VERTICAL VILLAGE:
Towards a New Typology of High-Density Low-Income Urban Housing

by

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ABSTRACT

Apocalyptic global urbanization is old news. For generations statistically supported oracles have warned against the rising tide of rapid urban growth, one must only casually search the keywords "urban slum" on google to witness the physical manifestation of these abstract predictions across the world.

One would expect that with such continuous and advanced warning the landscape of global low-income urban architecture would be highlighted with innovative approaches to housing our ever densifying urban populations. However contemporary high-density low-income housing projects largely continue to rely on post-war modern architectural paradigms that view the creation of high-density low-income housing in isolation avoiding the messiness of a diverse social, environmental, infrastructural and economic context.

Future typologies of high-density low-income housing must embrace and re-imagine their relativity within larger urban ecologies and in the process develop as responsive multi-cellular organisms, as opposed to autonomous products. This is not a new or novel idea, finding its roots in village models as early as the 14th century. The foundational components of communal living have not changed significantly in the last 800 years, remaining concretized in the defensibility, production and sociability of the collective.

It is the aim of this body of research to elaborate and expose the 21st century high-density low-income urban village and to three-dimensionally assemble its components into intelligent and evocative discourse.

Thesis Supervisor: Mark Jarzombek
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Kent Larson, my thesis reader, mentor, research partner and friend. Thank you for your unwavering support during my tenure as a student at MIT. Your work and teaching were the inspiration for me to pursue research in future cities and urban agriculture.

This thesis is dedicated to my parents Steve and Nancy Harper and my brothers Eric, Micah and Jeremy Harper. You have unconditionally loved and supported my through all the trials and tribulations of my life. I would not be at MIT, have completed this degree program or be the person I am without you. I love you.
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THESIS POSITION

Apocalyptic global urbanization is old news. For generations statistically supported oracles have warned against the rising tide of rapid urban growth, one must only google search the keywords "urban slum" to witness the physical manifestation of these abstract predictions across the world (Figure 1). One would expect that with such continuous and advanced warning the landscape of global low-income housing development would be highlighted with innovative approaches to addressing the needs of densifying urban populations. However contemporary high-density low-income housing projects largely continue to rely on post-war modern architectural paradigms that view the creation of high-density low-income housing in isolation avoiding the messiness of a diverse social, environmental, infrastructural and economic context (Figure 2).

Future typologies of high-density low-income housing must embrace and re-imagine their relativity within larger urban ecologies and in the process develop as responsive multi-cellular organisms, as opposed to singularly charged autonomous products. This is not a new or novel idea, finding its roots in village models as early as the 14th century. The foundational components of communal living have not changed significantly in the last 800 years, remaining concretized in the defensibility, production and sociability of the collective. It is the aim of this body of research to elaborate and expose the 21st century high-density low-income urban village and to three-dimensionally assemble its components into intelligent and evocative discourse (Figure 3).

This thesis finds its scale as a response to future urban population predictions. "By the middle of the 21st century, it is estimated that the urban population of developing counties will more than double, increasing from 2.5 billion in 2009 to almost 5.2 billion in 2050" (The United Nations Human Settlement Program). Low-Rise (1-5 stories) was, and is currently, an appropriate solution to begin to address urban housing deficits worldwide. However, the investment of future cities should consider the exponential growth they will certainly face within the next 20 to 30 years. If contemporary low-rise residential typologies continue to be employed to decrease low-income housing deficits in developing countries, the future city will face the same urban sprawl problems that many developed countries currently face. In 20 years the low-income housing stock and support infrastructure will be outdated, undersized and obsolete. This thesis seeks to illicit solutions for alternatives that can secure urban investment for the next 50 years.
FIGURE 3 - Vertical Village Concept Collage
GLOBAL CONTEXT: A series of exploratory mappings and correlations

FIGURE 4 - CIA World Factbook 2009 - 4.1 GINI Coefficient (top left), 4.2 Population Below Poverty Line (top right), 4.3 Urban Population Densities (bottom left), 4.4 Population Using Improved Sanitation (bottom right)

Now more than ever in human history, big data can be employed as both an analytical and design tool often making apparent correlations that are not otherwise obvious. Part of goal of this research is to create a new methodology of approach to reimagining low-income high-density housing. In the above diagram (figure 4) the CIA factbook was utilized as a platform to query global urban conditions that generally represent social mobility, lifestyle, urbanity and health. It is proposed that this exercise can be performed at various scales to aid in a more holistic understanding of complex social issues.

The first parameter mapped was the GINI coefficient (figure 4.1) which represents economic inequality. Economic inequality, also known as the gap between rich and poor, and comprises disparities in the distribution of economic assets and income within or between populations or individuals. When the economic inequality is greater, it can be understood that social mobility is reduced. Our first filter for this exercise is a GINI Coefficient greater than .50, countries with a GINI coefficient greater than .50 are thought to have a high level of economic inequality.
The second parameter to be mapped was the percentage of population living below the national poverty line. The poverty line, or poverty threshold, is the minimum level of income deemed adequate in a given country. When a large portion of population is living near the poverty line the social and financial priorities of that population are likely to be very specifically related to their economic circumstance. Our second filter for this exercise is countries with 50% or more of the percentage of population living below the national poverty line.

The third parameter to be mapped was urban population density (figure 4.3). Urban density is a term used in urban planning and urban design to refer to the number of people inhabiting a given urbanized area. Urban density is considered an important factor in understanding how social networks, infrastructural networks and cities function. Our third filter for this exercise is countries with 50% or more of their national population residing in urbanized areas.

The final parameter to be mapped was the percentage of population using improved sanitation (figure 4.4). An improved sanitation facility is defined as one that hygienically separates human excreta from human contact. Improved sanitation is an important variable when assessing the overall potential for disease and major health concerns of a population. Our final filter for this exercise is countries with 50% or more of their national population living without access to improved sanitation facilities.

The result of correlating our filters revealed, based on the CIA factbook 2009 data, Peru and Brazil are the only countries in the world that represent the largest population bases with the highest income inequality, national poverty, urban density and lack of access to sanitation infrastructure. It was this correlation that guided the research to choose to explore low-income high-density housing in the south american context of Brazil.

FIGURE 5 - Convergence of Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4
BRAZILIAN CONTEXT

The writing is on the wall in Brazil. According to the 2011 census, there is a 6.6 million unit housing deficit in Brazilian cities. Even with the promise of the world’s fifth largest economy, half of the 11 million people in Sao Paulo are living in informal housing. Massive foreign and domestic investment is currently underway. The venue for both the 2014 World Cup and the 2016 Olympics, Brazil is currently investing heavily in low-income housing stock and urban infrastructure.

On the verge of an unprecedented scale of urban development, it is helpful to consider past, present and future demographic trends in Brazil. In the figure above (figure 6) data was gathered from the Brazilian census and the resulting visualization shows very clearly a population in rapid transition. The population pyramid in 1950 is consistent with that of a developing nation characterized by high birth rates and short life expectancy. Currently, the population pyramid in 2010 is consistent with that of a developed nation characterized by slow growth, declining birth rates and longer life expectancy. The predicted population pyramid in 2050 is consistent with that of a developed nation characterized by negative growth, low birth rates and long life expectancy.

The current urban residential typologies of the governmentally supported Minha Casa Minha Vida - my house my life - development program are clearly trending in the direction of increased density (figure 7) but lack a larger strategy for supporting the demographic transition that lies ahead. Homes are often the sole asset low-income populations have to leverage for financial gain and accordingly should be designed to respond to the physical, social and economic transitions of its users. However, low-income housing development in Brazil remains focused on volume production rather than creating flexible and adaptable environments for supporting the complexities of 21st century living.

Why build our future cities on the paradigms of the past? Now is the critical moment to question the definition of “urban infrastructure” and redesign the interface of urban infrastructural investment and high density low income housing development.
Brazil will announce 15 billion reais ($7.2 billion), in urban sanitation and road investments in coming weeks, the country's cities minister Agnelo Ribeiro said on Wednesday. The investment plan will direct 5 billion reais toward paving roads and 10 billion reais toward basic sanitation as Brazil approaches municipal elections in October and President Dilma Rousseff tries to revitalize economic growth, which helped sweep her into office.

Overdue investments in roads, airports, ports, sewage and other infrastructure are seen by economists as essential to putting Brazil on the path to sustainable growth after major macroeconomic reforms in the 1990s and the emergence of a new middle class in the past decade.

The government has been attempting to prod the economy into motion by slashing interest rates, cutting taxes and weakening the currency, which slipped over 15% this year and fell to an 18-year-low.

Funded primarily through the PAC 2 program, at least one third of units will be designated to families making up to three minimum wage salaries. Jorge Alves, Secretary of Housing, reports that 3,701 units have already been constructed and that a total of 12,654 new units will be available by the end of the year. As funding pours in, the Minha Casa Minha Vida program is advancing very quickly, which for some is reason for concern. "It's a speed of construction never before been seen," says architect Luciana Gomes da Lage, of the Institute for Research and Regional Urban Planning (Instituto de Pesquisa e Planejamento Urbano e Regional, IPUE), noting development, the architect critiques, leads to protests with the new units, that are "alright, always of poor quality, cheap land, without proper construction profit, apart from the normal income of the families who bought them."
TRANSFORMATIONS: thoughts on adaptable urban architectures

As Koolhaas describes the conception of the walled city in The Voluntary Prisoners of Architecture, "Once a city was divided into two parts. One part became the Good Half, the other part the Bad Half" one can imagine this as the genesis story of any city they have ever intimately known. The ubiquitous urban condition of good and bad, us and them, safe and unsafe, progressive and regressive is a reality of modern urban living. A reality that it is often a wayfinding device employed to explain to visitors and friends how to navigate the complex relationships that exist between places one "should" and "should not" go. However one might reasonably predict that the starting and endpoints of that journey will vary greatly depending upon the individuals perception of what constitutes good and bad. One is left wondering what makes good "good" and bad "bad" and in the potential of transformation or evolution from good to bad. What components, relationships, idiosyncrasies, perceptions and perspectives shape value in urban environments and is it possible for these elements to be reassembled into productive and symbiotic hybrids? This research intends to explore this issue through the vehicle of low-income housing as it is often the presence of low-income housing that defines the character of the sector of the city in which it is placed, or conversely it is often the design and sites chosen for low-income housing development that predetermine its relationship to the city.

FIGURE 8-1954 Pruit Igoe Complex, St.Louis, MO (right) 1974 Pruit Igoe Complex, St.Louis, MO (right)

FIGURE 9-2006 PROSAMIM Complex Manaus,BR (left) 2012 PROSAMIM Complex, Manaus Br (right)

FIGURE 10-1982, Workers City, Cairo, Egypt (left) 1988 Workers City, Cairo Egypt (right)
A central position to examine is the city's concept of the value of low-income housing and its incentive of production. This research proposes two common value propositions from the perspective of the city which have vastly different social and physical manifestations:

The need model - Housing the largest population possible with the least amount of cost.
The future model - Housing the largest population possible with the greatest social mobility.

The need model considers an immediate solution and tends to locate itself in parts of the city where sizeable quantities of city-owned low-cost land are available and currently underperforming. This production and siting strategy services the need model value proposition most efficiently and internally evaluates success as a percentage of population benefit. The unintended consequence of the need-based model is often social stratification/isolation, underperformance, and obsolescence (figure 8). The future model considers evolution over time of investment and tends to be located closer to the city center on moderate to high-value land that is serviced by infrastructural and mobility networks. This value strategy evaluates success as a function of economic growth and the production of a thriving middle class. The unintended consequence of the future model is often the lowering of the percentage of the low-income population that are able to benefit as a result of higher costs as well as the highlighting of class-based insolubilities (Figure 9).

FIGURE 11- The wall in Koolhaas's Voluntary Prisoner of Architecture

Both models have the potential to result in what Koolhaas describes as "the wall" that creates "division, isolation, inequality, aggression, destruction...". The need model often manifests as an exteriorized wall keeping those outside from wandering in and the future model often manifests as an interiorized wall keeping those inside the wall from wandering out. One might also argue a potential in the converse reading of the wall as "a mirror image... a force as intense and devastating but used instead in the service of positive intention... architectural warfare against undesirable conditions" (Koolhaas, 4). The architecture of the wall might then be used to provide an upgradable platform for transition from the need model to the future model based on the desires and perceptions of its users (Figure 10). With this reading one begins to imagine a potential transcendent value in the recombination of singularly charged components to imbue transformation in collision.
TRANSFORMATIONS: thoughts on differentiated systems

While it was the work of many earlier urban theorists to bring low-income housing out of periphery and back into cites, it is no longer enough to be proximate to the city, or inside the city, but to become the city. One might imagine that operating within a city is not unlike operating on a human body or an animal. It is the difference between the approach of the urban butcher and the urban surgeon that seems fertile ground for exploration in this research.

A butcher operates with broad strokes to create different apportionment by similar taste, fillets are not pot roast. Predictably this method finds efficiency in the clear delineation and valuation of proximal components. The law of supply and demand is king, tender cuts are a lower percentage of the animal than tougher cuts, and therefore the price and preference of tender cuts is high and tough cuts low. One has only to look at the planometric isolation of the butcher to understand the severity and immutability of undifferentiated systems (Figure 8).

To move beyond this one dimensional understanding one must consider qualitatively what makes good good and bad bad as a series of more complex relationships. According to the American Cattleman's Association the more tender cuts (New York Strip, Porterhouse, rib-eye, sirloin, etc) or "middle meat" are produced in an area of the cow where the least body movement and stress occurs allowing for marbling of fat between the muscle fibers, and it is the marbling that makes the muscle juicy and flavorful. Conversely the tougher cuts (pot roast, swiss steak, chuck, etc) or "end meats" are produced from the shoulder and hind areas, muscles with that do most of the work, resulting in more connective tissue and less fat.

One has only to look at the "yield" of the cow to understand the proportional implications of these phenomena:

A 1200 pound steer yields 500 pounds of retail cuts from a 750 pound carcass (41% yield). Within that yield 22% are steaks, 48% are roasts, ground meat and stew meat and 30% is fat, bone and shrinkage. With the exception of the 30%, the steers infrastructure, the steers locomotive systems are composed of the same elements in differing proportion and adjacency which results in textures and densities that delight our palettes or remain relatively tasteless.
If one desires more high quality yield we must increase precision, enter the Surgeon. What the surgeon must understand is the sectional implication of operating in plan. To remove a single muscle intact requires the destruction of hide, fat, cartilage, tendon and bone. A surgeon has the advantage of being able to remove small parts of differentiated muscle groups without permanently damaging life supporting infrastructure.

The metaphor ends here and the architectural proposition begins. If we consider what we prefer in the “middle meats” and “end meats” as urban architectural actors, through selective dissection and recombination of infrastructure, site and program their arises a potential to create a hybrid capable of producing a larger yield over time without sacrificing quality. By programatically isolating and physically agglomerating immutable low-income housing settlements into specific sectors of the city one is “butchering” the metropolitan experience and denying the transcendent implications of combination beyond physical proximity (Figure 14). However, when seen as a mirror, it’s hidden potential as a mechanism for confrontation, exchange and transformation is revealed. To paraphrase Rem Koolhaas, causing a chain reaction that leaves neither side unaltered and challenged with the freshness and suggestiveness of these parallel performances activating dormant parts of the brain and triggering a continuous explosion of thoughts and ideas in the users (Koolhaas, 13).
TRANSFORMATIONS: thoughts on site, density, infrastructure and metrics

Metrics of evaluation must be established to gain a nuanced understanding of the complexities of site, density, program and infrastructure in the development of low-income housing settlements. This thesis proposes to investigate these metrics by introducing a sample population as a method of gaining a finer grain of analysis and resolution. This study will consider a sample population of 3,000 individuals that belong to a settlement of 750 families. In a way this sample population is arbitrary, however, this sample size makes it possible to test metrics that range from the urban to the individual. The two images below represent squatter settlements of approximately 750 families (figure 15).

FIGURE 15-Villa Los Piletones, Buenos Aires, Argentina (left) Toree David, Caracas, Venezuela (Right)

The first image is an aerial image of the Villa Los Piletones settlement, Buenos Aires, Argentina (figure 15). This low-density informal settlement contains a variety of program from housing, to childcare, clinics, recycling operations, civic spaces, commercial enterprises and recreational facilities. The second image is of the Torre David an informal vertical settlement in Caracas, Venezuela (figure 15). This tower was informally occupied by 750 families after the collapse of the Venezuelan oil market in the late nineties. Again, this settlement contains a range of social program from residences, to markets, sports facilities and churches in its first 29 floors. While different in configuration, these examples represent extreme ends of informal urban populations of approximately the same size which can be found all over the world. It is with these two concepts that I begin to understand the implications of 750 families living together in one community.

FIGURE 16-Density study of Villa Los Piletones and Torre David
The first metric this study seeks to establish is the minimum space requirements, performance and characteristics of a single family home. This study will cross reference the United Nations Millenium Development Goals, SPHERE's Handbook “Humanitarian Charter and Minimum Standards in Humanitarian Response” and UN-HABITATS global recommendations handbook to derive a definition of simple and decent housing standards. The fields of evaluation will be design, materials, location, durability, safety, tenure, water and sanitation. The combined parameters are below:

**Design**
Covered area: Each person in the household has a usable covered floor area of no less than 3.5 square meters (37.5 square feet) OR comprises a minimum of two rooms. If the minimum standard for usable space has not yet been met, the house is situated so as to allow for future extension.

**Materials**
Locally sourced materials and labour are used without adversely affecting the local economy or environment, and enable the maintenance and upgrading of the house using local tools and resources.

**Location**
The house is safely located; risks from natural hazards including earthquakes, volcanic activity, landslides, flooding or high winds are minimized, and the area is not prone to diseases or disease carrying agents.

**Durability**
In disaster prone-areas, construction and material specifications mitigate against future natural disasters.

**Safety**
Structural materials are durable enough to allow safe refuge and exit in case of a natural disaster.

**Secure tenure**
Land and property ownership and/or use rights for buildings or locations are established prior to occupation and permitted use is agreed as necessary. Where use rights do not exist, there is de facto protection against evictions.

**Water**
Water is palatable, and of sufficient quality to be drunk and used for personal and domestic hygiene without causing significant risk to health. There is safe and equitable access to and/or adequate storage of sufficient quantity of water for drinking, cooking and personal and domestic hygiene. Public water points are sufficiently close to households to enable use of the minimum water requirement.

**Sanitation**
Communities have adequate numbers of toilets, sufficiently close to their dwellings, to allow them rapid, safe and acceptable access at all times of the day and night. Toilets are sited, designed, constructed and maintained in such a way as to be comfortable, hygienic and safe to use. Dwelling has an environment in which the health and other risks posed by water erosion and standing water, including storm water, floodwater, domestic wastewater and wastewater from medical facilities are minimized.
FIGURE 17 - Minimum size of a single family home diagram

For this research the minimum space requirements of a single family home will be accepted as 3.5 square meters (37.5 square feet) per person (figure 17). With an average family in Brazil of 4 members this would equate to 14 square meters (150 square feet). The corresponds to the smallest size of residential units found both in the Torre David as well as in Villa Los Piletones. This is believed to provide a basis for the absolute minimum net space requirement of a single residence. By working with net values one is able to eliminate infrastructural space (structure, utilities, circulation, etc) and simplify calculations and comparisons (figure 16).

In order to understand metrics related to infrastructural systems and utilities, one must examine in detail the inputs and outputs of a 3,000 person population. In this study we will examine both the potential thermogenesis, body heat production of the collective, as well as the production of solid and liquid biowaste from the sanitary systems. We chose these two systems to analyze as representative of systems that are not often considered in traditional approaches to designing low-income housing. We seek to prove that through data driven analysis of all aspects of living one can develop more robust architectural provocations and solutions for future development.

How much heat do we produce?

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<td>3.0&lt;br&gt;3.3&lt;br&gt;3.5&lt;br&gt;4.0&lt;br&gt;5.5&lt;br&gt;3.9</td>
<td>174.6&lt;br&gt;192.1&lt;br&gt;203.7&lt;br&gt;232.8&lt;br&gt;320.1&lt;br&gt;224.7</td>
<td>314.3&lt;br&gt;345.7&lt;br&gt;366.7&lt;br&gt;419.0&lt;br&gt;576.2&lt;br&gt;404.4</td>
<td>1,072.4&lt;br&gt;1,179.6&lt;br&gt;1,251.1&lt;br&gt;1,429.8&lt;br&gt;1,966.0&lt;br&gt;1,379.8</td>
</tr>
<tr>
<td>bicycling, leisure&lt;br&gt;bicycling, stationary, light&lt;br&gt;averages</td>
<td>4.0&lt;br&gt;5.5&lt;br&gt;3.9</td>
<td>232.8&lt;br&gt;320.1&lt;br&gt;224.7</td>
<td>419.0&lt;br&gt;576.2&lt;br&gt;404.4</td>
<td>1,429.8&lt;br&gt;1,966.0&lt;br&gt;1,379.8</td>
</tr>
<tr>
<td>vigorous intensity activitives</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>jogging, general&lt;br&gt;calisthenics (jumping rope, boxing)&lt;br&gt;calisthenics (running, pull-ups)&lt;br&gt;averages</td>
<td>7.0&lt;br&gt;10.0&lt;br&gt;8.0&lt;br&gt;8.3</td>
<td>407.4&lt;br&gt;582.0&lt;br&gt;465.6&lt;br&gt;485.0</td>
<td>733.3&lt;br&gt;1,047.6&lt;br&gt;838.1&lt;br&gt;873.0</td>
<td>2,502.2&lt;br&gt;3,574.6&lt;br&gt;2,859.6&lt;br&gt;2,978.8</td>
</tr>
</tbody>
</table>

FIGURE 18 - Metabolic production per activity per hour conversions
How much heat do we produce in a 24 hour period?

\[
\begin{align*}
4,607 \text{ btu} + 11,038 \text{ btu} + 23,830 \text{ btu} &= 39,476 \text{ btu}
\end{align*}
\]

How much heat do 3000 people produce in a 24 hour period?

118,427,554 btu per day

852 Gallons of Diesel Fuel

How much would we have to pay to produce the same heat from crude oil as 3000 people create in a day? and in a year?

8,115 USD (A DAY)

2,961,703 USD A YEAR

<table>
<thead>
<tr>
<th>units</th>
<th>btu production of 3,000 people per day converted to physical units</th>
<th>days</th>
<th>btu production of 3,000 people per year converted to physical units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>3,412,975 kilowatt hours</td>
<td>17,969,883 kilowatt hours</td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>119,202 cubic feet</td>
<td>365</td>
<td>42,048,694 cubic feet</td>
</tr>
<tr>
<td>Motor Gasoline</td>
<td>124,000 gallons</td>
<td>365</td>
<td>348,597 gallons</td>
</tr>
<tr>
<td>Diesel Fuel</td>
<td>139,000 gallons</td>
<td>365</td>
<td>310,579 gallons</td>
</tr>
<tr>
<td>Heating Oil</td>
<td>139,000 gallons</td>
<td>365</td>
<td>310,579 gallons</td>
</tr>
<tr>
<td>Propane</td>
<td>91,333 gallons</td>
<td>365</td>
<td>473,280 gallons</td>
</tr>
<tr>
<td>Wood</td>
<td>20,000,000 gallons</td>
<td>60</td>
<td>2,161 cords</td>
</tr>
</tbody>
</table>

FIGURE 21- Relating physical units and BTU's of production of 3,000 people

One 42 Gallon barrel of Crude Oil can be refined to produce

<table>
<thead>
<tr>
<th>Gallons of Crude Oil equivalent to BTU production of 3,000 people per day</th>
<th>Gallons of crude oil equivalent to BTU production of 3,000 people per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.4 gallons motor gasoline</td>
<td>17,969 barrels</td>
</tr>
<tr>
<td>10.5 gallons diesel fuel</td>
<td>29,617 barrels</td>
</tr>
<tr>
<td>9.2 gallons heating oil</td>
<td>33,802 barrels</td>
</tr>
</tbody>
</table>

FIGURE 22- Crude Oil Metrics
The urban housing typologies of the future must be designed to interact comprehensively within existing resource networks, both renewable and finite. Largely overlooked in the field of architecture, in favor of strategies for harvesting sustainable energy (wind, solar, etc.), are the streams of waste produced by urban populations. In a world of ever increasing resource scarcity it is imperative to evaluate waste streams for potential systematic redesign that would contribute to the effective reuse, reclamation and efficient removal of the by-products of the urban collective. One can look to solid and liquid biowaste management as a space for architectural innovation. Urine diversion refers to the separation of human urine from feces at the point source. Separation of urine from feces allows human waste to be treated separately and used as a potential resource. Separate treatment of the two types of waste is justified since urine is nearly sterile and low in pathogens, while on the other hand feces are high in pathogens. This means that urine can be readily utilized as a fertilizer or discharged with less risk to community, while fecal matter should either be composted or dried and burned as a biofuel.

 YEARLY GROSS URINE PRODUCTION OF 3,000 PEOPLE

404,976 gallons
202,588 lbs

YEARLY GROSS FECAL PRODUCTION OF 3,000 PEOPLE

80,000 gallons
641,602 lbs

3/4 of waste is water
481,202 lbs

1/4 dead bacteria, dead cells, and fibrous undigestibles
160,400 lbs

5% of urine is solids
31,431 lbs urea (N)
6,320 lbs chloride (P)
3,954 lbs sodium (P)
2,535 lbs potassium (K)
2,264 lbs creatine

95% of urine is water
364,727 gallons

2009 - NASA's Mission Control gave the Expedition 19 astronaut crew a "go" to drink recycled water from their own urine. "This has been the stuff of science fiction. Here we are today with the first round of recycled water" - Expedition Engineer

2008 - The monetary value of the nutrients in urine (NPK) is an incentive for urine diversion, both at household level as well as for the development of micro enterprises

2006 - Human urine is the most nutrient abundant component of the domestic waste stream and urine separation has been proposed to achieve maximum recovery and recirculation of nutrients in Sweden.

2003 - Guangzi, China. A urine diversion pilot project, in cooperation with UNICEF-Beijing started in 1998 with 70 households. By the end of 2003, 685,000 urine-diverting toilets had been installed in 17 provinces.

2011 Gates Foundation Winner
Columbia Professor Kartik Chandran is developing "Next-Generation Urban sanitation facility" in which it is possible to reclaim organic compounds from human fecal sludge into biodiesel and methane (two energy sources)
To respond to waste as architects we must first understand what it is that we produce and then provide a flexible framework within which to employ technological innovation at the scale of architecture. In this way the urban housing typologies of the future will become working laboratories of experimentation, monitoring and adaptation of complex systems of inputs and outputs.
TRANSFORMATIONS: a case study and field work in Brazil

In the summer of 2012 the author of this thesis, Caleb Harper, together with two colleagues Vasco Portugal MIT PHD and Layla Shaikley MITSMArchS 13’ conducted a field study of high density low-income housing in Brazil. The resultant publication of their combined research effort is relevant, pertinent and was conducted in parallel with the development of this thesis and is therefore included below.

Incremental Expansion:
Examining User-initiated Transformations in Government Housing in Manaus

Caleb Harper, Vasco Portugal, and Layla Shaikley
Massachusetts institute of technology

ABSTRACT

This paper examines user-initiated transformations of high-density government housing in the rapidly urbanizing context of Manaus, Brazil. The research, conducted in the summer of 2012, offers evidence-based analysis of two existing multi-story urban housing typologies, one traditional and one experimental, and the effects of these typologies on the process of incremental expansion. By critically examining two distinct contemporary typologies in identical social and geographical contexts, this paper seeks to provide nuanced strategies for future urban housing policy and development at the interface of informal and formal construction.

Results revealed that the first phase of development offered an experimental three story housing typology that inadvertently encouraged owners to significantly expand their units. Users of these units expressed satisfaction with the ability to personalize their space as well as their demonstrated ability to expand with high quality and craftsmanship. However, as the expansions were not predetermined, the government expressed concern with the high number of resident disputes over shared space along with code and zoning violations. As an instinctive response, the government shifted to a more traditional and inflexible three story walk up configuration, which decreased resident and municipal tensions while also decreasing user satisfaction and the quality of expansion.

In both typologies, expansions materialized relative to the individual desires of the inhabitant, but most notably in three categories: home-based entrepreneurship, additional storage, and additional living space. By analyzing the nature and specifics of these expansions, the necessity of a home to dynamically evolve in support of the physical, social, and financial growth of its residents was immediately apparent.

Considering the results of this research, there is a strong and substantiated user desire and global benefit in promoting incremental expansion in the high-density urban housing context. By reprogramming formal high-density multistory housing through the lens of user transformation, it is possible to create a symbiotic hybrid of the desires of professional practice and those of its beneficiaries.

*We are grateful to Professor Reinhard Goethert for being such a resourceful and rigorous researcher. The completion of this research would not be possible without his guidance and support. Acknowledgments and thanks are due to the PROSAMIM team, Concremat, Construtora Andrade Gutierrez, IDB, UBR A, and SUHAB. We also would like to thank Abrahim Frank Lima, the architect Luiz Fernando Almeida Freitas, Dr. Fernanda Magalhães, Professor Jaime Kuck, and Lúcio Rabelo for their general support.
INTRODUCTION
The Inter-American Development Bank (IDB) funded the Programa Social e Ambiental dos Igarapés de Manaus (PROSAMIM), located in the central business district of Manaus in Amazonas, Brazil, focuses on providing infrastructure and housing options to the residents of low-income communities who lived in the palafitas. The palafitas are informal floating wooden settlements that surround the igarapés, or streams, of Manaus. Through in situ upgrading, the program seeks to maintain preexisting social and economic networks and preserve communal identity.

We conducted an analysis of the range of informal expansions to the two typologies of government housing in the central business district and derived questions and propositions for guiding future project designs. Two typologies of settlement were extensively studied for similarities and differences. The first housing typology provides architecture to support incremental expansion, in discord with its legislating policy. The second iteration purposely rebuffs opportunities for expansion concretizing in a more rigid typology. While there was evidence of incremental housing expansion in both typologies, there was a direct correlation between the typology that adapted well to user-initiated expansion and the increased quality of life in the community. This became evident through personal surveys vis-à-vis both typologies, increased social life in the expandable typology, and decreased safety concerns in the more social settlements. Independent of typological variation, several factors remained consistent. Our key findings centralize on evidence of both formal interior and informal exterior expansion. Both methods of expansion illustrate the ability of the inhabitants to expand with high quality materials, despite governmental restrictions and without governmental support. Expansions materialized relative to the individual desires of the inhabitant, but most notably in three categories: home-based entrepreneurship, additional storage, and additional living space.

Considering the results of our analysis, we feel that there is a strong and substantiated urge for incremental expansion among local inhabitants as seen in projects throughout the world. We provide evidence to demonstrate how such provisions, when initially considered, are affordable and manageable for high-density low-income housing settlements. We also provide data to support a reevaluation of current government policy to facilitate user-initiated incremental transformation for these settlements.

This paper concludes by suggesting ways to adopt incremental flexibility in high-density low-income housing design, the creation of architectural opportunities for user-initiated transformation, and suggestions for the modification of current government policy to support participation and policy responsiveness to community needs, adding new dimensions to the existing literature.

CONTEXT AND ELUCIDATION
Like other Brazilian metropolitan areas, the city of Manaus expanded rapidly in the second half of the last century, growing by an average of 4.87 percent a year and outpacing nationwide growth following the creation of the customs free zone in 1967. According to the Brazilian Institute of Geography and Statistics (IBGE), the population of Manaus grew from 311,622 in 1970 to 1,802,525 in 2010. In 2007, the customs free zone created 100,000 direct jobs and achieved annual output on the order of $23 billion. Given the job prospects it offered, this zone has made Manaus a pole of attraction for large and particularly low-income population contingents. Yet while the city's population multiplied, Manaus had an insufficient urban infrastructure that had not been built to receive swollen population growth. In addition, business and industry could not absorb the quantity of unemployed constituents, causing haphazard and often illegal occupation of urban areas. Low-income immigrant populations occupied areas on the banks of the igarapés, the small streams that once traversed the Amazon when it covered the area before it was replaced.
once traversed the Amazon when it covered the area before it was replaced by the metropolitan capital. The end result has been a proliferation of precariously situated housing in the downtown area, creating what has historically been defined as the floating city.

Every year in the rainy season (January to June), the igarapés are flooded by the Negro River, whose volume increases significantly, leading to raised water levels. The settlements (palafitas) along the igarapés are flooded nearly every year, with the accompanying human, financial, environmental, and social damage (Rojas and Magalhaes 2007).

THE GOVERNMENTS STRATEGY

The current administration of the government of the State of Amazonas has adopted a strategy of working with the municipal to a broad range of actions and interventions to address these problems of the palafitas (Government of Manaus 2002). Total investments are $800 million over a twelve year period, calling for systematic planning and effective community participation. At the same time, the municipios acting to minimize the risk of new squatting in the igarapés through preventive policies based on increasing the supply of low-cost housing and by controlling vulnerable areas (IDB 2005).

The government of Amazonas, seeking to resolve the local environmental and social problems of the igarapés, founded PROSAMIM in 2003 to improve the quality of life for squatters. The methodology for intervention in PROSAMIM manifests itself in four ways, two corrective and two preventive:

1. The implementation of macro and micro drainage systems to regulate the impact of rainfall and flooding due to the Rio Negro;

2. The resettlement of the population occupying the igarapés land that is suitable for housing and equipped with all the basic services;

3. Creation of boulevards and parks in the areas most vulnerable to illegal invasions;

4. Establishment of a general master plan and increase of the supply of land for housing, by means of a greater control and surveillance;

In order to achieve these goals, it was necessary to eradicate the locally established palafitas by implementing a method of resettlement for the squatters. The options to relocate the families set out in the Operational Guidelines of PROSAMIM (UGPI 2012) are:

1. Building new housing units (as shown in figures 1 and 2), further prioritizing the resettlement of families from the reclaimed land along the igarapés (the focus of our research) and ensuring access to services and existing social infrastructure;

2. Monitored resettlement, subsidizing and supporting the resettlement of families to housing in the local and regional market through the delivery of a housing bonus of R$21,000;

3. Resettlement to affordable housing programs offered by the state government and the City of Manaus;
4. Independent relocation that is, compensation in cash, in accordance with the IDB policy, which applies to owners who meet conditions to initiate their own relocation process;

5. Housing allowance, as a monthly supplement to families that were previously renting in the squatters or to those with no other option to stay close to where they previously lived.

THE PREEXISTING SITUATION AND THE PROCESS OF INCREMENTAL POLICY DEVELOPMENT

The wooden palafitas that occupy the igarapé have historically been the most typical solution for squatters in Manaus, especially in areas close to the city center. For this exploration, we delimited our search scope to the palafitas deployed along the margins of the Igarapé Quarenta. These specific palafitas stood alongside new residential parks, which facilitated access to the existing squatter settlements. In addition, the palafitas had already been subjected to an extensive assessment from the government, which simplified our work in terms of socioeconomic characterization.

Fundamentally, we sought to understand the original context of this population. This would allow us to appreciate the social and household characteristics established, and we were able to comprehend the relevance of the palafitas in the context of Amazonian culture. Through an understanding of the palafitas, we looked for indications of the local culture to understand how the architecture of the palafitas would affect their integration into the new housing typologies of the resettlement program.

It is challenging to categorize the physical characteristics of the palafitas, but there are patterns of uniformity in certain formal characteristics and usage. We observed that the palafitas are used mainly for residential purposes, which eventually also function as the basis for home-based enterprises (HBEs) and a subsequent source of income. Structurally, the palafitas are supported by stakes at approximately 1.5 meters above the ground, so they are protected from water during the flood season. During the period when the water level is lower, some of the locals use the space underneath their houses as either living or commercial space. In terms of construction, there are explicit differences, such as diversity of shapes, sizes, material, and quality of construction.

The material used in the construction ranges from unit to unit, although there is a predominance of wood as a natural consequence of the proximity to the forest and a common pattern within the traditional architecture of the Amazon River region. Less commonly but still prevalent were concrete slabs, ceramic brick, and metallic plates. The roof, in most cases, had been made of wood frames and roofing cement or zinc.

The interiors of the dwellings usually exhibit one central space that is further divided through the use of furniture. However, some houses employed interior partitions to separate bathrooms and kitchens. The interior walls are usually made of wood and are independent from the exterior structure, indicating the user’s preference for some degree of flexibility to adjust space according to need. Regardless of the conditions of these structures, internally most of them had been guided by organization, creativity, and cleanliness. However, paradoxically, the exteriors were consistently dominated by garbage and contaminated water.

The facades of the palafitas clearly express some concern with aesthetics, regardless of their informal condition and independent of the fact that they had usually been built using construction debris or scavenged materials. We found a variety of construction details, such as wood moldings, an array of colors and paintings, small gardens, and detailed carpentry.

As part of our research activities, we deliberately accompanied one of the squatter families as they
resettled from the palafitas to the housing units in the residential area Gilberto Mestrinho. We observed that while the family moved their possessions from palafita to the PROSAMIM government units, neighborhood residents were already salvaging construction materials from the freshly abandoned palafita. While the palafita had been scrapped, the materials were being used to erect or expand a palafitaelse-where. These observations support the concept advocated by several authors (Jacques 2004; Tuhus-Dubrow 2009) that informal settlements should be understood as living bodies in constant development. In these settlements, as in the majority of cities, there are no standard units and no single solution to respond to the dynamics of these continuous transformations. This particular context, when combined with the geographical features of a river peninsula and the peculiarities that the local climate shows through floods and droughts, configures an extremely irregular framework. A simple observation gives us examples of a permanent necessity to adapt and change, especially when considering the extreme weather events and climate change that may result in significant structural changes in several of the physical spaces, particularly in the housing units to prevent the aggravation of the precarious existing social conditions. The process of informality responds to several of these changing pressures by adding structures, densification, or expansion of the settlements; as the occupants change; as the family grows; as a rental market emerges; and as sections may be demolished, and others may be gradually consolidated but that is the nature of the informal settlements (Turner 1972). For centuries, the inhabitants of Amazonas have depended on their own capacity to respond to their own housing needs (Oliveira Junior 2009). Considering the array of key challenges facing the informal sector, the built environment in the physical sense is not a major concern to those who live in Manaus's informal settlements. As observed, this self-built household sector is characterized not only by informality, irregularity, and illegitimacy but also by its flexibility and resilience. The occupants in the palafitas adapt their households to personal needs; as the family grows or needs to create an informal business, the unit responds and adapts by reappropriating adjacent spaces.

METHODOLOGY
The methodology was established from a combined application of subjective methods (qualitative assessment) and objective methods (quantitative assessment), based on our field research. The objective methods were focused on the physical constructions, population surveying, and collected data. The subjective methods were based on ethnographic research, which was derived from the visits to the site and empirical observation.

We started by gathering data from the combination of the analysis of documents and material available on the different phases of PROSAMIM. We furthered our understanding of the information obtained through interviews of the various stakeholders, from the coordination of the program to the users of the housing units. This allowed us to have a basis for comparison with the data collected during our field study. In the field study, detailed information had been gathered through observation and survey of the interiors and exteriors of the housing units.

The combined use of methods had the main objective of extracting conclusions about the housing units and their socioeconomic impact. We were interested in understanding the impact on the immediate surroundings and the city of Manaus as a whole, with particular interest in the units that had been informally extended in the new PROSAMIM housing projects. We were also interested in the reasons that motivated the adjustments and expansions to the original design.

We have used a comparative research methodology (Tipple 2000; Tipple and Willis 1991; Landaeta 1994) to evaluate and relate the many variables of the resettlement program, from its first phase (PROSAMIM I) to its inflexible second phase (PROSAMIM II).
Survey of Users and Building Expansion
In order to evaluate the use and modification in the housing units and to trace the social economic characteristics of the population living in survey of Users and building expansion In order to evaluate the use and modification in the housing units and to trace the social economic characteristics of the population living in allocated habitation units (HUs), we applied a total of 125 questionnaires semistructured to the local community, based on the model proposed by Gattoni, Goethert, and Chavez (2011).

We used the sampling method defined as a nonprobabilistic accidental sample, where those who responded to the survey were the people present at the time when the survey was conducted and who agreed to be surveyed. This is to say that the study interviewed one person for each dwelling and, therefore, one representative sample per household. We established five sampling areas, 25 questionnaires being implemented in each of the PROSAMIM residential parks (figure 24)

<table>
<thead>
<tr>
<th>RAs</th>
<th>HUs</th>
<th>Program Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manaus I</td>
<td>567</td>
<td>PROSAMIM I</td>
</tr>
<tr>
<td>Manaus II</td>
<td>252</td>
<td>PROSAMIM I</td>
</tr>
<tr>
<td>Jefferson Pères</td>
<td>150</td>
<td>PROSAMIM I</td>
</tr>
<tr>
<td>Mestre Chico</td>
<td>498</td>
<td>PROSAMIM II</td>
</tr>
<tr>
<td>Giberto Mestrinho</td>
<td>372</td>
<td>PROSAMIM II</td>
</tr>
</tbody>
</table>

FIGURE 24-Residential Areas (RAs) Built by the PROSAMIM and the Quantity of Housing Units (HU) per RA

The research was restricted to these specified parks primarily since these were the areas where homes have already been delivered and because they were in the center of Manaus, which was relevant for our study while pro-viding us with greater ease of access to the area. The study took place in the summer of 2012. In addition to the questionnaires, the survey consisted of informal conversations with people. For statistical analysis of the questionnaires and survey, a comparative analysis was employed (Tipple 2000).

EXAMINING USER-INITIATED TRANSFORMATIONS
The significance of understanding the design of a house from its extensions is that it allows us to see beyond the problems of a spatial and physical nature. This is especially true when one observes that the current problems that social housing programs face seem to be particularly related to the individual nature of residents. Thus, the breakdown of this study focuses on the user initiated transformations made to the housing units, which ultimately turn out to be descriptive vectors of the residents' own needs. Outcomes allow us to affirm that the design of the building and houses directly influences the behavior of residents and has a direct impact on the web of social relationships, status, and integration into the city, while explicitly the prod-uct of government choices. Understanding the dimensions of the residents' conduct after the distribution of the houses, and the impact that different typologies may have on them, allows us to begin understanding what should be the role of the government in a resettlement project of this nature.

Housing Typologies
The design of the housing blocks from PROSAMIM I (HB1) comprises three HUs, a ground floor and two duplex apartments on the top floor. Each HU has a similar plan, with slight variations; among them, the most prominent is a 180-degree rotation from floor to floor to create a cantilever to produce shaded areas on the ground floor and balconies (cantilever roof) in the duplex units. What ultimately results are two patios on the ground floor, one near the entrance and another at the back of the house. The duplex units on the upper floor also gain two balconies, one that provides
access to the households and an additional one on the second floor of the duplex in one of two rooms found there.

The housing blocks from PROSAMIM II (HB2) are three-story walkup buildings of six apartments (two per floor), horizontally stacked on top of each other, with a floor area of 48 square meters apiece. All the apartments have the same plan layout. Access is through a common staircase, and there are no additional balconies or patios.

Despite the differences, the two typologies have a number of interesting features and share common elements; both are built of ceramic brick, load bearing walls and have a fiber cement roof. None of the mentioned materials could be considered local or traditional, but a new industry had been created to supply the work being done for PROSAMIM. In order to meet budgetary constraints imposed by the available funds, the internal finishes were the exclusive responsibility of the residents. Given the social character of the project and existing budget, there is a consensus that material options were adequate thermally and formally.

![HU1 Plans](image1)

**FIGURE 25** - Housing Units (HUs) Plans from Both Phases of PROSAMIM

With regard to the layout (figure 25) of the interior spaces, both phases are well designed with a good functional configuration. All HUs have a kitchen, a bathroom, a living room, and two bedrooms. Entrance to the interior of the dwellings is gained through the balconies or patios.

There are some aspects that have been improved from the first to the second typology, particularly in the roof of the HB1, which was relatively weak and responded poorly to the unforgiving heat and rain of Manaus. There were also some improvements in the services and bathroom organization. However, the main reason for the change was essentially linked to governmental requirements rather than resident desires.

It is interesting to perceive that the prime reason that led the government to opt for a different typology in the second phase is directly linked with the appropriation of the adjacent spaces in the initial project. In the opinion of those responsible for the program, the building design urged
residents to expand their homes and occupy spaces that were appointed to be open spaces for communal leisure and circulation. The government has chosen to create a more rigid model, where the housing units are stacked on each other, and with less communal circulation space. While the HB1 has some extra communal circulation space, in the HB2 the vertical and horizontal communal space was reduced to its minimum.

This amendment, in addition to being highly inflexible with respect to extending the apartments, directly affects the sociability among neighbors. The extra communal area that we can find in HB1 generates spaces that also serve to encourage residents to eat, talk, relax, and increase their sociability in the neighborhood as a whole. Something felt instantly upon initial contact with either neighborhood is a tremendous difference between how the two neighborhoods socialize. Even though we have no quantitative data to substantiate such a claim, we can confirm this same fact through observation and daily contact with both neighborhoods during our fieldwork (figure 26).

When reflecting on the ability of this project to integrate and blend within the rest of the city, we feel that despite the fact that there is some typological variety, particularly in the HB1, ultimately one is unable to avoid drawing a monotonous urban picture. Even if the quality of urbanization was quite satisfactory, the quality of the project follows a strong and recognizable pattern, which ultimately reflects the social condition of its residents. In this program, the design and scale of houses or blocks are very simplistic. This is not necessarily flawed, but produces a repetitive urban landscape, which differs from the expected assortment of a city and highlights visual prejudice and segregation against this new context (Magalhães and Villarosa 2012) (figure 27).

With the aim of developing a more consistent profile of both typologies, we developed two forms (figure 28; also see figure 29), where residents identify the best and worst qualities of both, so that we could shape a diagnosis of the connection between the built environment and its residents.

There is a general dissatisfaction about how the HUs are arranged, which is different from the preceding arrangement in the squatters and unlike the traditional practice of Amazonian culture, which is the vertical stacking of the units. There is also some disappointment concerning the areas of
the HB2 typologies. The HB1 typologies have additional 8 square meters of area per unit. But if we consider just what useful space is, this does not have great relevance, particularly in the duplex units, whose interior stairs ultimately subtract that portion of extra space.

Residents were unhappy with the inflexibility of the HB2 plans. The HB1 had two extra balconies per HU and additional communal space, these additional spaces allowed its residents to do amplifications and make improvements to the houses. Conversely, in the HB2, despite the fact that there were also communal spaces, they were reduced to a bare minimum, which make it difficult to extend and transform the households without directly interfering with the neighbors from the same block.

The lack of space to dry clothes is also a common protest in both typologies. In general, residents were happy with the quality of construction materials, but it is interesting that most of the people who identified materials as the worst feature lived on the third floor, due to the heat retention on the roof. Although not significant in percentage, some residents mentioned natural light as the best feature of the house. The units have proper glazed areas as fenestration, particularly in the HB1, which have large glazed walls next to the entrance, adding to the two balconies for each duplex unit. This generates pleasant natural interior lighting and provides opportunities for natural ventilation in all HUs. Ventilation seems to have little significance for the tenants. However, there is a curious fact that we should highlight: The 2 percent who specified ventilation as the most positive aspect resided on the ground floor.

The most significant feature for both typologies was sanitation. Residents of both units reported that the greatest improvement from being resettled from the palafitas was access to basic sanitation, such as clean water and a sewage system. Adversely, there were also many complaints concerning services by both typologies. This particularly happened as residents were commenting on different aspects of the services. The criticisms had more to do with the quality of services than with the service itself even though the houses were new, they posed several problems of infiltration and a degradation of
materials. The percentage that identified electricity as the most positive feature referred particularly to the capacity to purchase appliances, air conditioning, and multimedia devices.

A gap between buildings in the HB2 was identified by 13 percent as a negative feature. The way in which buildings had been organized in the residential areas created a dark alley between the rear of one building and the next one, leading residents to complain that these hidden alleys common attract illicit activities.

<table>
<thead>
<tr>
<th>User-Initiated Transformations</th>
<th>Parque Igarapé Manaus</th>
<th>Parque G. Mestrinho</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Percent</td>
</tr>
<tr>
<td>Total HBs</td>
<td>273</td>
<td>100</td>
</tr>
<tr>
<td>Total HUs</td>
<td>819</td>
<td>100</td>
</tr>
<tr>
<td>Total extensions, HBs</td>
<td>174</td>
<td>64</td>
</tr>
<tr>
<td>Total extensions, HUs</td>
<td>193</td>
<td>24</td>
</tr>
</tbody>
</table>

FIGURE 29 - User-Initiated Transformations in the Habitation Blocks (HBs) and Habitation Units (HUs), Total Percentage

Residents disliked the insecurity manifest by this spatial adjacency. Despite the fact that this was more of an urban problem than a housing concern, residents reported that the issue is emphasized by the fact that the HUs do not have a back door in the ground floor, which is found in the original typologies of HU1. This makes it impossible to monitor what goes on in that space, since access to it is limited. In addition, it obstructs the appropriation of that space by the residents, an area that could be used to dry clothes, as recreational space, or for the expansion of the units.

Characterization: User-Initiated transformations

The residential area Igarapé Manaus has a total of 277 HBs, and each of these blocks holds 3 HUs, with one ground floor unit and 2 duplex HUs. From the 273 existing HBs, 174 had already been changed by their residents, which amounts to 64 percent of present HB. In the residential area Gilberto Mestrinho, there are 372 HUs, with 76 (20 percent) having undergone some sort of transformation resulting in 38 percent of HUs transformed (figure 29).

As mentioned above, the HB1 offers more "opportunities" for extensions of units; the verandas, balconies, communal space, and courtyards have been extended in a wide variety of designs (see figure 26 above), and have proportions ranging from the simple extension of a veranda to the expansion of about 25 square meters of the house. Yet it is clear that there is a desire to expand and transform in both typologies. Where space allows, there is an obvious tendency to create additional rooms, particularly on the ground floor and especially for commercial purposes. In some cases, this is simply achieved by erecting a boundary fence with an entrance to the street.

An initial analysis of the objectives of PROSAMIM to improve the quality of life for squatters of the palafitas through the establishment of residential areas was clearly achieved successfully. However, the program did not anticipate the settlement of 127 micro and small businesses (PEPAC 2007), which were previously sources of income for some of the residents. Moreover, it is interesting to understand the benefit of mobility in relation to the contractual clause that prevents homeowners from selling the new property during a period of ten years.

31
We have identified three main triggers for the propagation of user-initiated transformations in the new households. Most transformations are related to informal trade purposes, followed by the creation of additional living space and, last, storage requirements (figure 30).

Room renting and the establishment of small private businesses are strongly preferred for the transformation and expansion of the space of the households; the dwelling is one of the few resources that they have for generating income. If we take into account the prime localization, we easily recognize that renting is not just convenient but also very profitable for local standards. Yet the main reason for expanding the area of the dwelling is the establishment of illicit home-based enterprises (HBEs); thus, in the Manaus residential area, 62 percent of houses have been extended to make room for a diverse number of services, ranging from catering and minimarkets to teaching and bicycle rental. These activities have a critical relevance for many of the residents, who without such services would be forced to spend more time and money on journeys to adjacent neighborhoods—which would result in undercapitalization in a context that by itself suffers from numerous financial difficulties. Most important, these activities generate many jobs, which are cheaply created, absorbing a number of residents who probably would otherwise be unemployed and a burden to society.

<table>
<thead>
<tr>
<th>Types of Expansion</th>
<th>Parque Igarapé Manaus</th>
<th>Parque G. Mestrinho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home-based enterprises</td>
<td>62</td>
<td>38</td>
</tr>
<tr>
<td>Living space</td>
<td>28</td>
<td>41</td>
</tr>
<tr>
<td>Storage</td>
<td>10</td>
<td>21</td>
</tr>
</tbody>
</table>

FIGURE 30 - Percentage of Expansion Types in the Settlements Igarape Manaus and Gilberto Mestrinho

<table>
<thead>
<tr>
<th>Material</th>
<th>Parque Igarapé Manaus</th>
<th>Parque G. Mestrinho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement blocks</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Bricks</td>
<td>37</td>
<td>27</td>
</tr>
<tr>
<td>Corrugated metal</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Metal bars</td>
<td>59</td>
<td>49</td>
</tr>
<tr>
<td>None</td>
<td>0</td>
<td>22</td>
</tr>
</tbody>
</table>

FIGURE 31 - Wall Materials Used in Extension Construction, in Percentage

Extension Materials
Most of the HB1 transformations followed the same selection of materials used to construct the buildings. This created some difficulties for recognizing some of the transformations in the houses, such was the degree of formality, so we had to resort to the original plans numerous times to survey the extensions. On the contrary, the extensions in the HB2 often resorted to cheaper materials or were extended without permanently closing the space, as can be seen in the 22 percent of additions without walls—which we ended up classifying as extensions, because residents paved the ground, conquered space by placing their personal items in it, or added metal or plastic covers. In any case, the major conclusion that can be drawn by observing figure 31 and the other tables below is that there is a clear difference of formality in the materials nominated to extend the houses in both typologies.

The HB1 presents a far more formal arrangement and superior finish as opposed to the HB2. Even though it is risky to establish a direct link between the design of the houses and the behavior of
residents, we dare to say that the preference for cheaper materials and unpretentiousness in the HB2 has mostly to do with an understanding that the houses where they live were specifically designed to abolish transformations, which means that residents who do choose to extend their houses tend to do so using a more ephemeral approach, perhaps anticipating that sooner or later someone will remove them, or, as a preventive measure, by not making it clear that they can be classified as extensions of the house (figures 32 and 33).

These differences between materials also affect market perceptions of house values. Some households come out valued higher, but others were devalued due to the cheap materials and low-cost extensions. Even if both occupy the same area with extensions, materials play a very important role in perception not only in terms of value but also of status.

<table>
<thead>
<tr>
<th>Material</th>
<th>Parque Igarapé Manaus</th>
<th>Parque G. Mestrinho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrugated metal</td>
<td>71</td>
<td>15</td>
</tr>
<tr>
<td>Plastic</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Fabric</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Roof tiles</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>None</td>
<td>12</td>
<td>59</td>
</tr>
</tbody>
</table>

FIGURE 32 - Roof Materials Used in Extension Construction, in Percentage

<table>
<thead>
<tr>
<th>Material</th>
<th>Parque Igarapé Manaus</th>
<th>Parque G. Mestrinho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Concrete</td>
<td>68</td>
<td>86</td>
</tr>
<tr>
<td>Ceramic</td>
<td>29</td>
<td>13</td>
</tr>
</tbody>
</table>

FIGURE 33 - Floor Materials Used in Extension Construction, in Percentage

<table>
<thead>
<tr>
<th>Measure</th>
<th>Parque Manaus</th>
<th>Parque G. Mestrinho</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBE range</td>
<td>3-25</td>
<td>0-6</td>
</tr>
<tr>
<td>HBE average</td>
<td>14 square meters</td>
<td>3 square meters</td>
</tr>
<tr>
<td>Living space range</td>
<td>5-25</td>
<td>3-15</td>
</tr>
<tr>
<td>Living space average</td>
<td>15 square meters</td>
<td>9 square meters</td>
</tr>
<tr>
<td>Storage range</td>
<td>3-16</td>
<td>0-4</td>
</tr>
<tr>
<td>Storage average</td>
<td>9.5 square meters</td>
<td>2 square meters</td>
</tr>
</tbody>
</table>

FIGURE 34 - Size of Extension, Range, and Average

Increase in size and value by transformation

Another aspect of user-initiated transformations in the built environment is that they also express the personality and socioeconomic status of each resident. Indications lead us to consider that the house represents the image of the owner himself or herself, and therefore it also constitutes a classification of status and social values. It is important for social groups that inhabit a particular place to build reference values and sociocultural meanings around their households. The house represents to its occupants a conception of social status, which is supposed to make them different while approaching their near social environment. Through the construction and transformation of their houses, residents show their competence to climb the ladder of socioeconomic growth, which has an impact on their neighborly relations, their contacts, and their reassurance about personal and social identities. The
home is an expression and symbol of personal and social identity, of the realization of their desires and their projects, while it is also concerned with the protection of the bodily self.

In the last five years, the housing market has shown progressive growth in Manaus. With the rise of the construction industry and competition in areas for the deployment of new residential developments, the market value of land in the capital has risen. A significant change has been in the price per square meter in Manaus, which is valued among the most expensive in the country (Oliveira 2012).

This ultimately makes the residents even more engaged with transformations in the house, because now is not only utilitarian issues that lead residents to expand their homes; there is a second variable, in that each square meter conquered from the public space happens to be a commercial valorization of the house itself.

Looking at figure 34, there is an obvious disparity between the expanded areas of the two typologies. In large part, the difference in sizes of the expansions ends up being legitimated by the physical form of both HBs. The HB1 provides more opportunities for growth, which end up inadvertently inviting users to take possession of the balconies and spaces that can be found under the cantilevers to create additional space in their houses. The HB2 also has balconies and communal space, but it would be impossible to close that space since it would interfere with the access to personal space and also access to the neighbors’ houses. In the HB2, most of the storage spaces were highly informal, where the owners would make a fence of cardboard boxes or fabric in order to close that space. Similarly, in most HBEs in the HB2, it was impossible to increment the ground floors as in the HB1, where users could go up to 25 square meters closed with bricks, metal bars, and fiber cement roofing. In the HB2, users had to give up their living rooms to have microbusinesses. Users also appropriated the exterior spaces by covering the space with a textile roofs.

DISCUSSION
Typically, resettlement and social housing projects are conceived based on cost/benefit studies, often excluding the assessment of indirect social costs. These costs are frequently neglected, but they have a substantial relevance, particularly if the house is intended for more than merely providing shelter. Assuming that there is also an urgent need to improve the social condition of the inhabitants, such a study may be far more significant than a simple cost/benefit analysis. Our investigation has shown that a better understanding of the value given to design elements and a detailed study of the inhabitant’s desires can point out opportunities for the introduction of policy improvements while reducing the cost per dwelling unit. Therefore, we recommend a constructive approach to encouraging and supporting transformations in the built environment. A division of responsibility for the construction and development of the dwellings between the government and residents, and an approach that allows for gradual investments in improvements to the house, are important steps that include the occupants in the conception of their own spaces and avoid unjustified investment from the government. A structured and transparent decisionmaking process is needed in social housing programs to provide a link between design criteria and user desires, giving voice to end users and avoid inadequate solutions (Kowaltowski and Granja 2011).

Based on the research work presented in the preceding chapters, we conclude with a set of strategies that should be taken into account when drafting the already approved third phase of the PROSAMIM resettlement effort. We offer strategies with application in two major sectors: policy, and the built environment.
POLICY FOR INCREMENTS
Along the various interviews we undertook with officials of PROSAMIM, we realized that there is no policy to address the changes that have occurred in the buildings delivered, nor take into account future changes. It is clear that the program and the local government do not support the practice of an incremental policy and that their approach has a strong resistance to change. Soon, we confirmed this position in our first meeting, where we were told that there were no changes to any of the housing blocks. However, even before embarking on any survey, we could easily detect that this did not match reality. Regardless of this opposition, changes occurred in fact, and in such magnitude that the government was forced to silently consent. It was impossible to monitor all the dwellings, or to proceed with all the heavy bureaucracy involved in demolishing the illegal extensions, and officials did not want to cause general dissatisfaction among residents. Thus the program opted to overlook the changes in the first typologies built, and to build housing blocks with a far more rigid structure and with fewer opportunities to "increment" in the second phase of the program. This was an incorrect approach, according to our analysis, because it not only failed to inhibit the transformations but also resulted in several extensions with an informal character, causing a condition that they were indeed trying to avoid. Consequently, our proposal begins precisely by appealing to a policy that considers the genesis of the residents.

Legal Condition
The first step should be to improve the legal condition of the extensions and transformations to the HUs. Essentially, the illegal status of the increments to the house makes it unmanageable for the government or program to monitor and support the changes. Without clear legal guidance regarding what is allowed and what is not, the residents will never be encouraged to report their upgrades to the built environment. Especially if residents feel that the changes made are at permanent risk of being demolished or are not legally recognized, this makes it harder to expect them to invest in good-quality and lasting transformations. Consequently, extensions may result in informal structures, as seen in the HB2 example.

Financial Sustenance
The units from PROSAMIM were offered for free, and this ends up influencing the behavior of the occupants toward their houses. They are not only highly unsustainable as investments but also result in permanent dependence on the government, since residents never really feel like home-owners. They revealed that they are unable to take initiative and carry out maintenance to their houses because they feel it should be a program duty. This can be avoided with an approach in which residents become legally responsible for the completion and expansion of their homes, stimulating a sense of identity and ownership among them while sharing the cost per unit built. This additional cost can be further supported through various types of public-private solutions. Our study clearly indicates that families are perfectly able to increase the value of their residences through personal investment; nevertheless, in situations of a lack of personal currency, alternatives can be generated. Solutions like housing subsidy programs and microloans have been used successfully for similar projects (Ferguson and Smets 2009). The poorer population normally has difficulty getting formal housing finance support, but through a coalition between the government, banks, resident associations, and tenants an agreement can be established to support incremental house improvement. By means of microloans for house extensions, the upgrading of the houses can be done in a faster and more permanent way than through residents’ own investment.
Also, the integration of HBEs is an additional aspect that should be taken into consideration as a solution. The HBEs were excluded from the built environment planning (PEPAC 2007) of the previous phases of the program, which has not prevented residents from setting up their micro-businesses, but there is no reason for the absence of legal status as a part of the housing program. The HBE is a main trigger for upgrading social conditions, and thus an excellent resource to generate income and foster sustained finance. Therefore, it is essential to facilitate the establishment of a diverse microeconomy and encourage economic activities. Local entrepreneurship should have more economic viability and operate formally.

**Sense of Ownership**

Finally, implementing this new policy results in an enhanced sense of ownership and gratification. It strengthens occupants' sense of belonging, and they feel that the changes made are secure, a consequence of their own effort and investment. This ultimately results in improvements to the spatial quality of the built environment and will lead to healthier living conditions for all residents (De Soto 2003).

**The Built Environment: A Design to Enable Increments and Anticipate Transformation**

A housing design is so contingent on other factors that it is not possible to provide a single solution but rather a set of guidelines that can drive the elaboration of a residential block. The design role in terms of adaptability should be more of a facilitator as opposed to determiner. The starting point for the habitation unit process should consist of defining a base unit to provide what homeowners cannot do for themselves—that is, the building frame, sewerage, electricity, and the like. The next step is to then establish an approach to simplify what residents can in fact do on their own. A possible solution may perhaps comprise a single multiuse room with a vertical distributed sanitary core plus electricity connections, coupled with one or more adjacent spaces providing solutions for the increment of housing space. To increase housing density, three or six units could be coupled to a main frame serviced with staircases and balconies to generate housing blocks. Such an approach would allow future homeowners to finish their house at their will, pursuing their own possibilities while reducing the cost per unit and allowing the government to increase the number of units built. The design of HB1 is a good example of how one can design a building with a degree of flexibility for change. These blocks, even if unintentionally, had a number of voids on their structures that could be understood as hints for an incremental process. The truth is that the extensions we observed never exceeded the perimeter of these voids, which leads us to conclude that these areas are not only important because they invite residents to expand, but also they allowed setting subliminal limits to the transformations. An important aspect is then the integration of such voids in the design of an HB—a space that is suggestive of how it may be changed and tailored to multiple uses. Per unit and with the areas equally dispersed, the design should intentionally provide spaces for appropriation, without determining their exact use or configuration. Thus, this would create visual clues in the building form of how expansion over time can be accomplished. Both HB1 and HB2 have load-bearing walls, which leaves little room for flexibility beyond the annexed areas. Also, the use of non-load-bearing exterior and internal partitions might facilitate the alteration of the original design to other possible layouts from which future tenants could choose. Last, the foundations should also anticipate an increased load from the expansions.

**The Support System for Transformations**

A housing support system should be created in order to assist with the transformations of the houses. A support system is a physical space with the tools and equipment needed to support the implementation of the transformations. Such system would be responsible for giving the permission to build, offering advice with design and structural problems, assisting throughout the process of...
construction, and guiding the method of sponsoring. The aim would be to ensure that changes are made with a formal character and with the best quality possible. Consequently, quality will attract more economic opportunities to the area and will lead to higher densities. This space should be created not only to facilitate the implementation of transformations but also to ensure that homeowners can learn and acquire both personal and professional skills. The space should be supervised by trained professionals capable of supporting and teaching construction techniques. The system ultimately benefits both the government and the residents, since it ensures that buildings are well monitored and executed while teaching new skills to the inhabitants. This generates education and job creation, two important social dimensions that need to be integrated into the social structure of the residents of the housing. This technical support should focus on finding the right methods to build the house extensions at affordable prices, with easy maintenance, sustainability, and local employment opportunities. Such support aims to contribute to a better infrastructure that will not only enhance the economic value of the area but also help to close the gap between the poor and the middle class. The support system should not only promote the use of good-quality building technology that is suitable for the local context, but also facilitate the transfer of available, more traditional knowledge on house construction to individual families, mutual building groups, and local communities. Finally, it also may help to change the public's perception of the resettlement housing areas.

CONCLUSION

There are three questions that we wanted to answer that make this research paper unique. First, we aimed to understand the resistance against an incremental approach in the built environment. Why should a user be hindered from taking control of his or her space and identity? Second, what were the benefits of a new design conceived precisely to prevent the first signs of expansion in the first units of the program? And third, where can we find a consensus between government objectives and the beneficiaries of the houses? If this understanding can be achieved within a flexible approach that considers the identity of residents, the role of those affected most heavily in the project is emphasized.

From the interviews and conversations we had with the different stakeholders, the conclusion that can be drawn is that the instinctive opposition of any kind of flexibility or expansion of the houses has to do with the concern that it might lower the standards that they have set for the housing projects and that ultimately they could be backing the erection of a new slum. However, we feel that the flaw starts in the delineation of these same preset standards. The fact is that this definition of what is standard in social projects ultimately results in dwelling units designed with the minimal acceptable conditions. It could even be argued that this specific project was above that minimum, yet the inability to improve or expand their future houses lead the owners to a perpetual condition of resettled from the palafitas. The development of monotonous standard housing blocks repeated adjacent to each other differs from the diversity we are supposed to appreciate in cities, leading to preconceptions and visual segregation against the so-called residential areas. It was easy to anticipate what would happen in these areas and that the new residents of these units would feel the need to expand and readapt the granted houses, especially if we take into account that Manaus is a city with a large and rapidly growing low-income population and with an accelerated birthrate. These could be considered the main triggers for the house expansions: the absolute need to improve the financial situation of its inhabitants and family planning, in which the house and its flexibility have the important role of encouraging entrepreneurship—plus, in a city like Manaus it is critical to project the number of houses needed, anticipating that the number of inhabitants per household will necessarily be changing, especially when they cannot afford to seek other alternatives. And so it does not seem surprising that in such a short time of existence, there are already so many clandestine
expansions being made to the houses. Neither is it surprising to see houses overcrowded with people, either because the family has grown or they rented one of their rooms for subsistence.

This research demonstrates that none of the inhabitants of these areas enjoys living in informal lodgings, and that the former dwellings were only informal due to a lack of practical and financial conditions. In fact, the ability to build formally was unequivocally confirmed through our research; in many of the extensions we analyzed, it was nearly impossible to distinguish between the original building and the extensions, which looked like they were part of the original design itself—such were the construction precision and the quality of materials selected. Given the facts that we observed, we believe that a fairer model should allow the residents to be able to deliberate and develop their own space according to their resources and will, and that the government’s role should be to guide, support, and establish the rules of how it could be done. Providing many different ways of accomplishing the same end, this abolishes the latent lack of identity of the allocated houses and promotes better integration within the city—especially when considering the prime location of the residential areas. And it is here that we seek to intervene, in defining a framework that helps policymakers to establish a support system for a different and more flexible approach. Because we consider that every problem has more than one solution, and that one beginning could have a number of ends.

REFERENCES


PEPAC. 2007. Plano de participação comunitária PROSAMIM. Manaus: PROSAMIM.


TRANSFORMATIONS: design parameters and prototypes from Manaus joint research

**FORM:**
- 3-STORY VERTICAL STACK
- ROTATION / SHIFT
- INFILL
- VERTICAL EXPANSION

**PLAN:**
- 20 sqm
- 60 sqm
- TOILET
- SHOWER
- KITCHEN
- LAUNDRY
- BEDROOMS
- DINING
- SOCIAL
- EXPANSION SPACE

**WHAT SHOULD THE SIZE BE?**
Determine for your context the minimum maximum size appropriate per family / unit.

**WHAT IS ESSENTIAL?**
What elements of the plan need to be there from day 1 of occupancy and what can be left for expansion?

**WHAT SUPPORT IS ESSENTIAL?**
Vertical and horizontal circulation, locate stairs, access, utilities, daylighting and national ventilation.

**SUPPORTING GROWTH?**
How can you support incremental growth? Contractor consulting, material subsidy, training.

**STRUCTURE:**
- INFILL
- INFILL
- INFILL

**STRUCTURAL TYPE?**
Load bearing wall vs independent structure with infill panels. Both offer strategies at limiting and enhancing extension.

**HOW TO REDUCE COST?**
By utilizing an independent structure there is an opportunity to remove non-structural elements and accept user materials.

**POTENTIAL FOR HYBRID?**
By cross breeding two or more types of structure you can better articulate responses over time.

**INCOME GENERATION:**
- CORE
- S FOR RENT S
- S COMMERCIAL S

**HORIZONTAL EXPANSION**
Often the first additions are rental units and provide income for families to support future growth.

**HORIZONTAL EXPANSION**
Expansion space often becomes a commercial space for the family to offer local goods and create income.

**LAND VALUE / SCARCITY:**
- 3 LEVEL
- MULTI-FAMILY
- SINGLE LEVEL
- SINGLE FAMILY

**HOW CAN WE AFFORD CENTER CITY LAND?**
By aggregating in multi-story you can reduce the amount of land needed to achieve the same densities.

**UTILITIES:**
- IS UTILIT CAN PLANNING IMPORTANT?
- MULTI-STORY VENTILATION

**FIGURE 35 - Parameters for Design**
Prototypes

3 FAMILY MULTI-STORY HOUSING - **80% GOVERNMENT COST / 20% USER COST**

**EXT.FINISH**
- Stair railings, exterior elements such as roofing, safety, code compliance, safety and performance
- 10% of total cost

**INT.FINISH**
- Interior finish elements such as fire rated, structural, electrical, plumbing, heating, ventilation, etc.
- 5% of total cost

**FOUNDATION**
- Depth reduction based on loading conditions of the ground or underlying structure
- 15% of total cost

**SERVICE CORE**
- Consolidated area for essential services (plumbing, electrical, natural ventilation, etc.)
- 20% of total cost

**HYBRID STRUCTURE**
- 35% of total cost

**INFILL WALLS**
- 15% of total cost

**FIGURE 36** - Parameters for Design applied to prototype

**FIGURE 37** - Prototype unincrement (left) Prototype after incremental addition by users (right)

**END CO-AUTHORED RESEARCH**
this is the future of low-income housing!
Eu não quero o seu futuro, eu gosto confuso!
isometric low-income housing development

**Elevator Core**: Sized to fit two passenger elevators and one freight elevator.

**FAR 9.3**: Built floor area is 9.3 times the parcel size consistent with high density urban development zoning.

**Facade Design**: Openings sized at 1/3 ratio to unit exterior.

**Retail Plinth**: Revenue generation for the development as well as clearly defined "public zone" accessible by pedestrian and auto traffic.

**60% Highest Minimum Percentage of Dedicated Low Income Units Required for Municipal Low Income Subsidy**

**20% Lowest Percentage of Dedicated Low Income Units Required for Municipal Low Income Subsidy**

**5,000 sqm as well as clearly defined "public zone" accessible by pedestrian and auto traffic**

**44**
plan low-income housing floors

fire stair / emergency egress 4 m x 10 m
distributed exactly 50 m from central core the maximum allowable egress distance

82% NSA ratio
net internal saleable / leaseable area
excludes lift wells, stairs, lobbys, etc

section aa

68 m (223 ft)
2.9 m (42.3 ft)
5th facade: The topography of the units creates an opportunity for interacting with the 5th facade visually and physically, increasing social connection.

Vertical yard: 2nd and 3rd floor units share rooftop connections allowing for light and air access as well as social mixing space.

Pinch point: Pinch points in the circulation allow control of entry without the need for a physical barrier.

Community eye: Terraced shifting of units allows neighbors to maintain visual connection the street while in their home.

Sell it on the street: Exterior units on the public facing sides squeeze together to create a barrier as well as the feel of a "main street".

Section aa
plan diagram favela Sao Paulo

section bb

favela grammar

bar

square

section bb
centralized infrastructure

municipal water storage tower
300,000 gallons

municipal water treatment plant

municipal trash service

municipal mixed waste consumer landfill

municipal energy grid

municipal power plant
decentralized infrastructure

- Privatized water service
- Individual water reservoirs
- Trash picker
- Non-recyclable environmental contamination
- Sorted recyclables for resale
- Illegal connections to municipal grid
- Municipal power plant
50 FAMILY PROTOTYPICAL NEIGHBORHOOD ANALYSIS

- 60 ft³ non-recyclable
- 30 ft³ recyclable
- 70 gallons urine
- 11 gallons fecal
- 4 gallons fecal
- 47.5 sqm (10m x 5m x 2.5m)
- 10,000 gallons (3.5m dia x 4m height)
- 9,450 gallons (3.5m dia x 4m height)
- 1,500 kW generator (2m x 6m x 2.5m)
**INPUTS: electricity**

<table>
<thead>
<tr>
<th>Daily per person usage</th>
<th>Daily per family usage</th>
<th>Per family audit</th>
<th>Per 750 family audit</th>
</tr>
</thead>
<tbody>
<tr>
<td>clock radio: .01 kW X 24 hours = 0.24 kWh</td>
<td>portable fan: 0.15 kW X 4 hours = 0.60 kW</td>
<td>daily 25 kWh ($42.20)</td>
<td>daily 1251.8 kWh ($212.50)</td>
</tr>
<tr>
<td>bar dryer: .12 kW X 24 hours = 2.88 kWh</td>
<td>coffee maker: 0.9 kW X 5.0 hours = 4.5 kWh</td>
<td>monthly 762 kWh ($193.54)</td>
<td>monthly 30,100 kWh ($616.05)</td>
</tr>
<tr>
<td>clothes iron: .12 kW X 10 hours = 1.2 kWh</td>
<td>clothes washer: .36 kW X 10 hours = 3.6 kWh</td>
<td>yearly 9144 kWh ($1,564.46)</td>
<td>yearly 457200 kWh ($85,160.05)</td>
</tr>
<tr>
<td>personal laptop: .05 kW X 12 hours = 0.6 kWh</td>
<td>refrigerator: .725 kW X 16 hours = 12 kWh</td>
<td>per family audit</td>
<td>per 50 family audit</td>
</tr>
<tr>
<td>cell phone charger: .004 kW X 9 hours = 0.036 kWh</td>
<td>television (flat screen): 0.12 kW X 4.0 hours = 0.48 kWh</td>
<td>daily</td>
<td>daily</td>
</tr>
<tr>
<td>game system: .06 kW X 3.0 hours = 0.18 kWh</td>
<td>vacuum cleaner: 0.12 kW X 10 hours = 1.2 kWh</td>
<td>yearly</td>
<td>yearly</td>
</tr>
</tbody>
</table>

**INPUTS: water**

<table>
<thead>
<tr>
<th>Daily per adult usage</th>
<th>Daily per child usage</th>
<th>Per family audit</th>
<th>Per 750 family audit</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 minute shower: 30 gal</td>
<td>hands / face: 2 gal</td>
<td>daily 202 gal ($2.29)</td>
<td>daily 10,080 gal ($160.90)</td>
</tr>
<tr>
<td>hands / face: 2 gal</td>
<td>face / leg shaving: 1 gal</td>
<td>monthly 2,424 gal ($24.24)</td>
<td>monthly 121,080 gal ($3,602.50)</td>
</tr>
<tr>
<td>toilet (2 flushes): 3.2 gal</td>
<td>toilet (2 flushes): 3.2 gal</td>
<td>yearly 73,657 gal ($756.57)</td>
<td>yearly 1,180,200 gal ($51,910.50)</td>
</tr>
<tr>
<td>drinking water (daily): 0.5 gal</td>
<td>drinking water: 0.5 gal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INPUTS: groceries**

<table>
<thead>
<tr>
<th>Per family grocery expenditures</th>
<th>Per 750 family grocery expenditures</th>
<th>Grocery sizing per sqm (sqft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily $7.40</td>
<td>Daily $5,550.00</td>
<td>Per family 1 sqm (10 sqft)</td>
</tr>
<tr>
<td>Monthly $221.74</td>
<td>Monthly $160,312.50</td>
<td>Per 50 families 475 sqm (162 sqft)</td>
</tr>
<tr>
<td>Yearly $1,133,043.00</td>
<td>Yearly $1,055,645.00</td>
<td>Per 750 families 713 sqm (776 sqft)</td>
</tr>
</tbody>
</table>

**Outputs**

**Grey water:**

<table>
<thead>
<tr>
<th>Daily</th>
<th>Per 50 families</th>
<th>Per 750 families</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily 189 gal</td>
<td>Daily 8,650 gal</td>
<td>Daily 1,417.50 gal</td>
</tr>
<tr>
<td>Monthly 5,708.5 gal</td>
<td>Monthly 287,424.5 gal</td>
<td>Monthly 4,313,269.8 gal</td>
</tr>
<tr>
<td>Yearly 68,981.9 gal</td>
<td>Yearly 3,449,095.1 gal</td>
<td>Yearly 51,736,426.8 gal</td>
</tr>
</tbody>
</table>

**Solid bio waste:**

<table>
<thead>
<tr>
<th>Daily</th>
<th>Per 50 families</th>
<th>Per 750 families</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily 58 lb</td>
<td>Daily 29 lb</td>
<td>Daily 425 lb</td>
</tr>
<tr>
<td>Monthly 1,758 lb</td>
<td>Monthly 807 lb</td>
<td>Monthly 13,050 lb</td>
</tr>
<tr>
<td>Yearly 2117 lb</td>
<td>Yearly 10,585 lb</td>
<td>Yearly 158,775 lb</td>
</tr>
</tbody>
</table>

**Black water:**

<table>
<thead>
<tr>
<th>Daily</th>
<th>Per 50 families</th>
<th>Per 750 families</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily 12.8 gal</td>
<td>Daily 640 gal</td>
<td>Daily 9,600 gal</td>
</tr>
<tr>
<td>Monthly 389.5 gal</td>
<td>Monthly 19,478.6 gal</td>
<td>Monthly 292,193.6 gal</td>
</tr>
<tr>
<td>Yearly 4,675.1 gal</td>
<td>Yearly 239,754.9 gal</td>
<td>Yearly 3,506,329.3 gal</td>
</tr>
</tbody>
</table>

**Post consumer municipal waste:**

<table>
<thead>
<tr>
<th>Daily waste production</th>
<th>Daily recyclables sorted (50 families)</th>
<th>Mass of residential solid waste daily</th>
<th>Yearly economics of waste recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 kg (6.5 lbs) per family</td>
<td>organic matter: 20.7 kg (45.5 lbs)</td>
<td>per family non-recyclable: 0.0 m³(3.9 ft³)</td>
<td>value of recyclables per family: $150.00 (R$250.00)</td>
</tr>
<tr>
<td>per 50 families</td>
<td>paper and cardboard: 9.0 kg (19.9 lbs)</td>
<td>per family recyclable: 0.3 m³(10.6 ft³)</td>
<td>value of recyclables (55)</td>
</tr>
<tr>
<td>per 750 families</td>
<td>plastics: 6.7 kg (14.8 lbs)</td>
<td>50 families non-recyclable: 1.6 m³(57.6 ft³)</td>
<td>value of recyclables (750)</td>
</tr>
<tr>
<td>2,220.0 kg (4,894.2 lbs)</td>
<td>metals: 1.8 kg (4.0 lbs)</td>
<td>50 families recyclable: 2.6 m³(90.7 ft³)</td>
<td>jobs at national minimum salary R$622</td>
</tr>
<tr>
<td>daily recyclable waste production</td>
<td>garbage: 5.9 kg (12.9 lbs)</td>
<td>750 families non-recyclable: 24.6 m³(866.3 ft³)</td>
<td></td>
</tr>
<tr>
<td>per family</td>
<td>rejected mix: 5.8 kg (12.9 lbs)</td>
<td>750 families recyclable: 12.6 m³(440.5 ft³)</td>
<td></td>
</tr>
<tr>
<td>per 50 families</td>
<td>(8.9 lbs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>per 750 families</td>
<td>(18.0 lbs)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: waste management BRAZIL 2013*
Infrastructural systems will be discretized by 150 family neighborhood. The potential for each neighborhood to be autonomous from city infrastructure, become net positive producers of energy, produce jobs as well as to significantly reduce water consumption are illustrated in the tables on page 52.
**Inputs:**

**Electricity:** per borough generation

<table>
<thead>
<tr>
<th></th>
<th>Daily</th>
<th>Monthly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>3755.4 kwh</td>
<td>114,226.75 kwh</td>
<td>1,370,721 kwh</td>
</tr>
<tr>
<td>Monthly</td>
<td></td>
<td>(3638.40)</td>
<td>(319,418.00)</td>
</tr>
<tr>
<td>Yearly</td>
<td></td>
<td>(233,816.00)</td>
<td>(233,816.00)</td>
</tr>
</tbody>
</table>

**Water:** per borough use

<table>
<thead>
<tr>
<th></th>
<th>Daily</th>
<th>Monthly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>30,270 gal</td>
<td>920,712 gal</td>
<td>11,048,550 gal</td>
</tr>
<tr>
<td>Monthly</td>
<td></td>
<td>(302.7)</td>
<td>(3632.4)</td>
</tr>
<tr>
<td>Yearly</td>
<td></td>
<td>(1,048.55)</td>
<td>(1,048.55)</td>
</tr>
</tbody>
</table>

**Groceries:** per borough grocery expenditure

<table>
<thead>
<tr>
<th></th>
<th>Daily</th>
<th>Monthly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>$1,110.00</td>
<td>$33,762.50</td>
<td>$405,150.00</td>
</tr>
<tr>
<td>Monthly</td>
<td></td>
<td>$33,762.50</td>
<td>$405,150.00</td>
</tr>
<tr>
<td>Yearly</td>
<td></td>
<td>(1,536 sqft)</td>
<td>(1,536 sqft)</td>
</tr>
<tr>
<td>Grocery sizing</td>
<td>142.5 sqm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Thermal Biomass Converter - 750 Families**

- Organic clean waste: 477.7 kg (1053.1 lbs)
- Solid waste (fecal): 199.4 kg (439.5 lbs)
- Solid waste (urine): 201.3 kg (443.8 lbs)
- Paper and cardboard: 134.7 kg (297.0 lbs)
- 1,013.1 kg (2233.5 lbs) 3,350 kwh

An important consideration with biomass energy systems is that unprocessed biomass contains less energy per pound than fossil fuels—it has less "energy density." This means that unprocessed biomass typically can’t be cost-effectively shipped more than about 50-100 miles by truck before it is converted into fuel or energy.

It also means that biomass energy systems may be smaller scale and more distributed than their fossil fuel counterparts, because it is hard to sustainably gather and process more than a certain amount of in one place. This has the advantage that local communities will be able to design energy systems that are self-sufficient, sustainable, and adapted to their own needs.

*US Green Energy Council 2012*

*1 lb of biomass = 6,000 btu/lb*

*50% efficiency in thermal conversion = 1 lb = 1.5 kwh*
The vertical village is conceived as an armature that allows for incremental growth while protecting light, safety, and access to physical and social infrastructure in a high density environment. The infrastructurally autonomous tower is a net positive producer of energy and food as well as integrated with bands of retail, community and food production program.

The tower is subdivided into five neighborhoods of one hundred and fifty families as a mechanism to create social relationships within the village at various scales. The individual facades are intended to be incremented over time to reflect the identity and desire of the users. The floor slab has also been broken and stepped in elevation to reduce the monotony of the "pancake" slab, increase personal identity and to allow for ramped circulation.

Integrated retail space is to serve as a supportive infrastructure for home based entrepreneurship as well as to bring amenities such as child care, markets, etc to the users of the building.

Integrated community gathering space allows for each neighborhood to differentiate its character based on community program desires. It is imagined that the community space can serve a variety of functions including workshop and training space, religious and gathering space and recreational space.

**INTERNAL RETAIL SPACE**
4200 m\(^2\) / 45000 ft\(^2\) - total
1.4 m\(^2\) / 15 ft\(^2\) - per person

**INTERNAL COMMUNITY SPACE**
3600 m\(^2\) / 38000 ft\(^2\) - total
1.2 m\(^2\) / 12 ft\(^2\) - per person

**INTEGRATED FOOD PRODUCTION**
1100 m\(^2\) / 12000 ft\(^2\) - total
.4 m\(^2\) / 4 ft\(^2\) - per person

**WATER / SEWER / CONSUMER WASTE / ENERGY INFRASTRUCTURE**
2400 m\(^2\) / 25000 ft\(^2\) - total
.8 m\(^2\) / 8 ft\(^2\) - per person
INCREMENTALLY UPGRADEABILITY
All facades in the tower are non-structural infill allowing for reconfiguration based on user desires. This allows for flexibility of use, upgrading at the pace of the user and individual expression on the facades.

BUILDING INTEGRATED FOOD PRODUCTION
Subsistence and community gardening is no longer a viable alternative to offset global food and resource shortages and increasingly contaminated global environments. Residential aeroponics is capable of maximizing crop yield 45 to 75% while requiring 98% less water, 60% less fertilizer, 6 to 12 times the growing cycles per year and all while eliminating the need for pesticides completely.
FIGURE 38 - Typical Plan Shown with Maximum Density
FIGURE 41 - Rendered View of the Interior Courtyard and CityFARM

Model Views Inside of Courtyard (left) and Inside of Infrastructural Core (right)
Model Views of one grouping of 50 homes (left) and the complete tower color coding each neighborhood

Model Views of one grouping of 150 homes (left) and the inside of one community space in relation to the cores
Research Bibliography


Illustration Credits

Figure 1 - Sao Paulo Brazil 2012
Source: http://alizardwandering.files.wordpress.com/2012/10/20121016-1528381.jpg

Figure 2 - Sao Paulo 2012
Source: http://2.bp.blogspot.com/-k-6Wr1b1oQ/TclcqNWodRI/AAAAAAAALI/wY---L4ciH/s1600/SP%2Bfrom%2BSkyScraper%2BCity%2BLiving%2Bbin%2BBrazil.jpg

Figure 3 - Vertical Village Concept Collage
Source: Created by Caleb Harper

FIGURE 4 - CIA World Factbook 2009 - 4.1 GINI Coefficient (top left), 4.2 Population Below Poverty Line (top right) 4.3 Urban Population Densities (bottom left), 4.4 Population Using Improved Sanitation (bottom right)
Source: https://www.cia.gov/library/publications/the-world-factbook/

FIGURE 5 - Convergence of Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4
Source: Created by Caleb Harper

FIGURE 6 - Past, Present and Future - A study in brazilian national demographics
Source: Created by Caleb Harper

FIGURE 7 - Minha Casa Minha Vida / Prosamim BRAZILLIAN PUBLIC HOUSING CAMPAIGN - 2009 to PRESENT
Source: Created by Caleb Harper

FIGURE 8-1954 Pruitt Igoe Complex, St.Louis, MO (right) 1974 Pruitt Igoe Complex, St.Louis, MO (right)
Source: http://upload.wikimedia.org/wikipedia/commons/b/b9/Pruitt-igoeUSGS02.jpg

FIGURE 9-2006 PROSAMIM Complex Manaus,BR (left) 2012 PROSAMIM Complex, Manaus Br (right)
Source:http://2.bp.blogspot.com/_n1I2gMjQJa4/TFiEEp45svl/AAAAAAAFeU/wIPfaP_Rr6I/s1600/,Pros amim%2B-%2Bapartamentos.jpg
Source: Created by Caleb Harper

FIGURE 10-1982, Workers City, Cairo, Egypt (left) 1988 Workers City, Cairo Egypt (right)
Source: Graham Tipple

FIGURE 11- The wall in Koolhaas’s Voluntary Prisoners of Architecture
Source: http://socks-studio.com/img/blog/Exodus7-800x653.jpg

FIGURE 12- Cuts of Beef in Plan (left) Cambridge in Plan (right)
FIGURE 13 - 3D Image of Cow (left) Exploded Axon of Cow (right)
Source: http://static.neatoshop.com/images/product/70/570/Cow-3D-Anatomy-Model-Puzzle_2214.jpg
Source: http://www.hectorsfarmshop.co.uk/shop/diagram.jpg

FIGURE 14 - Villa Los Piletones, Buenos Aires, Argentina
Source: Created by Caleb Harper

FIGURE 15 - Villa Los Piletones, Buenos Aires, Argentina (left) Torree David, Caracas, Venezuela (Right)
Source: Housing Ministry of Buenos Aires

FIGURE 16 - Density study of Villa Los Piletones and Torre David
Source: Created by Caleb Harper

FIGURE 17 - Minimum size of a single family home diagram
Source: Created by Caleb Harper

FIGURE 18 - Metabolic production per activity per hour conversions
Source: Created by Caleb Harper

FIGURE 21 - Relating physical units and BTU's of production of 3,000 people
Source: Created by Caleb Harper

FIGURE 22 - Crude Oil Metrics
Source: Created by Caleb Harper

FIGURE 23 - Metrics of Solid and Liquid Biowaste production of 3000 persons
Source: Created by Caleb Harper

FIGURE 24 - Residential Areas (RA) Built by the PROSAMIM and the Quantity of Housing Units (HU) per RA
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 25 - Housing Units (HUs) Plans from Both Phases of PROSAMIM
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 26 - Habitation Blocks (HBs) from the Two Phases of PROSAMIM.
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 27 - Survey Results for the question, "What is the best feature if the New House?"
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 28 - Survey Results for the question, "What is the worst feature if the New House?"
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 29 - User-Initiated Transformations in the Habitation Blocks (HBs) and Habitation Units (HUs), Total Percentage
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely
FIGURE 30 - Percentage of Expansion Types in the Settlements Igarape Manaus and Gilberto Mestrinho
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 31 - Wall Materials Used in Extension Construction, in Percentage
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 32 - Roof Materials Used in Extension Construction, in Percentage
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 33 - Floor Materials Used in Extension Construction, in Percentage
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 34 - Size of Extension, Range, and Average
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 35 - Parameters for Design
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 36 - Parameters for Design applied to prototype
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely

FIGURE 37 - Prototype unincrement (left) Prototype after incremental addition by users (right)
Source: Created by Caleb Harper, Vasco Portugal and Layla Shaikely