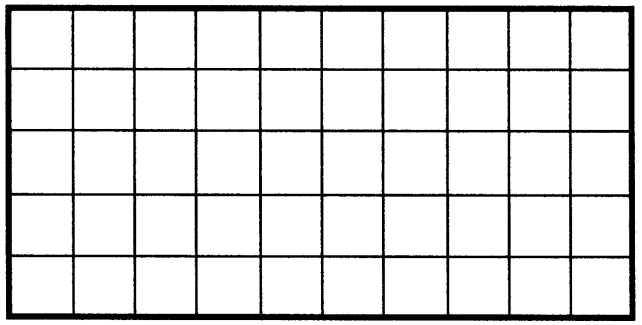


FIG 2.19: 90 CM GRID USED FOR ROOM SIZINGS

Unit Size	# of Units
81	16
69	10
40.5	6
Total Units	**32**
Total m2	**2229**

ACQUISITION COSTS		**PREFAB**	**TRADITIONAL**
Total Land Cost		$486,000	$486,000
Land Cost $	$600		
Land Size m2	810		

HARD COSTS		**PREFAB**	**TRADITIONAL**
Total Construction Cost		$445,800	$557,250
Construction (Prefab)	$200		
Construction (Traditional)	$250		
Labour Cost (labour x number of wokers x time)		$19,200	$112,000
Labour per person/month (Traditional)	$350		
Number of Workers (Traditional)	40		
Time (traditional months)	8		
Labour per person/month (Prefab)	$300		
Number of Workers (Prefab)	20		
Time (prefab months)	3.2		

SOFT COSTS	**PREFAB**	**TRADITIONAL**
Architecture/Engineering Design & Inspection	$25,000	$25,000
Permits	$26,748	$26,748
Survey	$25,000	$25,000

Total Development Cost		**$1,027,748**	**$1,231,998**
Time Savings (months)		**4.8**	
Construction Savings		**$204,250**	
Bank Interest Savings- 80% at 8% per year $5,481.32		**$26,310**	
Insurance Savings- 1% of bld cost per year $856.46		**$4,111**	

Total Cash Savings		**$234,671**	

FIG 2.20: PROFORMA OF COMPARATIVE FINANCIAL COSTS BETWEEN TRADITIONAL CONSTRUCTION VS. PREFABRICATION

PART 3: AN INNOVATIVE DESIGN GRAMMAR LINKING CULTURE, CUSTOMIZATION, & PREFABRICATION IN CASABLANCA

A- HOUSING GRAMMAR DESIGN RULES
APARTMENT TYPE-1
APARTMENT TYPE-2

B- LAYOUT CATALOGUE
TREE DIAGRAMS
CATALOGUE OF UNIT TYPES

C- ARCHITECTURAL DRAWINGS
DERIVATIONS
FLOOR PLANS
SECTION, ELEVATION AND 3-D

PART 3

A- HOUSING GRAMMAR LINKING CULTURAL ADAPTIBILITY, CUSTOMIZATION AND PREFABRICATION

Prior to developing the housing grammar I used Legos to determine the stacking possibilities of the building and structural system. The primary constraint was keeping the courtyard open to the sky and not covered by the apartment above. The secondary constraint was limiting the cantilever constraints to two meters. Numerous stacking options are possible and below are a series of Lego experimentations. Following the Lego experimentations I will introduce the details of the housing grammar.

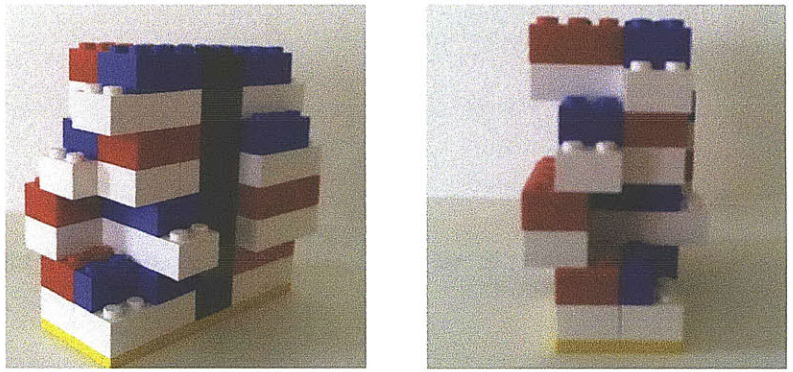


FIG 3.1: POSSIBILITIES FOR APARTMENT AGGREGATIONS

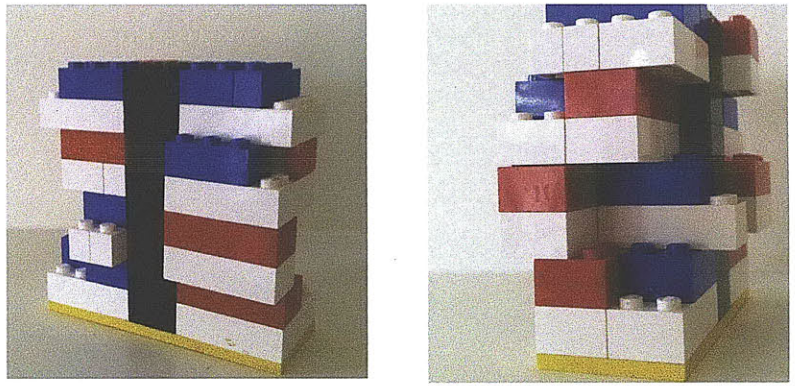


FIG 3.2: POSSIBILITIES FOR APARTMENT AGGREGATIONS

GRAMMAR

The housing grammar, which is the core of this thesis, allows for the mass customization of apartment units for affordable housing projects in Casablanca.[1]

The grammar generates customizable floor plans that are inherently cultural and prefabricatable.

There are two types of apartments that can be produced. The first one, type 1 is 81 m2

(a combination of 9 m by 4.5 m modules). The second, type 2, is 69 m2 (one 9 m by 4.5 m module attached to one 6.3 m by 4.5 m module). Every module is attributed a function, private or public. There are two apartment units per floor, each attached to one side of the core module. The core module incorporates the staircase as well as the mechanical systems. The grammar rules can be applied in reflection and in rotation and need to be applied sequentially.

I have drawn the rules for both apartment types, but I will only be explaining the rules for type-1, as they are both very similar.

Stage A:

Rule 1-0 is the first rule of the series. This rule introduces the main staircase and mechanical system.

Rules 1-1 to 1-5 insert the first module, the public space (in blue). The public module can be located in five locations along the staircase. Once the location of the public space is chosen, it is placed along the staircase. The entrance to the apartment is always through the public module.

Stage B:

Rules 1-6 to 1-13 place the private space modules (in red) and insert the courtyard marker. In Rules 1-6 to 1-8 and 1-12 to 1-13, the public module is in the same location but private module is placed adjacent to it in two separate locations. This is possible because even if the private module is rotated, it does not cantilever out more than 2 meters. In Rule 1-9 and rule 1-10, there is only one possible placement of the private module because if it is rotated, it cantilevers out more than the allowable 2 meters.

1 I would not have been able to develop this grammar without the precious help of my thesis advisors, Terry, Jose and Reinhard. This has truly been a collaboration.

Stage C:

Rules 1-14 to 1-19 place the interior spaces within the public module. Rules 1-14 and 1-15 substitute the courtyard marker with a courtyard. The courtyard can be accessed through the living room or the kitchen, depending on user preference. Additionally, the courtyard cannot be placed horizontally between a private and public module so that it is not closed of on more than two sides. Rule 1-16 and 1-17 insert the kitchen, which is always adjacent to the courtyard. Rules 1-18 and 1-19 place the living room in the public module. The living space is always square so that it can accommodate the traditional Moroccan living room.

Stage D:

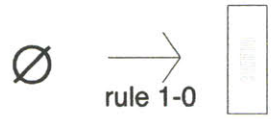
Rules 1-20 to 1-28 determine the location and the number of bedrooms and bathrooms in the private module. There are at least two bedrooms per module, with a maximum of three. The bathroom is almost always placed along the core staircase for easy access to the building system. However, when the bathroom is not placed along the core module, like in Rules 1-21, 1-23 and 1-28, a lower ceiling will be required to hide the connecting pipes.

Following the grammar is a series of tree diagrams for apartment type 1. The tree diagram illustrates the application of the rules and the resulting layout combinations. Superseding the tree diagrams is a sample catalogue of apartment layouts derived from the various combinations of rules and showing possible customization options. For apartment type 1, there are 45 different layout possibilities.

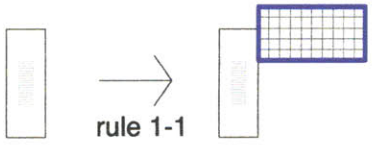
Additionally, I produced two detailed floor plans, one for type 1 and one for type 2. The floor plans are preceded by derivations which consist of the application of the rules based on user choice. The floor plans are supplemented with a section, elevation and 3d-images.

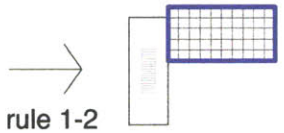
Apartment type 1: 81 m2

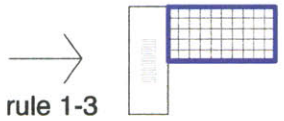
Initial shape

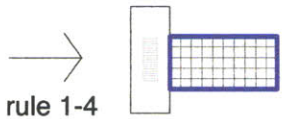


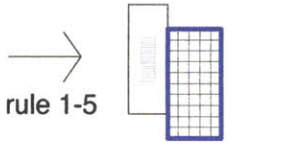
Insert public module and 90 cm grid



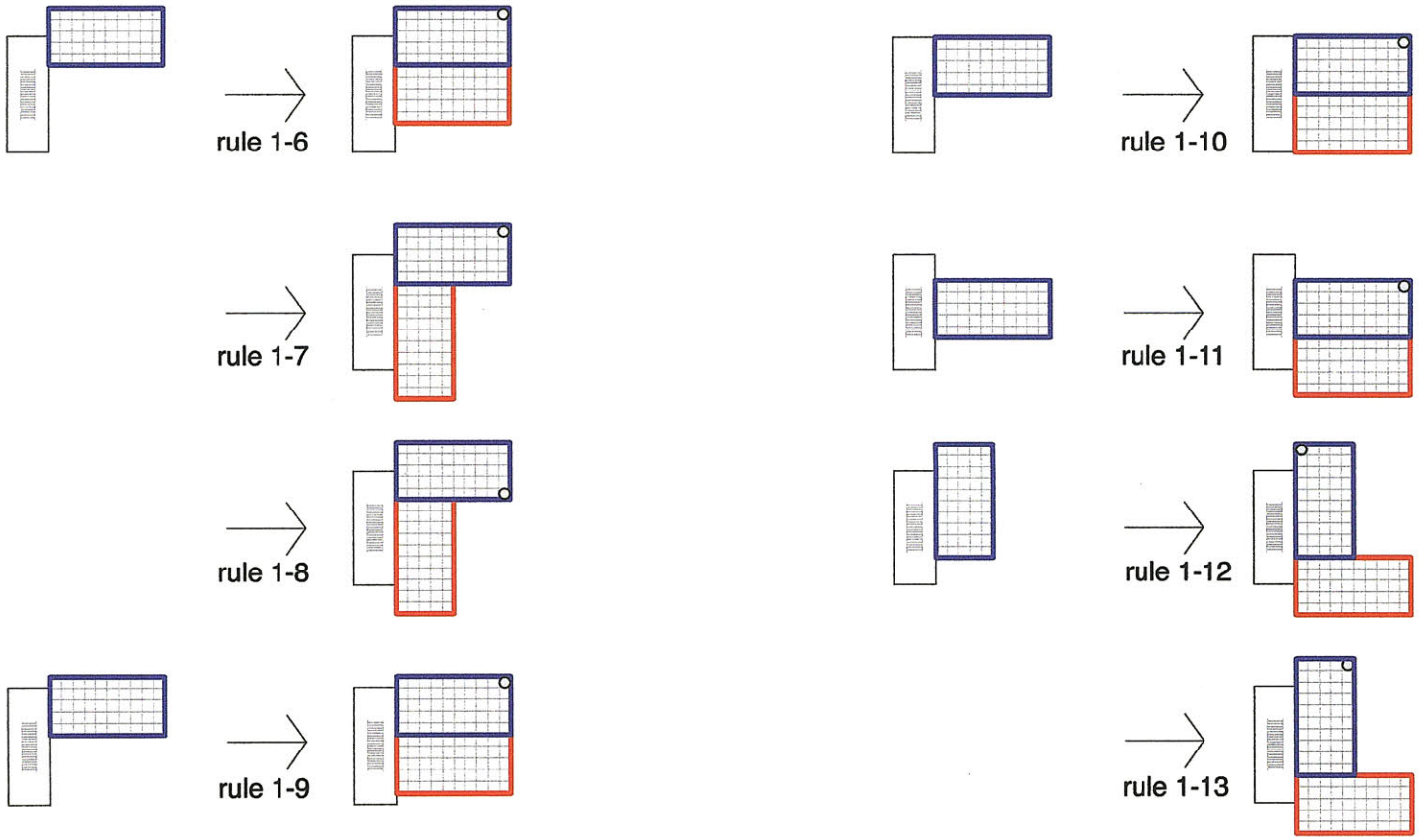




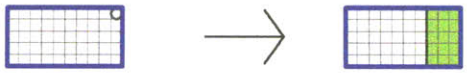




Insert private module and marker for courtyard



Insert courtyard

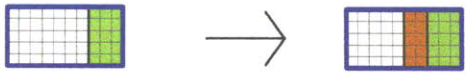


rule 1-14

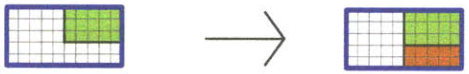
or

rule 1-15

Insert kitchen

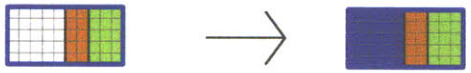


rule 1-16



rule 1-17

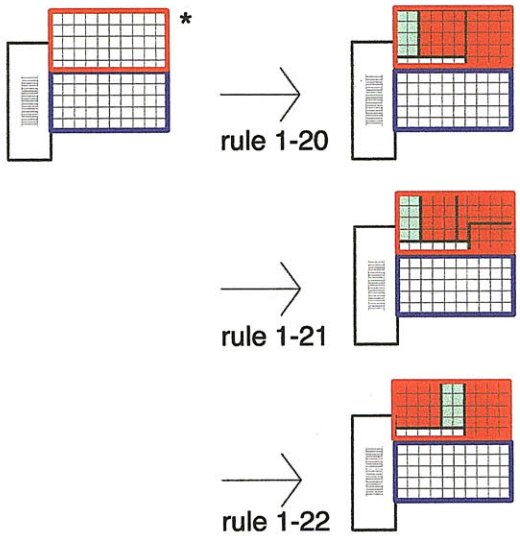
Insert livingroom

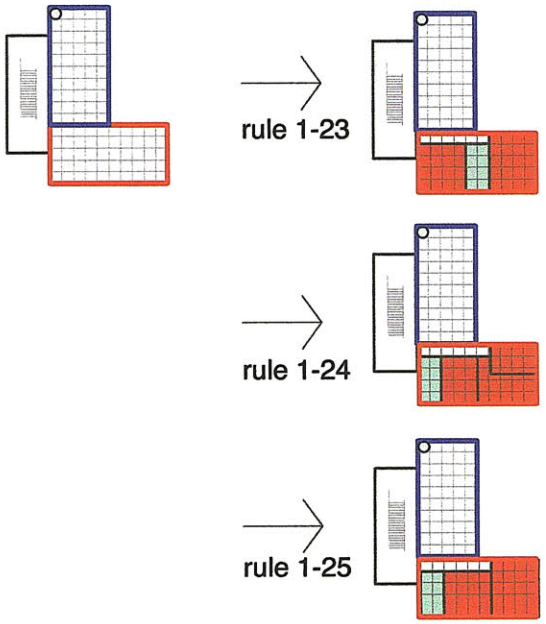


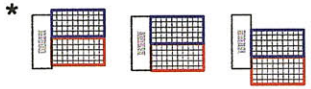
rule 1-18

rule 1-19

Insert bedrooms and bathrooms

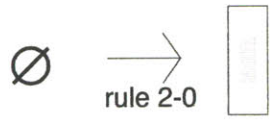




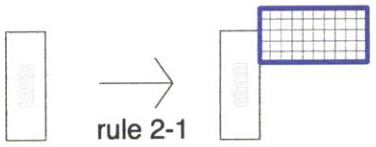


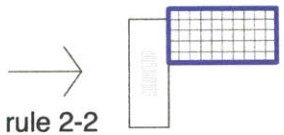
Apartment type 2: 69 m2

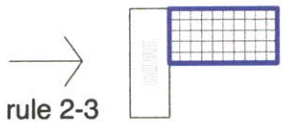
Initial shape

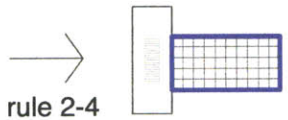


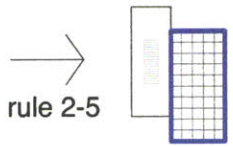
Insert public module and 90 cm grid



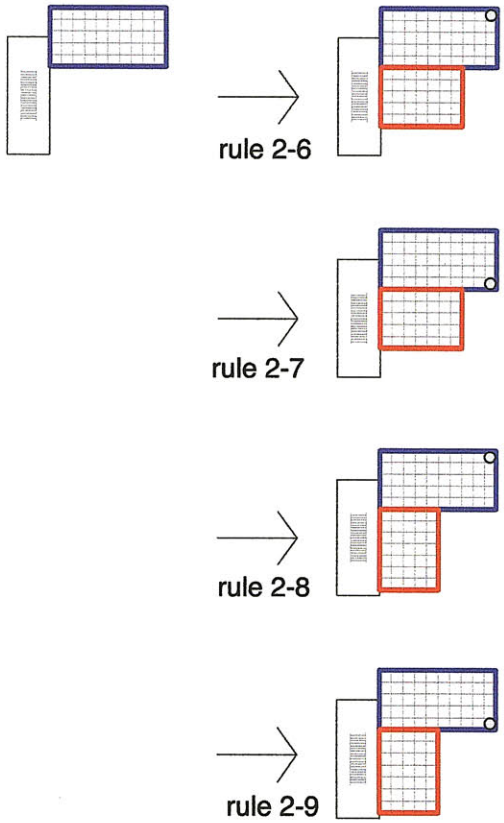


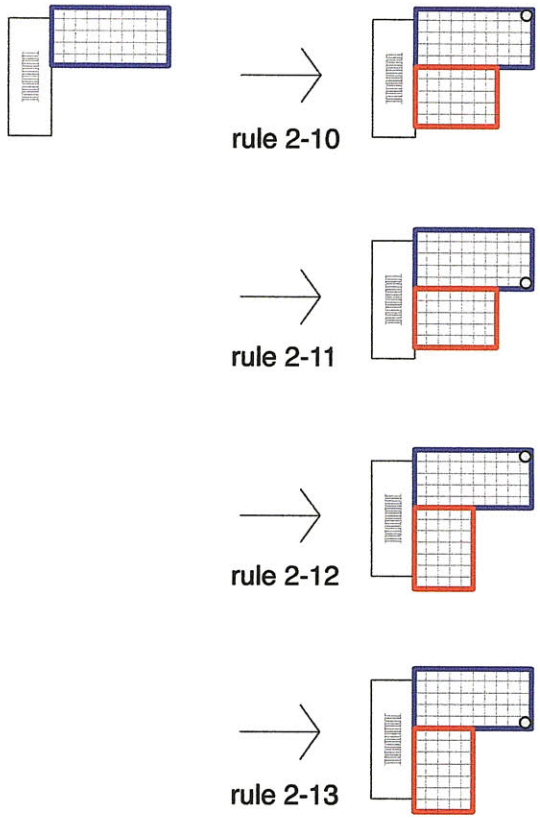




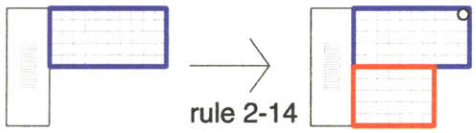


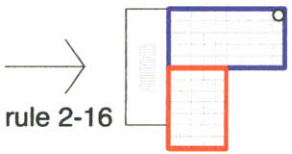
Insert private module and marker for courtyard

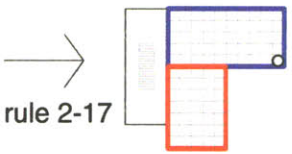


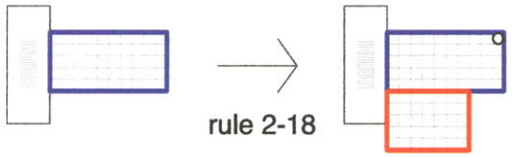


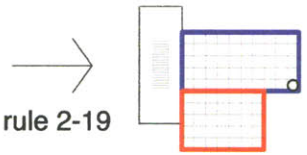
Insert private module and marker for courtyard

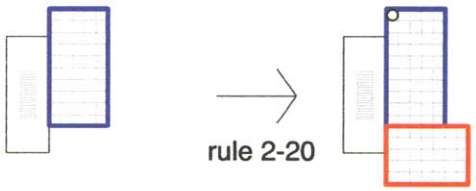


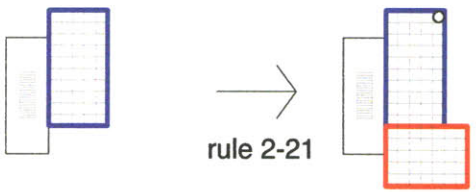




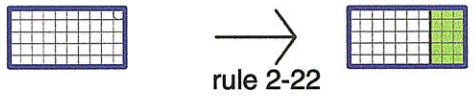




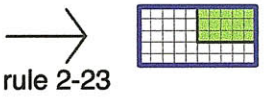




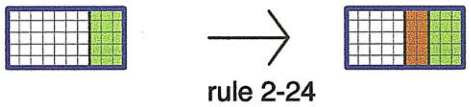
Insert courtyard

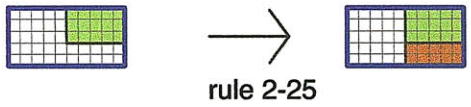


or

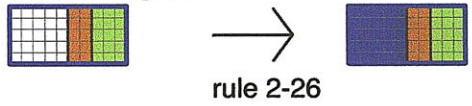


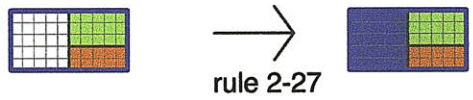
Insert kitchen



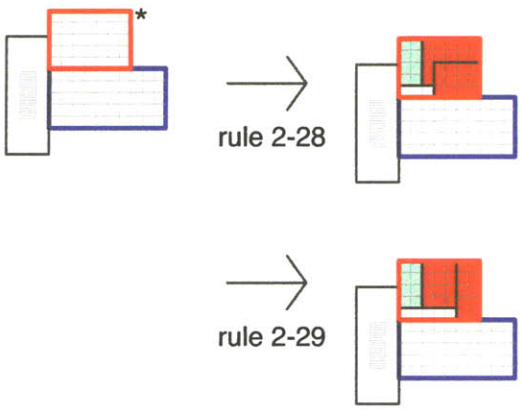


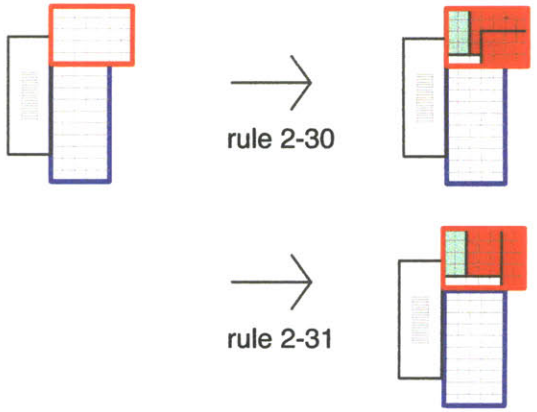
Insert livingroom

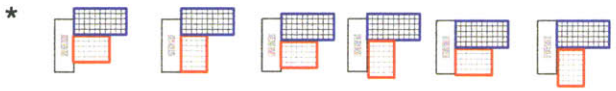




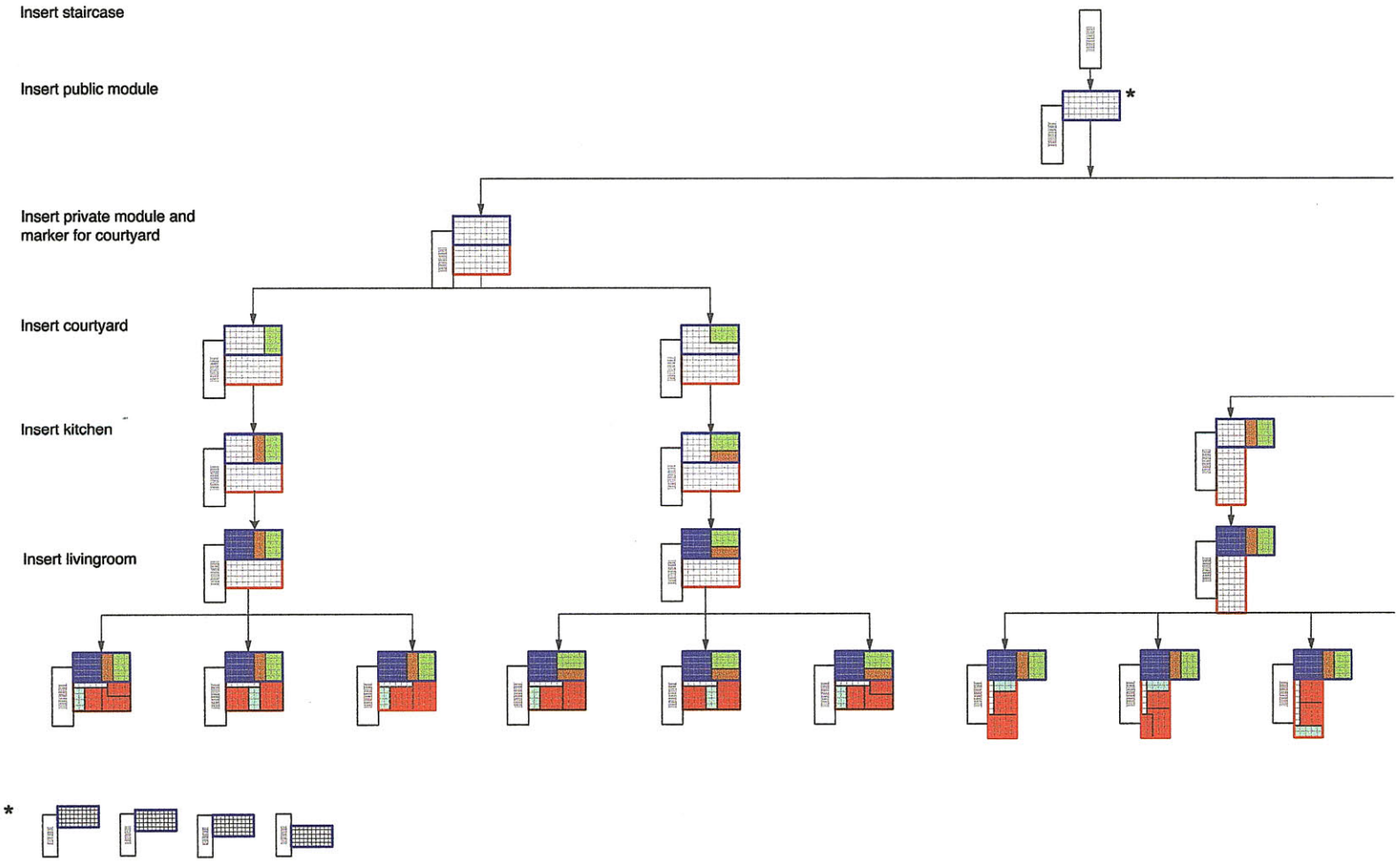
Insert bedrooms and bathrooms

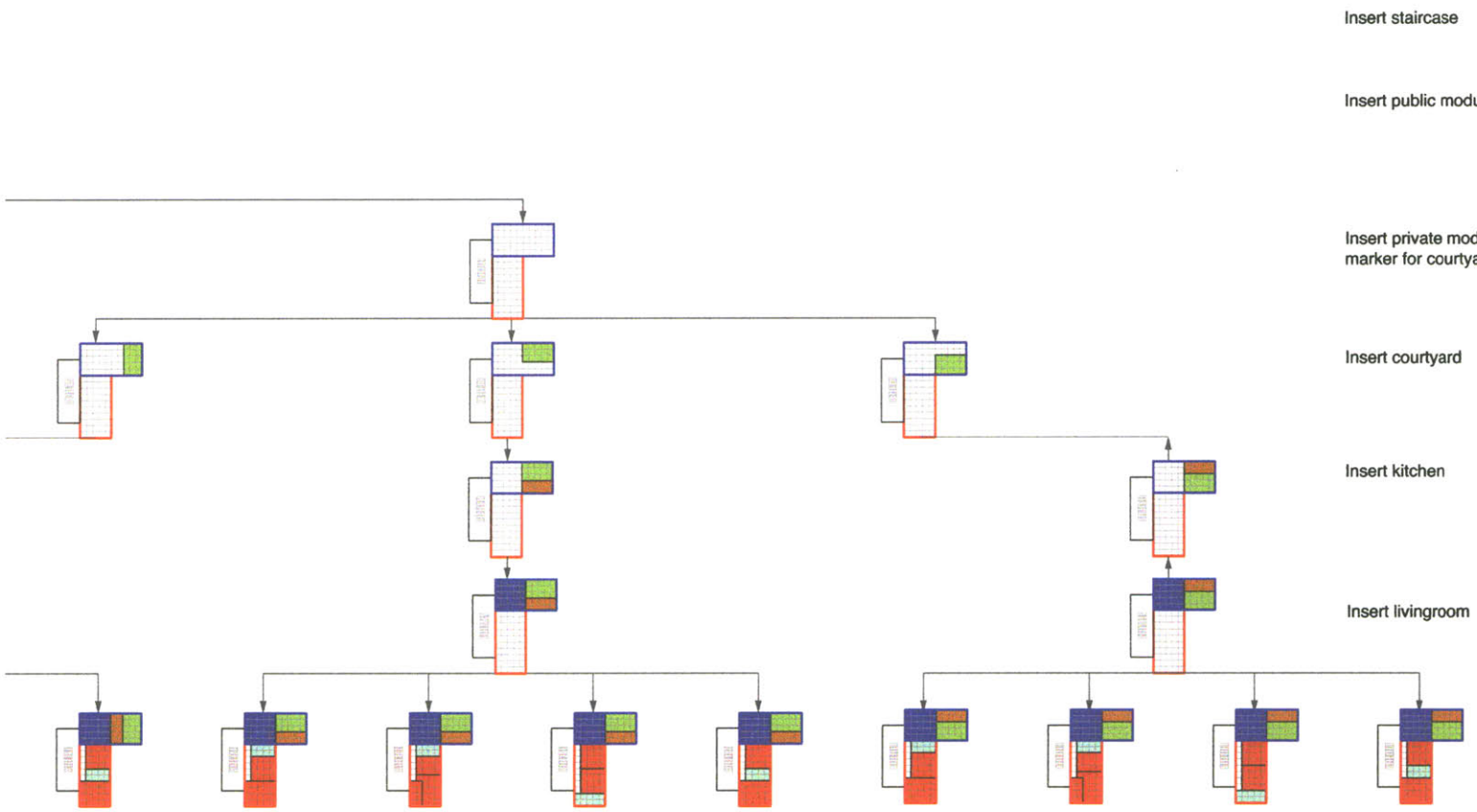




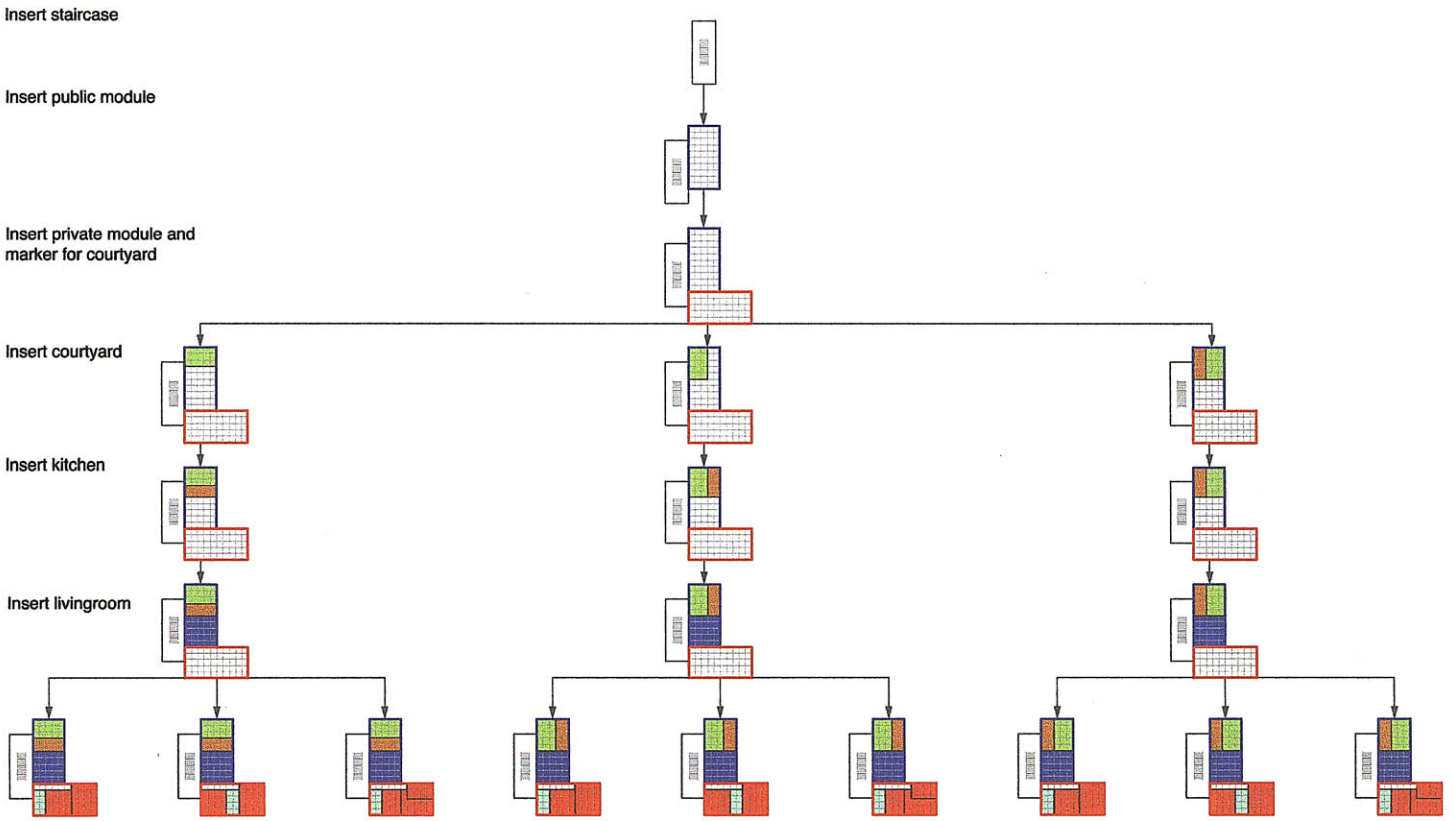


Tree diagram: type 1 apartments

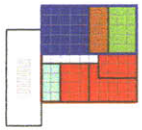



Insert staircase
Insert public module
Insert private module a
marker for courtyard
Insert courtyard
Insert kitchen
Insert livingroom

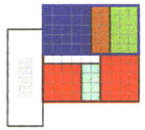
Tree diagram: type 1 apartments



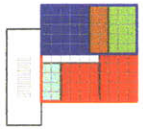
Catalogue of type 1A apartments



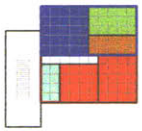
Sample 1A.1



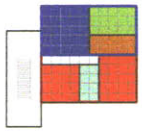
Sample 1A.2



Sample 1A.3

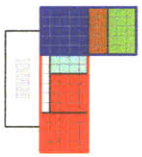


Sample 1A.4

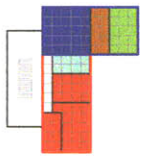


Sample 1A.5

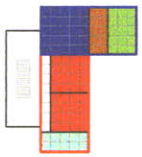
Sample 1A.6



Sample 1A.7

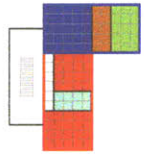


Sample 1A.8

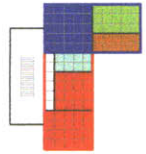


Sample 1A.9

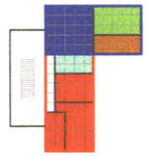
Catalogue of type 1B apartments



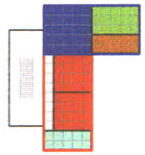
Sample 1B.1



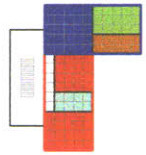
Sample 1B.2



Sample 1B.3

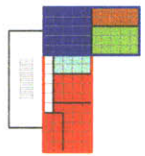


Sample 1B.4

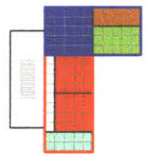


Sample 1B.5

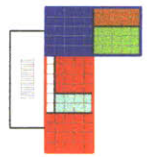
Sample 1B.6



Sample 1B.7



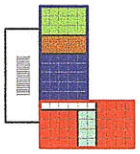
Sample 1B.8



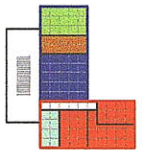
Sample 1B.9

Catalogue of type 1C apartments

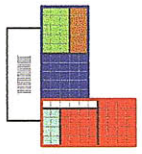
Sample 1C.1



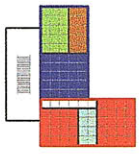
Sample 1C.2



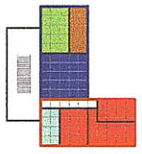
Sample 1C.3



Sample 1C.4

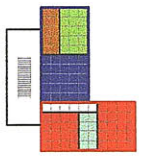


Sample 1C.5

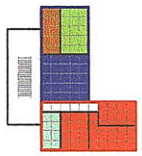


Sample 1C.6

Sample 1C.7

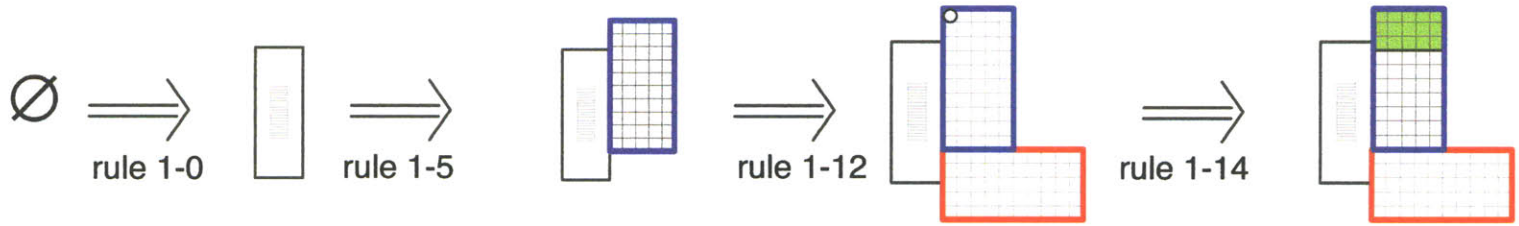


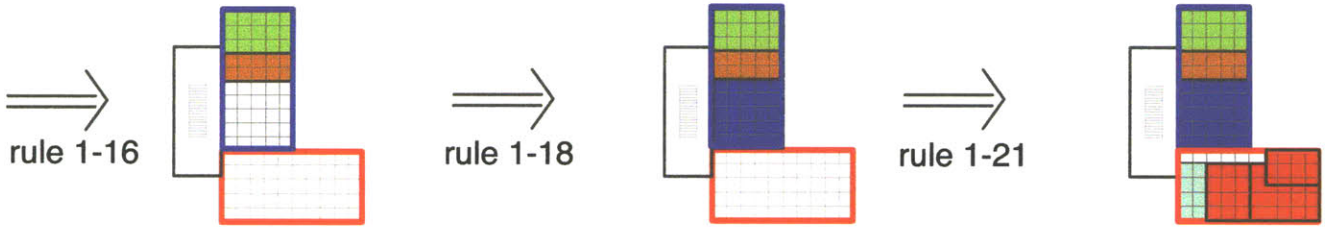
Sample 1C.8



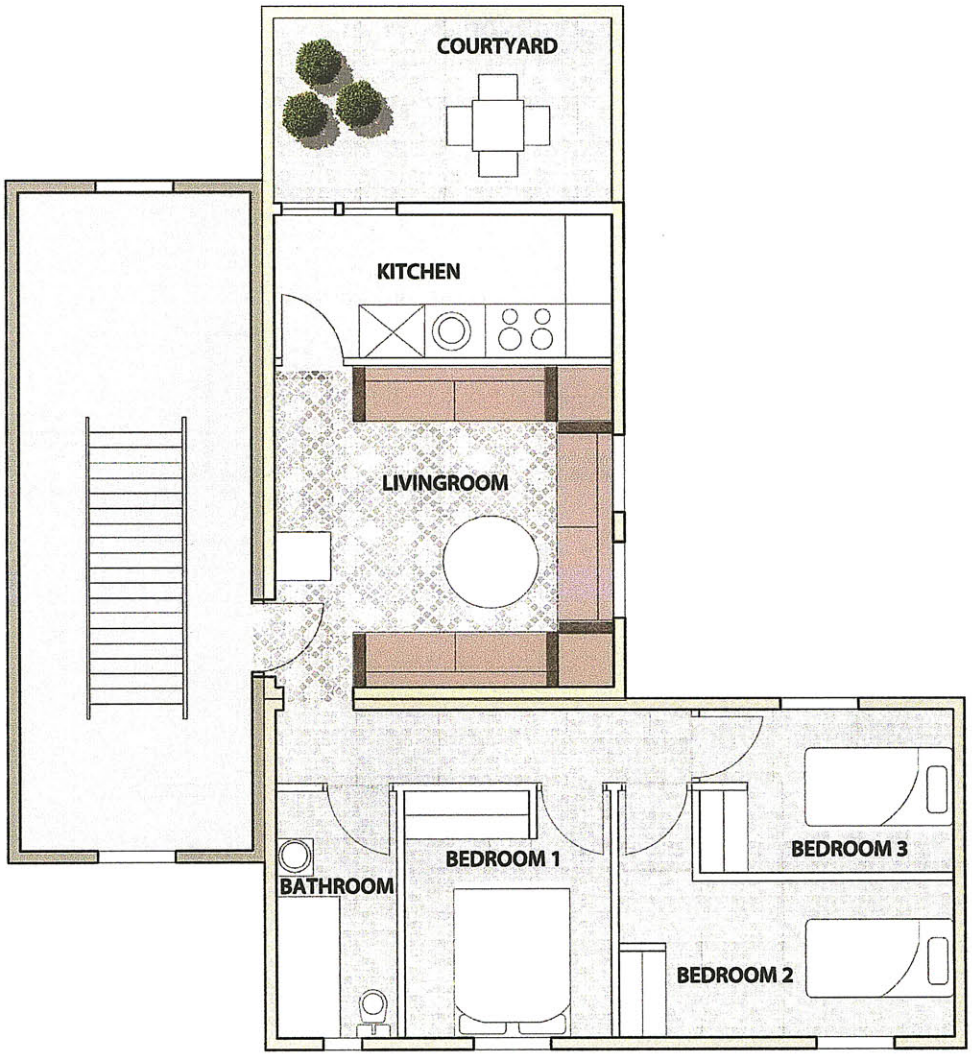
Sample 1C.9

Application of rules and derivation of apartment type 1- 81 m2

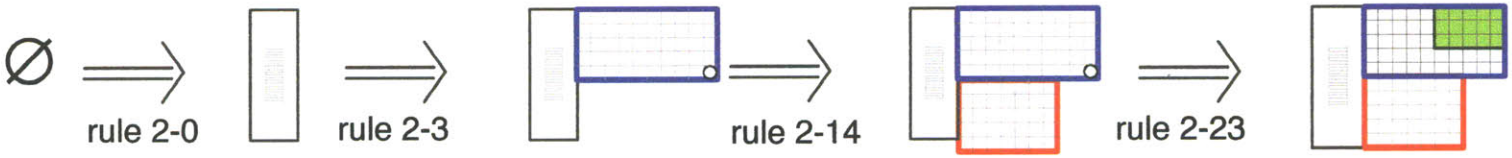


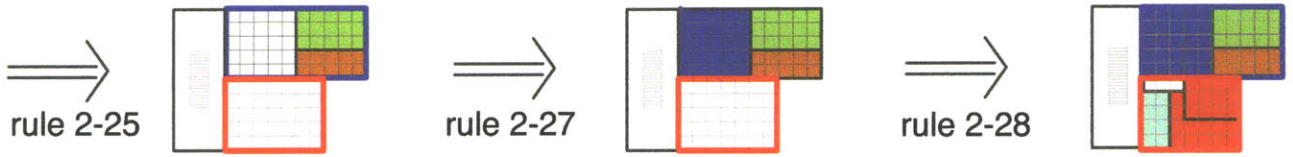


FLOOR PLAN TYPE 1

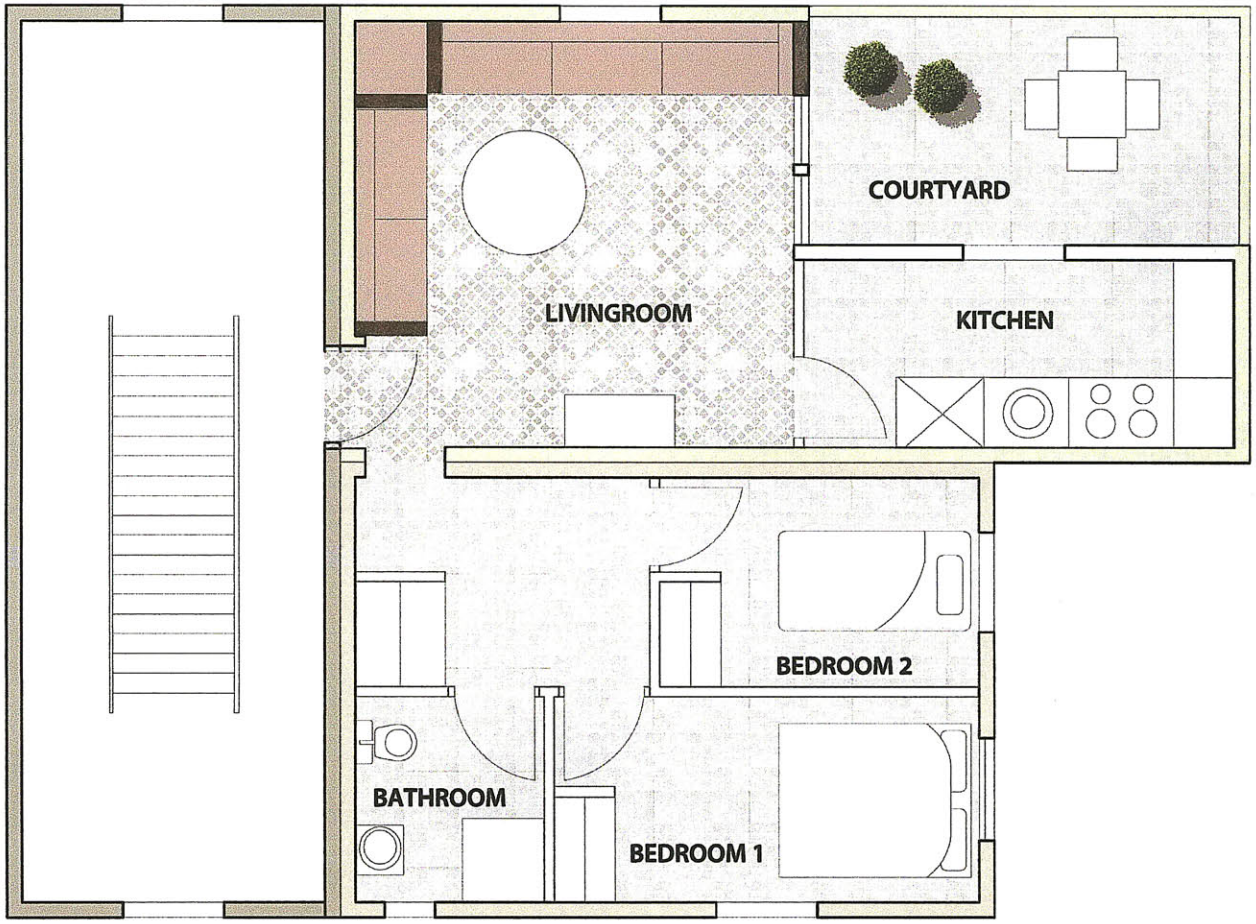


Application of rules and derivation of apartment type 2- 69 m2

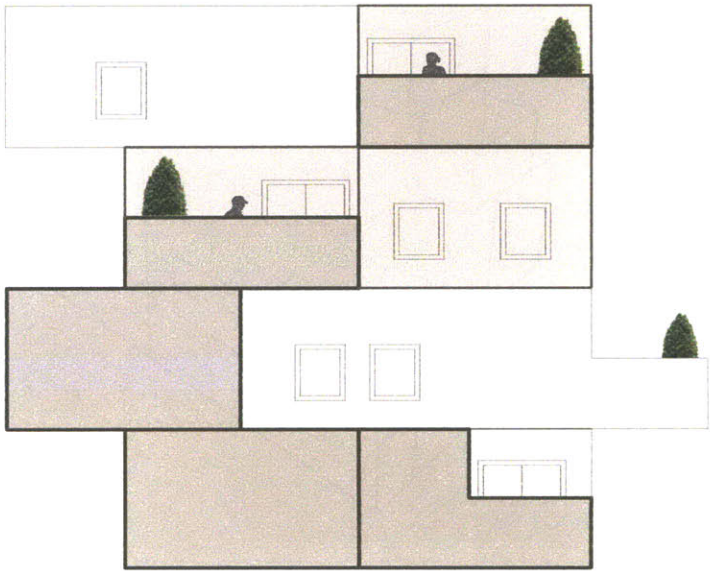




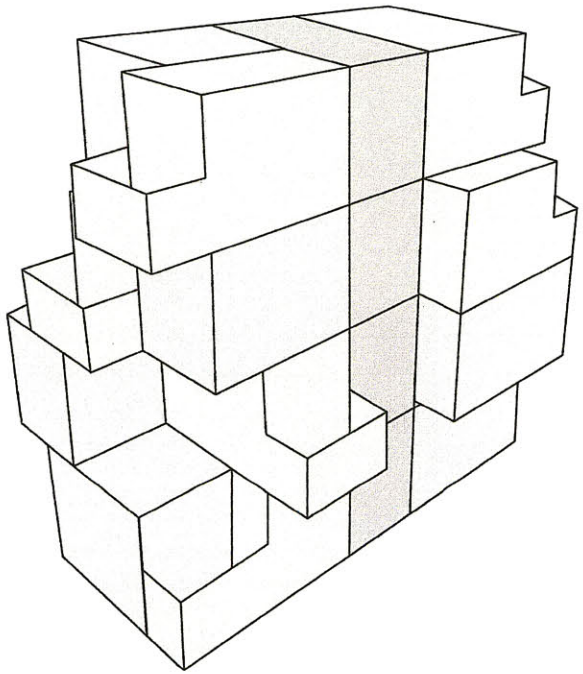
FLOOR PLAN TYPE 2

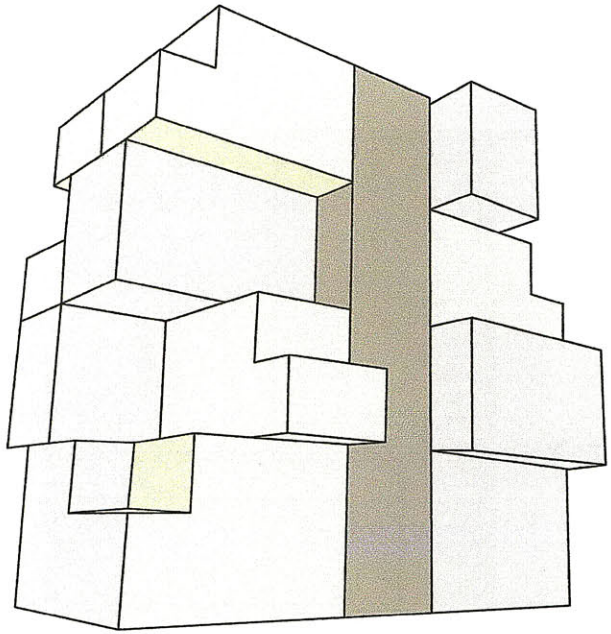


SECTION AND ELEVATION OF MODULAR AGGREGATIONS INTO A BUILDING



AGGREGATIONS





CONCLUSION

CONCLUSION

Growing up in Casablanca, Morocco, I became aware of urban and social inequalities within the city very early on. The lack of urban housing and the continuous sprawl of shantytowns always affected me and it is one of the primary reasons why I chose to become an architect. Additionally, the public or low-income housing projects that have been built and that are still being built today diminish the dignity of the residents as well as damaging the urban landscape with monotonous and institutionalized structures.

Therefore, the past two years I have spent at MIT have been focused on finding a sustainable solution for the eradication of urban slums, by providing a system that would be beneficial to the end user as well as to the urban city. This led to my investigation of a *grammar* that would be able to generate floor plans, buildings and perhaps even neighborhoods. It was important for me to develop an integrated system that would identify the significant cultural typologies, include user participation and preference, and allow for a fast and efficient production of unit.

This design grammar in this thesis embodies these three essential characteristics: cultural adaptability, customization and prefabrication. These elements enable the creation of a design that it suited to today culture and urban environment that is easily prefabricatable and therefore can be used to overcome the housing shortage and allow for additional construction savings.

I believe that the goals of this thesis proposal have been achieved and that if applied in practice, the grammar produced can largely overcome the existing housing deficit and provide inherent customization possibilities.

FURTHER INQUIRIES

The next step for this housing grammar is the design of a complementary grammar for stacking and aggregating units to form buildings. Currently, there are two constraints for the stacking of the units; 1) the courtyards are always open to the sky, and 2) the modules cannot cantilever out more than 2 meters. However, if a detailed grammar for the stacking were produced, it would allow for the creation of urban landscapes, neighborhoods, and the structuring of clusters to create communities.

Additionally extending the current grammar to incorporate studio apartments would also be beneficial. The current affordable housing building codes allow for 30% of a building to be comprised of the studio units. Taking advantage of this means enlarging the demographics of the occupants and providing for a broader range of users.

Finally, the scripting of this grammar into a computer program that would instantaneously produce apartment layouts as well as aggregations would be the ultimate goal. The program would significantly impact the final cost of a project and would additionally reduce design fees, making affordable and customizable housing attainable by all.

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APPENDIX A

Interview with Dr. Ling Yi Liu, Chief Integrator at AbodeZ

February 11, 2011 @ 11 am

* These notes are a summary of my meeting with Dr. Ling YI and not a verbatim transcription.

General Notes:

- AbodeZ is a developer specializing in housing innovations and prefabricated and customizable housing units
- They opened their firm in 2008
- They currently have two built projects
  - AbodeZ on Broadway
  - Park 87

  Dr. Ling Yi Liu, an MIT Alum, has worked at Oaktree development for 10 yrs prior to opening his own firm
- The team includes three partners: one engineer, one architect and one marketing
- They work on one project at a time due to funding
- Before they start a project they determine the demographic group within neighborhood and perform market studies
- Their goal is to market new innovations and technologies in housing
  - Works with Kent Larson at MIT
  - Ling Yi says that it is difficult to make innovations become a reality within the construction field
- He feels that customization is an underserved market and wants to better meet the demands
  - They try to make better housing, with higher quality at a lower prices
  - They also offer higher quality finishes at a reasonable cost
- As a firm they are making more revenue from building customizable prefabricated buildings vs. traditionally built housing
- Building with prefab, they are making twice the profit they would usually make, at half the cost
- They don't do any affordable housing because it means subsidized and they don't want to apply for state subsidies
- Their rents are market price
- Their main focus as a developer is return on investment

Factory construction:

- They try doing as much factory building as possible because it is more efficient and flexible
- The modular prefabrication is outsourced to a factory in Maine
- They bring all the interiors of for the units from factories in China
  - I.e. the customized kitchens, floors, bathrooms
  - They send the architectural drawings to the

factories in China to build the interiors
    - The interiors are then shipped to the prefab factory in Maine and installed
- They focus on having an integrated development process
    - A holistic way of building that only the developer can do
    - Less waste of materials
    - Pay less insurance
    - Lower risks
    - Employees are paid less per hour therefore less labor costs

Interview Questions:

Prefabrication Method:

1. **How do you make the final product?**
   They start with the architectural drawings as well as the building/structural systems.
   They then send the plans to factories in China that build all of the interior work. Once the interiors are ready, they are shipped to the prefab factory. The prefab factory builds all of the building blocks/modules and installs the interiors. The modules are then shipped to the site and assembled. The actual assembly of the modules takes 5 days. It then takes about 3 months to have the utilities installed, the building inspected, etc…

2. **How long does it take to build a prefabricated housing project?**
   For Park 87, which consisted of 54 units, it took them 10 months, from the start of construction to completion. It took them about 1 year to develop the project prior to construction. This was mainly due to paper work such as modifying existing building contracts, insurance etc…

3. **Does it work everywhere, for example cold & hot weather?**
   Yes since most of the work is done in a factory.

4. **What are the benefits of prefabrication?**
   Most of the work is done in a factory; therefore you can control bad weather conditions, humidity, and material waste. Moreover, you are bringing all of the services to one place (electric, plumbing, building); therefore it minimizes the miscommunications between different contractors and sub-contractors. You are basically moving all the money and all the people to 1 place- the factory. Main benefit is *timesavings*: time value of money- has to save time to be able to save money

5. **What are the shortfalls of using prefabrication?**
   Everything needs to be perfectly co-coordinated. If the whole supply chain and system is not executed exactly as planned, it will not work.
   The prefabrication construction cannot go wrong because as opposed to traditional construction techniques, you cant just tear something up and rebuild it- you have to go back to the factory and rebuild it- and that slows the whole process. This is one of the biggest issues of prefabrication. You can only succeed if you save time and money. If you don't save on either, the project will be a failure.

6. **Are all the factory workers skilled workers?**
   The workers are not all necessarily skilled at first, but they become skilled with time because they will become experts at the specific task they work on. However, you do need skilled workers to be able to install the modules on site. You need trained workers to perform that task.

7. **What are the different systems used for a prefab structure?**
   They use a different building system for every project. In AbodeZ on Broadway there are no structural walls. Instead we used a frame construction.

8. **What are the different materials used in factory built modular units?**
   They use wood modules because they usually do not build higher than five stories and only use steel and concrete for the underground parking structures.

Prefabrication Efficiency:

9. **What does it take for a prefabrication *factory* to succeed?**
   You need orders and flowing production. This is basically a catch 22- you need factory in place to be able to build prefab housing, put you need orders to have a prefab factory...

10. **What does it take for a pre-fabrication project to succeed?**
    Ling Yi says that coordination is the most important aspect. There has to be perfect communication and no problems should arise, as it will stop the process.
    He also says that a big aspect of it is to find partners that

are willing to take a 'risk', if they are not familiar with the process.

11. **How much volume is needed for a prefabrication company to sustain itself?**
    I would have to ask the prefab factory that they work with, but a factory needs a large volume to sustain itself.

12. **Is it only possible with easy transportation routes?**
    Transportation routes are essential for modular transportation.

13. **Is modular design the most efficient method for prefabrication?**
    For them is it very efficient because they try to build as much as they can in the factory. Additionally the building system is more important. The prefabrication adapts to their building system.

14. **Is it more profitable than traditional building methods?**
    It has been a lot more profitable for them. He estimates that it is half the cost, and twice the profit- but this is only the case if everything goes as planned with no issues and therefore no added cost.

15. **With your experience, do you think this system is realizable in Morocco?**
    He believes that such a system is only achievable with a prefab factory already in place. Before they picked the factory that they are currently working with, they interviewed several factories before picking one that they trusted. He suggests that if there isn't an existing prefab factory, then one should work and innovate with the existing building techniques.

    One has to use the current state of the industry and finance and can make changes to the current industry- small changes though, not radical. Most important is to determine what people want and to provide it- if the current system provides it then one should use it. It might also be possible make the modules in an existing factory in another country.

Customization:

16. **How much customization is possible with the building system you use?**
    In the building system they are using, only the interiors are customizable. The exterior shell is set. This is primarily due to building codes, permits and zoning and they also want

to maximize the building perimeter. Multifamily housing is different from single family housing since you have to do all the exterior customization beforehand- cannot consult with all of the families that will be living in the project

17. **How much customization do you do as a firm?**
They try to do as much customization as possible; however, it stays within the interior layout of the apartment. The apartments have flexible walls with open floor plans. Once a tenant moves out, they give the new tenant the option of reconfiguring the floor plan at no cost.

18. **Does the developer make the customizations decisions? By the tenants?**
The tenant makes the interior customization. The customization should not be done by the developer- the end user needs to have that control (even though it is cheaper to make the decision as a developer). The customization should only be done once you know who the client is, and then it can be performed in a few days.

APPENDIX B

Interview with Dennis Michaud, VP of Product Development at Blu Homes

Phone interview March 3, 2001 at 3 p.m.

* These notes are a summary of my meeting with Dr. Ling YI and not a verbatim transcription.

Prefabrication Method:

1. **Why do clients choose to use prefab?**

   Mainly for convenience, consistency and dependability. The client knows that what they expect to get is what they will actually get. The client can see examples of floor plans and they can pick the ones they want, and they will expect the same level of detail and consistency.

2. **What are the benefits of prefabrication?**

   In traditional construction, site work is very expensive and disruptive. You have neighbors and permits to deal with. There are extreme liability and safety risks for workers. Additionally, materials are often stolen from construction sites. Factory prefabrication eliminates all of that and cuts time to a fraction of what it would be onsite.

3. **What are the shortfalls of using prefabrication?**

   It's more difficult to make changes. If the product shows up on site and it's not what is expected, you can't really ship the same crew out there to fix the issue. Additionally, sometimes the pieces don't fit perfectly and have to be sent back to the factory and redone.

4. **Is it only possible with easy transportation routes?**

   You need good roads and routes or else you cant do a high level of detail within the units.

5. **Are all the factory workers skilled workers?**

   Skilled labor is not as necessary in modular construction. Additionally, workers agree to a lower pay because of work consistency.

6. **How much customization do you do as a firm?**

   We offer a selection of different floor plans. If the client trusts that the design is well thought out and that they have options a few options to select from, they are happy. The issue with completely customizing the interior is that there is going to be a lot of added design fees.

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