Sustainable architecture and engineering MIHOUSE project

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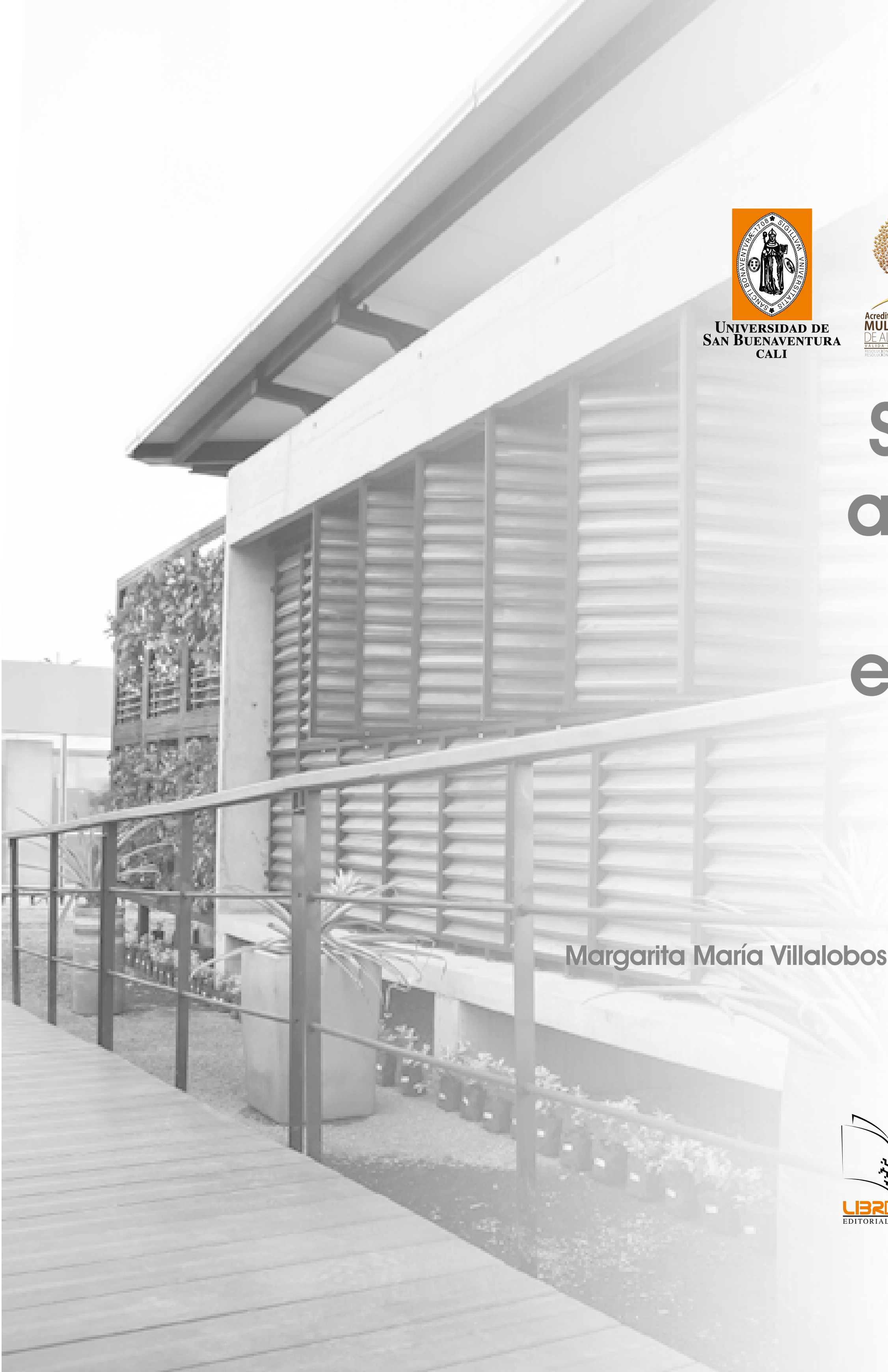

Sustainable architecture and engineering MIHOUSE Project

Margarita María Villalobos Ayala, Constanza Cobo Fray,
Olga Lucía Montoya

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Credits and acknowledgments

The largest solar energy competition in Latin America ended in Cali – Colombia in December 2015. With great joy, the MIHOUSE team wants to express all of its supporters and collaborators the most sincere gratitude for having believed in its academic proposal and for the support provided during this unprecedented event in the continent.

With a group of 40 students and teachers, the MIHOUSE team undertook this project to respond to the call of the Solar Decathlon 2015, which required an arduous work during one year and a half to develop the most efficient social housing solution for tropical countries. This meant long training days for students; an intense teamwork; multiple research and innovation processes; the search for financial support; strengthening the alliance between USB and UAO; and the work of designing, redesigning, calculating the structure, estimating the budget of the project and foreseeing the construction of both the prototype exhibited in the Solar Villa at UNIVALLE and the demanding documents required by the contest. No doubt, this experience was highly significant to all of the people involved in the project and to all of those who promoted with the MIHOUSE team the sustainable development of the country!

The MIHOUSE team wants to thank different schools and departments at USB and UAO that supported the development of the project:

- The Architecture Program at USB, which leaded the project, developed the design strategy and managed MIHOUSES´s research and building processes.
- The Engineering Department at UAO, which provided the electrical, environmental waste and water management solutions.
- The Faculty of Engineering at USB, which helped with industrial and agro industrial solutions and in the preparation of most of the multimedia content used in social networks, website and public releases.

- The Communications Departments, which contributed to the team´s communications project.
- The Research & Technological Development Departments.
- The deans of the Faculties of Engineering and Architecture, Arts & Design for their constant support and encouragement.
- The heads of each of the study programs involved in the project who facilitated the participation of an interdisciplinary group of students and professors.
- The Language Center and Language Institute for their constant support with translations used in every delivery during the SDLAC2015 contest.
- The FabLab at UAO, which facilitated the construction of urban and architectural models.
- The Broadcasting Coordination at USB that helped with the preparation of all audiovisuals.
- Costume Design students who designed the uniforms of MIHOUSE decathletes.
- Arch. Liliana Carvajal for helping with the financial aspects of the project and for her unconditional support.
- Professors José Salazar and Jerfenzon Vidarte for their advice on the project´s economic feasibility.
- Professor Luis Alberto Buitrago for his advice on urban orchards and home gardens.
- Arch. Lucas Arango and his team; Eng. Carlos Castang and his group of students; and Arch. Carlos Giraldo for their contributions with the bioclimatic aspects and calculations.
- Teacher Carlos Ortega for his support with translations.
- The Maestría en Bioclimática at Universidad de San Buenaventura Medellín.

The MIHOUSE team also recognizes the enormous support from its sponsoring companies and hopes that the established relations can continue being fruitful over the next years and in future projects:

It is also important to thank USB and UAO for their valuable efforts that made possible the disassembly of the MIHOUSE prototype constructed at the Solar Villa and its reassembly at USB campus, where it is being turn into a Sustainable Housing Laboratory. In the next years, the MIHOUSE Laboratory will serve as a place for research and experimentation with solar panels, furniture and other innovative technologies related to energy efficiency, indoor air quality, humidity, water management and sustainability. Undoubtedly, this laboratory will be a milestone that will allow the training of architecture and engineering students in future Solar Decathlons.

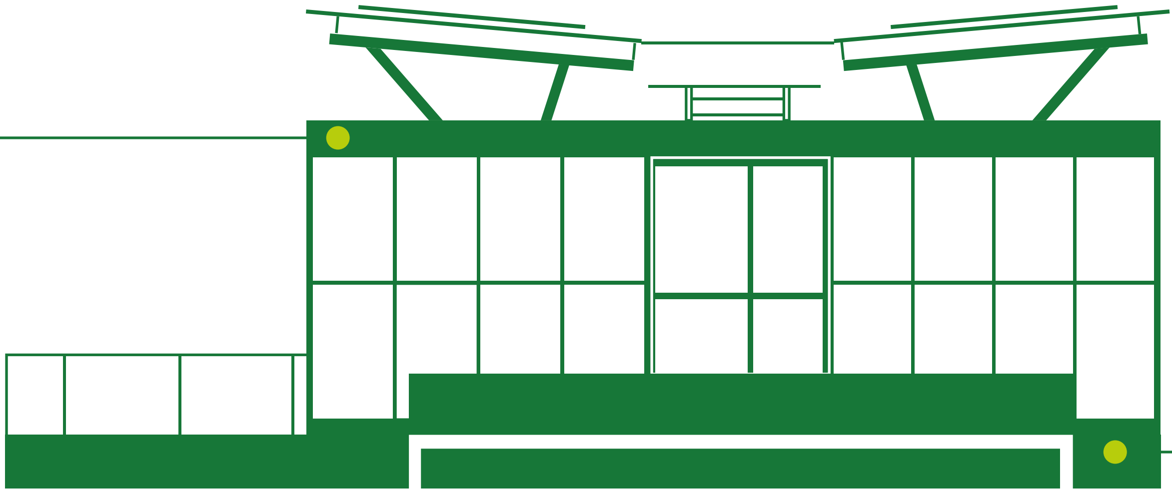
Last but not least, the MIHOUSE team wants to thank the Solar Decathlon organizers for making possible this event, and the people of Cali that kindly selected our housing prototype as the second favorite in the Solar Villa.

Margarita Villalobos

Contest Captain and Communications Coordinator of the MIHOUSE team.


MIHOUSE


MI HOUSE



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List of the MIHOUSE team

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Background

Universidad de San Buenaventura -USB- is a nonprofit organization located in Cali - Colombia. It was founded as a private post-secondary academic institution in 1969. This institution is recognized with a Multi Campus High Quality Accreditation under resolution #10706 from the National Ministry of Education since May 25, 2017. This accreditation ratified the institutional strength that clearly guides the educational processes, objectives and administration of USB´s campuses in Bogotá, Cali, Cartagena and Medellin.

The USB campus in Cali has 260.200 m2 and obtained the "Carbon Neutral Pioneer University" certification in the framework of the Carbon Neutral Organizational Seal created by DAGMA (Departamento Administrativo de Gestión del Medio Ambiente) in Alliance with CVC (Corporación Autónoma Regional del Valle del Cauca), and the support of ICONTEC (Instituto Colombiano de Normas Técnicas y Certificación), GAIA and Más Bosques BanCO2 Group. The Carbon Neutral Organizational Seal is a scheme where organizations in Cali acquire the voluntary commitment for the reduction and compensation of their greenhouse gas emissions, in order to mitigate and reduce the carbon footprint of the products or services derived from their activity. It is also to highlight, that USB is the first university in the Colombian southwestern region with a Technology Park, where students can get practical experience, develop their research, entrepreneurship ideas and start-ups.

USB has six schools: the Faculty of Architecture, Art and Design, the Faculty of Economic Sciences, the Faculty of Law and Political Sciences, the Faculty of Education, the Faculty of Engineering and the Faculty of Psychology. From them, 11 research groups recognized by Colciencias are derived. One of these groups is the Architecture, Urbanism and Esthetics Research Group which has 2 main research streams: one with focus in Architectonic Project with Habitat emphasis, where habitability, comfort and bioclimatic solutions for social housing is researched; and a second research stream with focus in Urban Project, where sustainable planning, residential segregation, urban and regional master plans are designed, researched and consulted. Results from both streams have been successfully presented in institutions such as the Municipal Housing Office, Camacol, Ford Foundation and Gobernación del Valle del Cauca, among others.

Universidad Autonóma de Occidente -UAO- is a nonprofit organization located in Cali - Colombia. It was founded as a private post-secondary academic institution in 1970 and has influence in the southwestern part of the country. This institution is recognized with a High Quality Accreditation under resolution #16740 from the National Ministry of Education since August 24, 2017. It also has an ISO 14001:2004 Environmental Management System.

With 400KWp, UAO currently has the largest photovoltaic system installed in a university campus in Colombia. It also has its own water treatment plant, green areas with organic gardening, recurring campaigns for the rational use of energy and water, and a robust waste management system. All of the above are part of the UAO´s Sustainable Campus Program, which was chosen as the winner in the 3rd Best Management Practices Award given to Colombian universities on behalf of the OCU International Foundation based in Spain. The Sustainable Campus Program also won an award in Environmental Protection from Caracol Television in 2016. It is to highlight that in January 2017, UAO ranked in the position number 154th (worldwide) and 4th (nationally) in the UI Green Metric Word University Ranking.

UAO has five schools: the Faculty of Engineering, the Faculty of Economics and Business Management, the Faculty of Social Communication, the Faculty of Basic Sciences and the Faculty of Humanities. From them, 27 research groups recognized by Colciencias are derived. Two of these groups are: the Energies Research Group (GIEN) that studies the technical and social aspects of micro grids for areas not interconnected to main electrical grids; and the Research Group in Advanced Materials for Micro and Nanotechnology (IMAMNT) that works with electronics applied to the monitoring of electrical variables and their inclusion in the IoT (Internet of Things).

In 2015 students and professors from USB and UAO participated as the MIHOUSE team in the first Solar Decathlon Latin America & the Caribbean 2015. The Solar Decathlon is the most important biannual university contest worldwide and was created in 2002 by the U.S. Department of Energy with the purpose of promoting technical innovation and the wise use of economic and natural resources applied to sustainable housing solutions among university students. The competition has been held biannually (2005, 2007, 2009, 2011, 2013, 2015 and 2017) in the United States, in 2010, 2012 and 2014 in Europe and in 2013 China. Future competitions will be held in the Middle East in 2018 and 2020, in China in 2018, in Europe in 2019, in Africa in 2019 and in Latin America in 2019.

The first version in Latin America took place in Cali Colombia during 2015 and challenged 16 collegiate teams to provide social housing solutions for low-income families living in tropical climate conditions. The winner of the contest was the team whose housing proposal demonstrated an attractive and affordable solution that achieved the highest score after the sum of the scores gathered through the following 10 contests: architecture, engineering and construction, energy efficiency, electric balance, comfort, sustainability, house functioning, marketing and communications, urban design and economic accessibility and innovation.

The MIHOUSE project presented by USB and UAO won the following awards: first place in Sustainability and second place in Architecture, Urban Design and Affordability, Engineering, Innovation and Energy Efficiency. The MIHOUSE prototype was also selected as the second favorite house chosen by the public and now a day's serves as a sustainable laboratory for students and researchers at USB campus. The success of the team and project was the product of a constant and interdisciplinary effort from all decathletes; a clear understanding of the contest rules; an arduous commitment to produce the best sustainable housing prototype for tropical contexts; an enormous effort from all research groups working in innovative solutions applicable to the constructed housing prototype; and an important engagement with sponsoring companies that worked with the MIHOUSE team in creating a better future.

Due to the success of the MIHOUSE project and the tremendous opportunity to participate once again in an international contest as the SDLAC, both universities decided to create a new group called TUHOUSE to participate in the new SDLAC2019. The selection of 16 new teams will be held at the same time this book goes under revision. Therefore, the aim of this book is to provide a pathway to new Solar Decathlon participants and a tool to inspire the new generation towards the design and construction of real sustainable housing solutions for low-income families in tropical contexts.

Chapter 1 provides general information about the location of the MIHOUSE project and its response to a real context in a tropical country. The analysis describes the global, regional, metropolitan and sectorial conditions that influenced the project. Chapter 2 offers a description of MIHOUSE´s urban proposal at "El Paraíso" neighborhood in Cali – Colombia, along with the description of the amenities included in the urban project (parks, bike paths, pedestrian paths, orchards, native trees among others). Chapter 3 explains the architectural design of the MIHOUSE prototype, its flexibility and accuracies of its exterior and interior design. Chapter 4 deals with the details of the engineering and construction of the MIHOUSE project; its structural design and elements; and with the particularities of the construction of the prototype at the Solar Villa. Chapter 5 introduces the innovative aspects included in the urban design, in the construction process, in the water management and for achieving energy efficiency. Chapter 6 describes the general sustainability aspects of the MIHOUSE project, including bioclimatic strategies at urban and prototype scales. Chapter 7 offers a description of the different aspects considered to achieve the affordability of the MIHOUSE project. Subsequently, the conclusions resumes the benefits of the MIHOUSE project and provides the comments given by the international juries.

The MIHOUSE team hopes this book also reaches curious students, committed community leaders, governmental agencies, NGO´s and people seeking to improve the living conditions of the most vulnerable ones.

Margarita Villalobos

Contest Captain and Communications Coordinator of the MIHOUSE team.

Global, regional, metropolitan and sectorial analysis

Authors: Hernán Felipe Contreras Escobar
Laura Cristina Sadovnik Sterling (student)
Alfonso José Madiedo Echeverri (student)

Global scale analysis

Colombia´s location

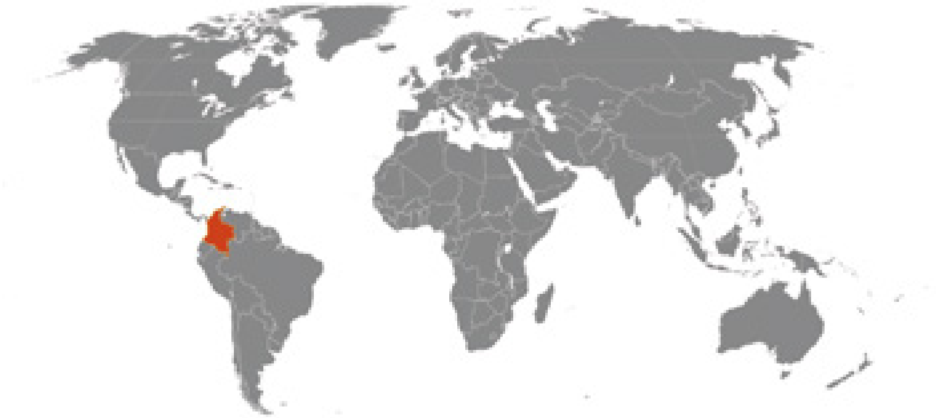

Figure 1
Location of Colombia in the globe
Source: taken from https://commons.wikimedia.org/wiki/File:Barbados_Colombia_Locator.svg

The continental territory of the republic of Colombia is located in the northwestern part of South America (Figure 1). The country is over the Equator Line tropical zone and has two coastal areas: one over the Caribbean Sea and one over the Pacific Ocean. The following coordinates locate Colombia: 12° 26' 46'' north latitude (at its further northern site "Punta Gallinas" in the Guajira peninsula) and 4° 12' 30'' south latitude (at its further southern site "San Antonio" next to the Amazon River). Neighboring countries are Venezuela, Brazil, Perú, Ecuador and Panamá (Figure 2).

Figure 2
Map of the Republic of Colombia
Source: taken from https://en.wikipedia.org/wiki/Geography_of_Colombia

Colombia´s population

Colombia´s population reported on August 2017 is of 49´364.592 inhabitants. There are several Colombian ethnic groups comprised by: “Mestizos” and “White” peoples corresponding to 86% of the population, “Afro” and “Mulattos” (10.8%), and “Amerindians” (indigenous) corresponding to 3.4% of the population Picture 1.

Colombia´s weather

Colombia´s location in a tropical zone allows the country to benefit from a privileged weather. Although the country receives the highest proportions of solar radiation, the weather is not dry. In some regions like “Chocó” in the Pacific coast, the precipitation levels can reach 12.000 mm per year, placing it as one of the places with the highest rainfall index in the world. This phenomenon is shown in a Koppen´s climate map on Figure 3, where Colombia´s location can be identified in relation to different variables such as temperature changes, precipitation levels and regional natural vegetation.

Picture 1
People from different Colombian ethnic groups
Source: A, taken from http://www.contrastes.com.co/noticias/index.php/ar/content-category-4/2882-este-fin-de-semana-es-el-sirenato-de-la-cumbia; B, taken from http://pueblosencamino.org/?p=3128; C, taken from https://co.pinterest.com/aasiyahpinkard/festivals-dancingholidays/?lp=true

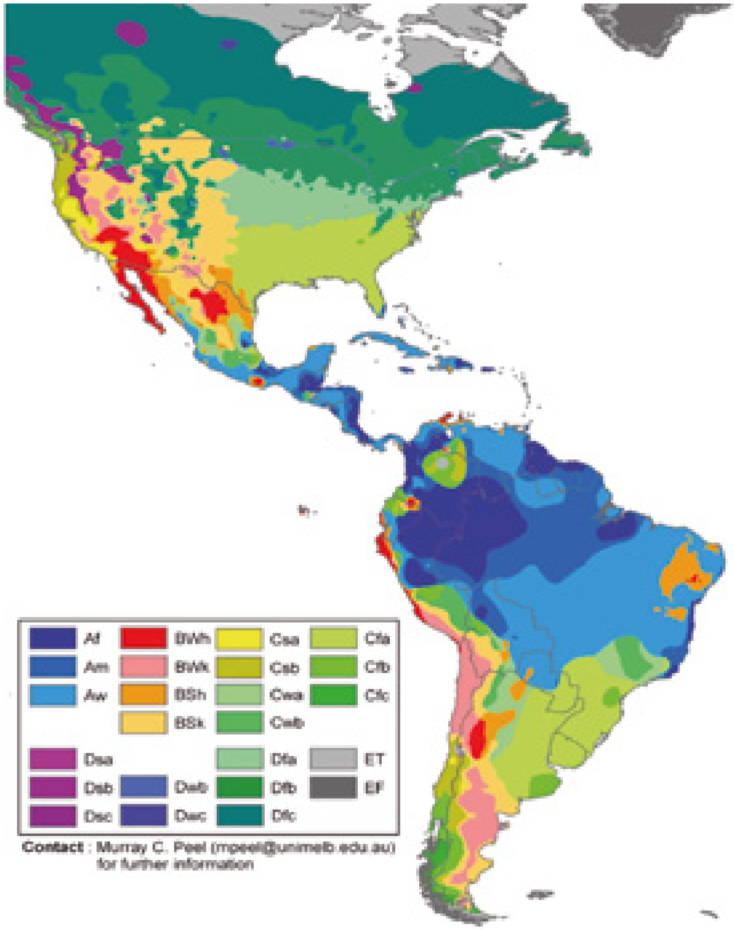

Figure 3
Koppen´s climate map
Source: taken from https://commons.wikimedia.org/wiki/File:Americas_Koppen_Map.png

Regional scale analysis

Regional ecosystems

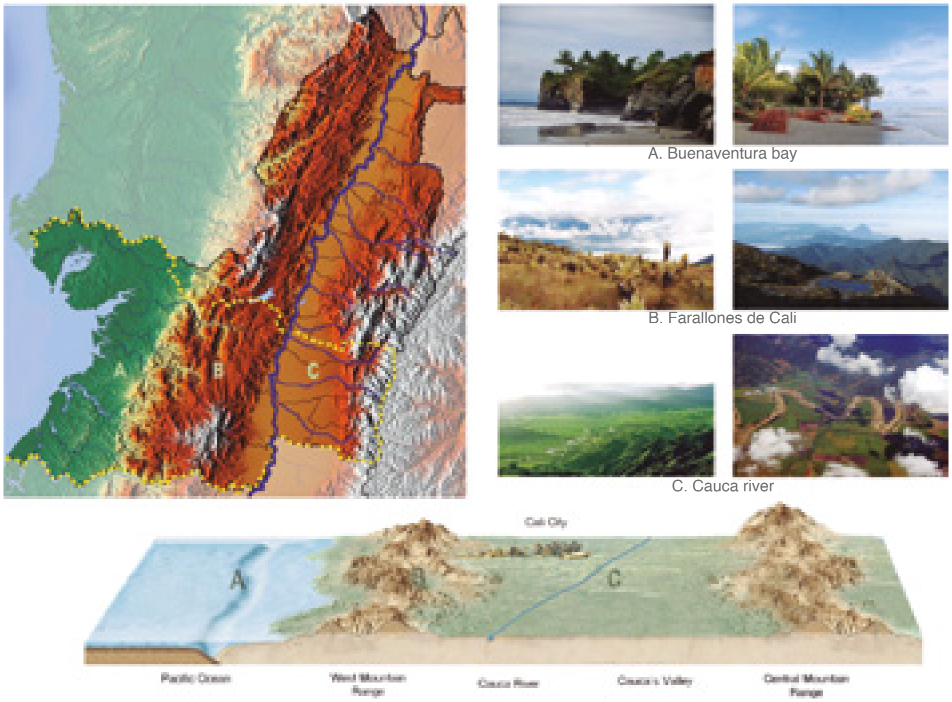

Figure 4
Regional natural ecosystems

Images sources:
Image base: https://es.wikipedia.org/wiki/Valle_del_Cauca
A1: http://elturismoencolombia.com/wp-content/uploads/2016/08/playas_juanchaco_ladrilleros_turismo_colombia.jpg
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C1: http://www.hotelcasafarallones.com/paginas/importancia-farallones-cali
C2: http://enosaquiwilches.blogspot.com.co/2011/03/el-rio-cauca-vuelve-por-lo-suyo.html
Image base: http://geografando.com/geologia/a-teoria-da-tectonica-de-placas/

The regional natural ecosystem and its dynamics are dependent of three main systems with particular characteristics (Figure 4):

a. The natural oceanic system: comprises 218 km of the coastal Pacific area plus surrounding bays, wetlands, mangroves and the rainforest.

b. The mountainous system: comprises two mountain ranges (western and central) derived from Los Andes mountain range that crosses and divides South America. In the western mountain range, the “Parque Nacional Natural los Farallones de Cali” is notorious with a height of 4.080 meters above the sea level. The climate conditions, the condensation phenomena, precipitations and winds are conditioned by these mountainous chains.

c. The “Cauca River” valley system: comprises the regional valley crossed by the “Cauca River”, in a south-to-north direction. It has an extension of 3.000 km.

The dynamics of this system mostly depends in the river overflows that provide minerals to nearby lands and floodplains. It is composed by the following ecosystems: river basins, lakes, ponds and the old courses of the “Cauca River”.

Environmental diversity

The environmental and landscape potential of the region is product of the 3 main natural systems. These provide a variety of ecosystems, climatic conditions and resources (Figure 5).

Flood risks

Flood risks are presented in the entire region (Figure 6) due to the natural condition that affects flat zones located aside of river flows. In urban centers, the risk mostly affects vulnerable populations located in flooding flat areas. In most cases, affected settlements are product of spontaneous urban growth.

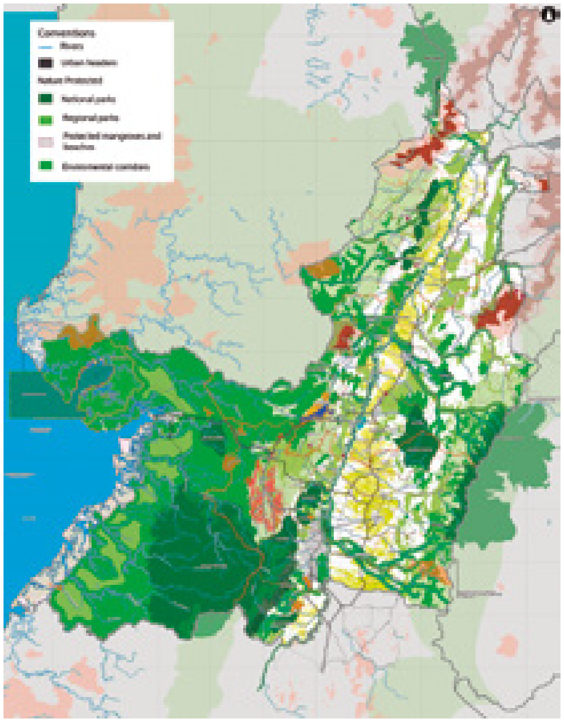


Figure 5
Environmental diversity
Source: Londoño, C y Falla, M (2014). POTD Valle del Cauca 2014.

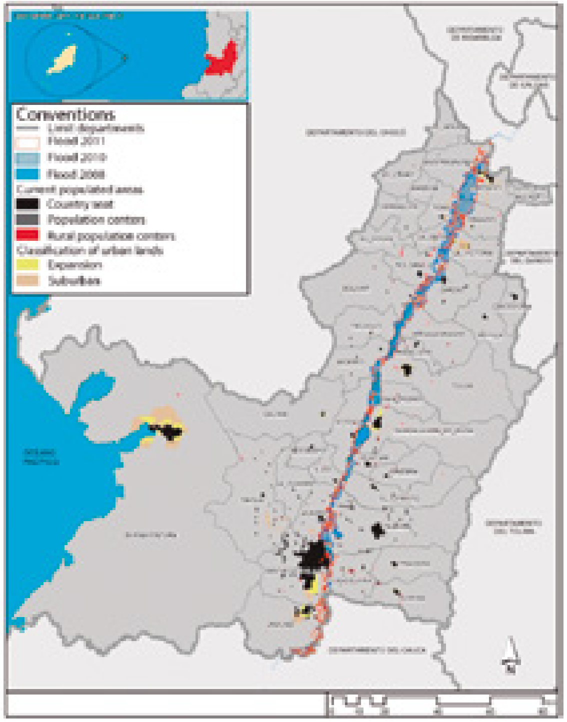


Figure 6
Areas with flooding risk
Source: Valle del Cauca POTD 2014

Regional anthropic system

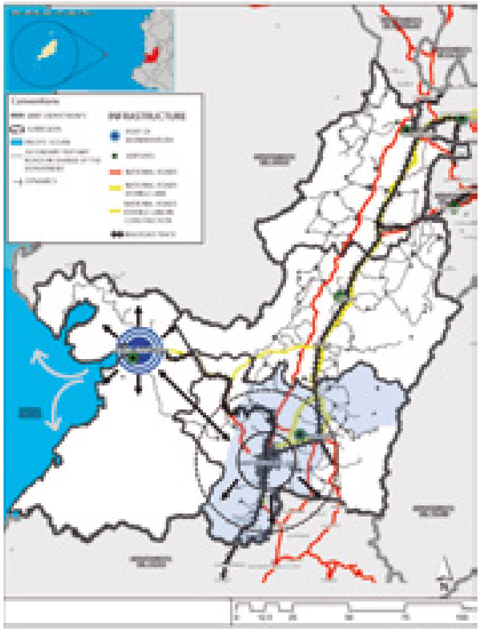
The Pacific region has main municipalities such as (Figure 7):

- The city of "Cali", the capital city in the region and the third most important in the country.
- The "Buenaventura" city and harbor, a logistics and development centrality.
- The city of "Yumbo", an industrial city.
- The city of "Jamundí", prepared for housing development.
- The city of "Palmira", with a vast agricultural economic development.

All of these municipalities are connected by road infrastructure and by economic, productive, population and cultural flows:

Regional connectivity

It is possible thanks to the road infrastructure and the rail freight network, connecting the different production and consumption centers in the region. The connection with the "Buenaventura" harbor (the main one in the Pacific Ocean), allows national and international integration (Figure 8).



Fright train

Yumbo industrial production

Sugar cane production

Buenaventura harbor

Figure 7
Regional anthropic system
Source: Londoño, C y Falla, M (2014). POTD Valle del Cauca 2014

Economic dynamics

There are two commercial lines: The first one is composed by the local market and commerce found mainly extended through the “Cauca River” valley, which provides the setting to different populations and urban municipalities like “Cali”, “Buga”, “Tuluá” and “Cartago”. The second one is based in external market and commerce, with goods transported to the rest of the national territory, mostly in a south-north relation. Goods destined for the international market are transported to “Buenaventura´s” harbor (Figure 9).

Consumption and production centers

They are associated regionally to the different connecting nets, allowing the transportation and commerce of goods and products. Cali´s metropolitan area is highlighted and includes the cities of “Yumbo”, “Palmira” and “Jamundí” (Figure 10).

Population flows

93% of the regional population is concentrated in urban areas while the 7% left, lives in rural areas. Due to migration processes, there are abnormal settlements with insecurity problems and informal employment conditions. Cali is positioned as the central node for the region´s development (Figure 11).

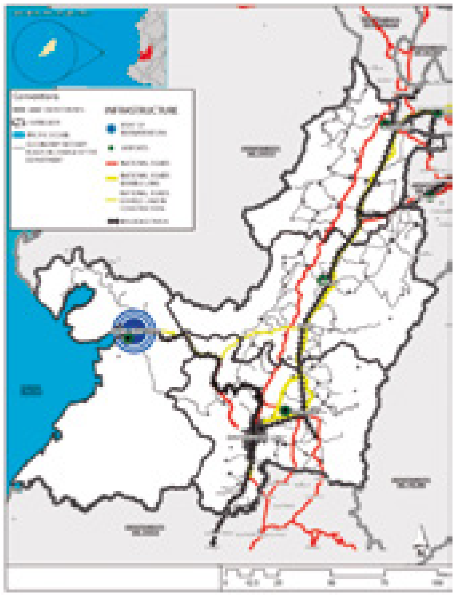


Figure 8
Regional connectivity
Source: Londoño, C y Falla, M (2014). POTD Valle del Cauca 2014

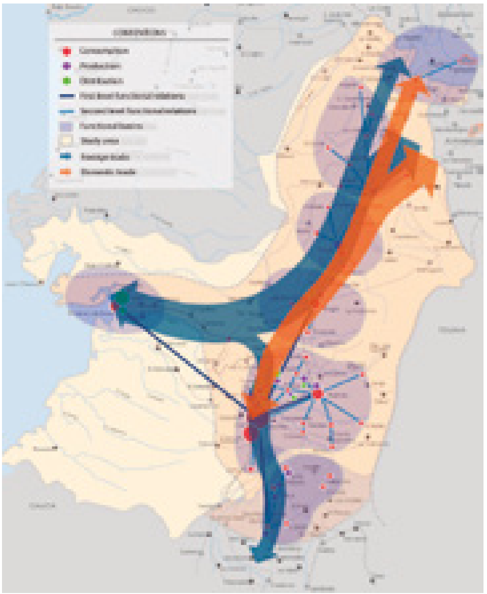


Figure 9
Economic dynamics
Source: Londoño, C y Falla, M (2014). POTD Valle del Cauca 2014

Figure 10
Consumption and production centers
Source: Valle del Cauca POTD 2014

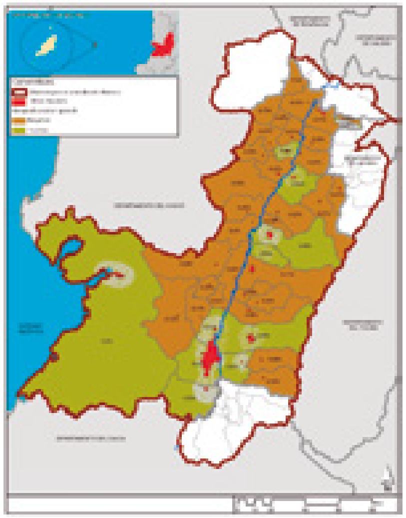


Figure 11
Population flows
Source: Valle del Cauca POTD 2014

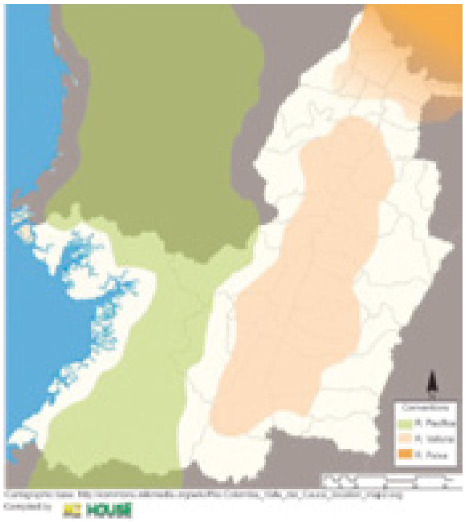


Figure 12
Cultural diversity

Cultural diversity

There are three identifiable cultural groups in the region which are closely linked to geographic conditions and nearby regions (Figure 12). The "Pacific" culture is based on its relation with the ocean; the "Valluna" culture is based on its relation with the "Cauca River" valley; while the "Paisa" culture is related to the states limiting to the north ("Caldas" and "Risaralda").

Metropolitan scale analysis

Environmental connections

The city of Cali is located in an exuberant natural system composed by two natural chains: the mountainous chain and the hydric system (Figure 13). The mountainous chain corresponds to the branch of the occidental mountain range that crosses the region from north to south. It also demarks the western limits of the city. In this system, the "Parque Nacional Natural los Farallones de Cali" is a national protected area that makes part of the System of National Natural Parks. "Los Farallones" has an extension of 206.773 hectares; it comprises 4 ecosystems and the river basins that flow downhill into the city. Two main hills in the city known as "Cristo Rey" and "Las Tres Cruces" are important to the social identity of the "Caleña" culture. The hydric system corresponds to seven rivers that flow downhill into the

Figure 13
Environmental connections

city (Aguacatal River, Cali River, Cañaveralejo River, Melendez River, Lili River, Pance River and Cauca River), plus a set of disseminated wetlands that create microsystems. According to the "Plan Especial de Espacio Público y Equipamiento, PEEPE" (Infrastructure and Public Space Special Plan), there is no clear articulation between the natural system and the city´s development. This means that all the environmental and landscape potential has not been taken into consideration.

Public spaces network

The current public spaces in Cali are insufficient for all of its population. Due to their scarcity, the existing public spaces have an emblematic character rooted in the memory of the population. Some of these highlighted public spaces are "La Plaza de Cayzedo" which was the founding square; "La Plazoleta de San Francisco" next to "San Francisco" Church; "Cristo Rey" Hill and viewpoint; the "Canchas Panamericanas" sports facility complex and park; and "La Tertulia" Museum of Modern Art. The location of some of these and other emblematic public spaces can be seen in Figure 14 and Figure 15. It is possible to say, that the natural system of the city has great potential for public space that so far has not been considered yet: in wetlands, in relation to the seven rivers in the city, and in natural protected areas such as the "Parque Nacional Natural los Farallones de Cali", among others.

Figure 14
Sightseeing places in Cali
1. "Las Tres Cruces" monument and hill. 2. "La Ermita" church, "La FES" building, the "Puente Ortíz" bridge and "La Merced" church in the city center. 3. "San Antonio" chapel in the "San Antonio" hill and neighborhood. 4. "Cristo Rey" monument and hill. 5. "Unidad Deportiva Alberto Galindo" sports facilities. 6. "Universidad del Valle" campus. 7. "Pance River". 8. "Canchas Panamericanas" sports facility complex. 9. "El Paraiso" neighborhood. 10. "Cauca River". 11. "Base Aerea Marco Fidel Suarez" air base.

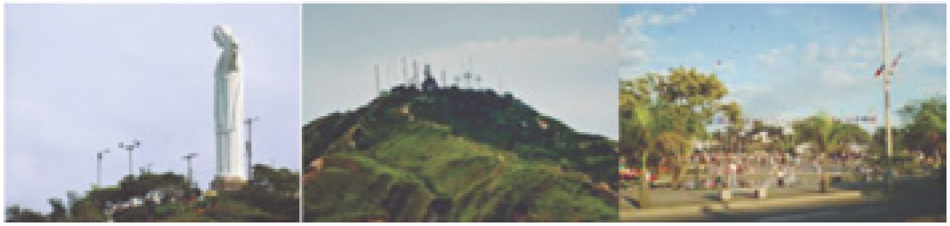


Figure 15
"Cristo Rey", "Tres Cruces" and "Parque de las Banderas"

Coverage of the transport, public spaces and health systems

In the city of Santiago de Cali there is a mass transport system ("Masivo Integrado de Occidente" MIO BRT) that covers 98% of the urban area through a network of

300 kilometers of roads. There are integrated bike paths to this system covering most of the city. There are also facilities with regional coverage: the “Hospital Universitario del Valle” is the most important public hospital and covers 100% of metropolitan health needs; parks and cultural scenarios cover 70% of metropolitan and regional needs; and sports venues and facilities have a 100% of metropolitan and regional coverage. These scenarios cover the needs and demands of the city´s population (Figure 16).

Figure 16
Infrastructure of regional and metropolitan coverage

Urban problems

Cali is a city located in the municipality of Valle del Cauca. It has a great importance in the region because it is a connecting point where diversity of its own and neighboring cities converge. Aspects related to economic, politics and society, among others, lead this city to be a shelter for immigrants in search of new opportunities (Figure 17). This generates a social, economic and urban transformation that makes the city a generator of a variety of possibilities for people. The settlement opportunities for immigrants are mostly located to the eastern part of the city increasing its densification and overcrowding. However, there is a high deficiency of job offers in this eastern side of the city (yellow area in Figure 17), compared to concentrated job opportunities available in downtown, northern, western and southern areas (red areas in Figure 17). This affects the quality of life of the population and, since most of the employment opportunities focus in the west side of the city, it creates a dysfunctional system that segregates and divides de city.

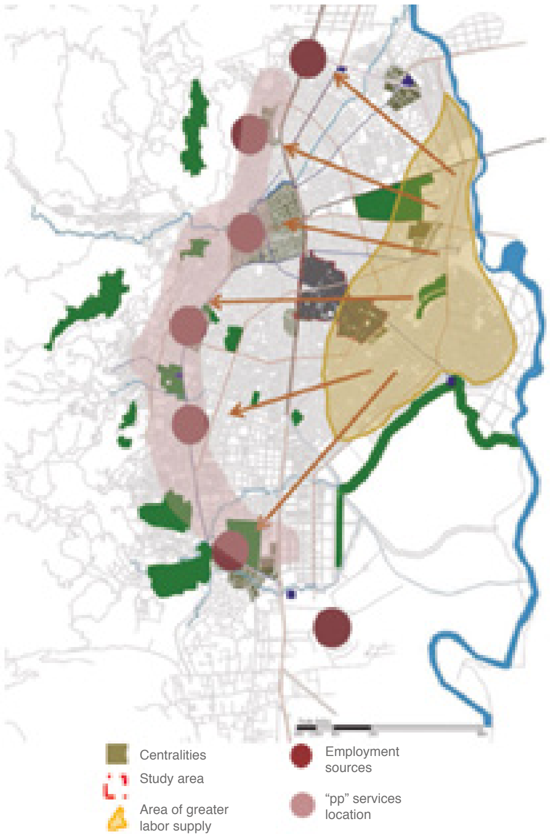


Figure 17
Cali´s urban problems
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Urban opportunities

Over time, the metropolitan area has spread in some areas and compacted in others, due to the conditions of environmental elements such as the guardian hills in the west and the bed of the Cauca River to the east, which are responsible of framing the city. Within the urban area, some centralized spots have been located, defined by the function provided and the services given to the city. These concentrations are structured elements that remain in the memory of the people. Some of them have suffered from decades of abandonment; however, in recent years, planners, architects and related professionals have identified them as potential elements for the development of a sustainable, friendly and inclusive city.

Due to its location, Commune 12 (the dark gray spot in Figure 18) could be a suitable articulator of urban connections because of its proximity to potential elements that enrich the city and provide an urban mixture. The potentials of the area are linked to the following facilities and future projects:

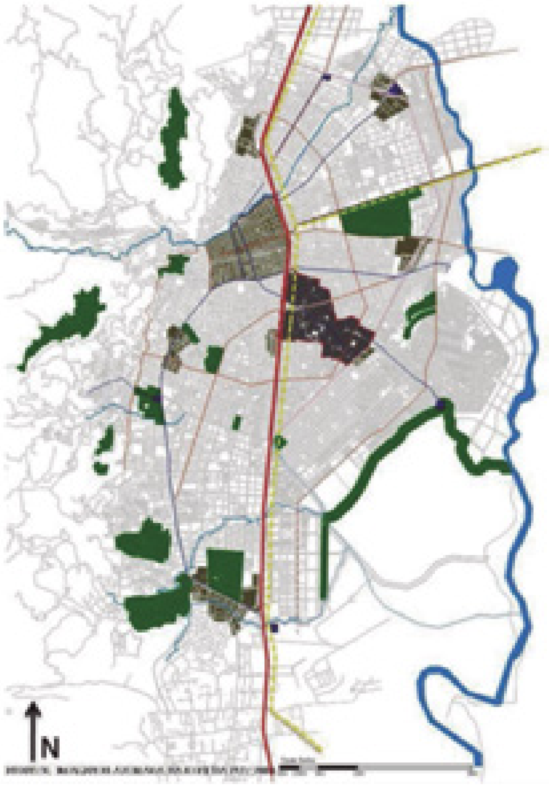


Figure 18
Urban opportunities
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

The Air Base as future Metropolitan Park

The area of the "Marco Fidel Suarez" Air Base is projected as a Metropolitan Park for the eastern part of the city. This will help to improve the living conditions of the people and will increase the value of surrounding zones. The study area has key vial connections for urban integration, the area to locate displaced people in new homes and the potential to link those homes with the new park. This will foment social integration and will provide with the availability of recreational spaces.

"Calle 26" – railway as future Green Corridor

Through history, the railway was the commercial and structural spine of the city, which optimized the vehicular mobility, communicated north and south, from Jamundí to Yumbo and still divides the city from west to east. The Green Axis project (the red and yellow lines in Figure 19 will integrate public space, boulevards, bike paths, the mass transit system and a multimodal station projected by 2030. This will influence the study area, demanding changes on "Calle 26" and sectors that precede it. Inhabitants of the sector currently use this route to commute from "Sameco" industrial area in the north, to the residential and educational areas in the south.

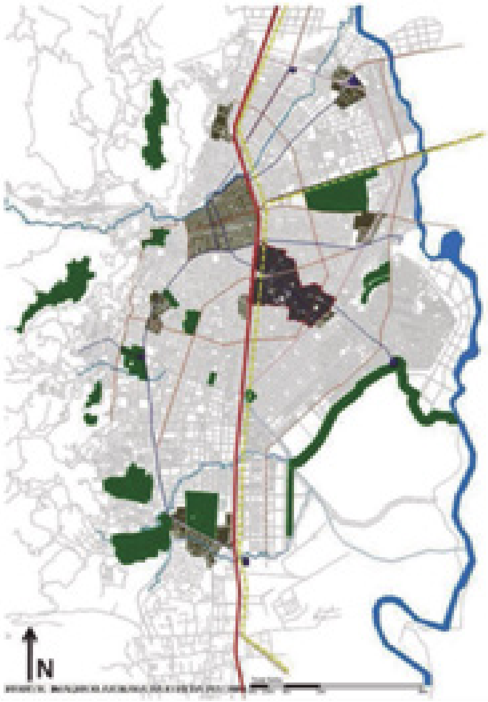


Figure 19
Green Corridor
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Extension of the "Aguablanca" main corridor

The study area is located between the historic center and the Cauca River. These are linked by the "Aguablanca" main corridor, which crosses the entire sector, creating tension and a significant flow since the first one is the historical and administrative center of Cali and the second is projected as an intermodal station at the junction of the corridor and the river. This route will be projected towards the Central mountain range, joining Cali, "Candelaria" and the mountain range.

Cauca River revitalization and CVC ecological park

Corresponds to the rehabilitation project of some areas surrounding the riverbed of the Cauca River, with the purpose of creating a lung for the city and a green axis. Activities for the social integration will be possible with the construction of scenarios for practicing water sports, sports venues and nature trails, which will position the area as an environmental element that fosters ecotourism. This project will demand services that could potentially be provided by the studied area in Commune 12. In consequence, Commune 12 will play an important connecting role in the "Aguablanca" corridor.

Central organ – connection with the historical administrative center

The study area has a valuable and strategic location in the metropolitan surface. Its development is a key factor for generating employment sources, retail and housing. It is also a key to the connection to the city center and for helping to meet future needs by adopting a role of removing functional density from it. In this way, the city adopts a polycentric character that optimizes rollovers, travel, customs, attractions and places of crowds (Figure 20).

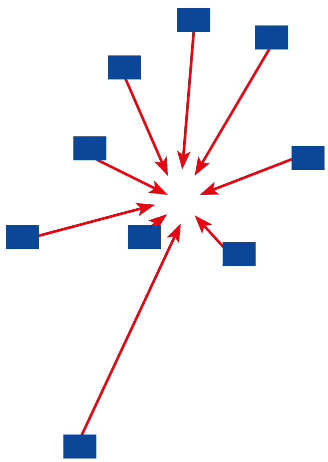


Figure 20
Connections with the historical administrative center

Ring of market places (commercial connections)

There are six interconnected market places which are commercial and job spotlights with day and night life. The position of the study area is key because the "Floresta" market is in it and its area of influence includes the "Santa Elena" market, which is the most important in the city. These markets are linked by a series of rings in order to generate connection to "CAVASA" (the main supply center) located in "Candelaria" (Figure 21).

"Calle 70" structural axis and façade

"Calle 70" is a structuring pathway in the city. It has an impact on land uses and building typologies. Due to its important role in the south to north connection and its large section hierarchy, it is projected as a future corridor for the mass transport system MIO. This will optimize the access and exit of the study area and will demand the transformation of the facade of "Calle 70" along 1.2 kms (Figure 22).

Sectorial analysis

Economic aspects

Land prices

The socioeconomic analysis gave a global vision about the diversity of the economic activities in Commune 12. The analysis is structured from the price of land by square meter, differenced by colors in Figure 23. Land prices vary according to the use of the buildings and locations, and vary from $160.000 to $120.000 COP/m^2 at "El Paraiso" neighborhood (where the MIHOUSE urban project is proposed).

Figure 21
Ring of 6 market places
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

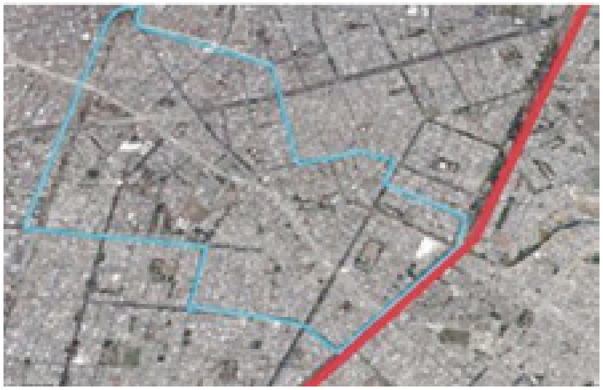


Figure 22
"Calle 70" structural axis and facade
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

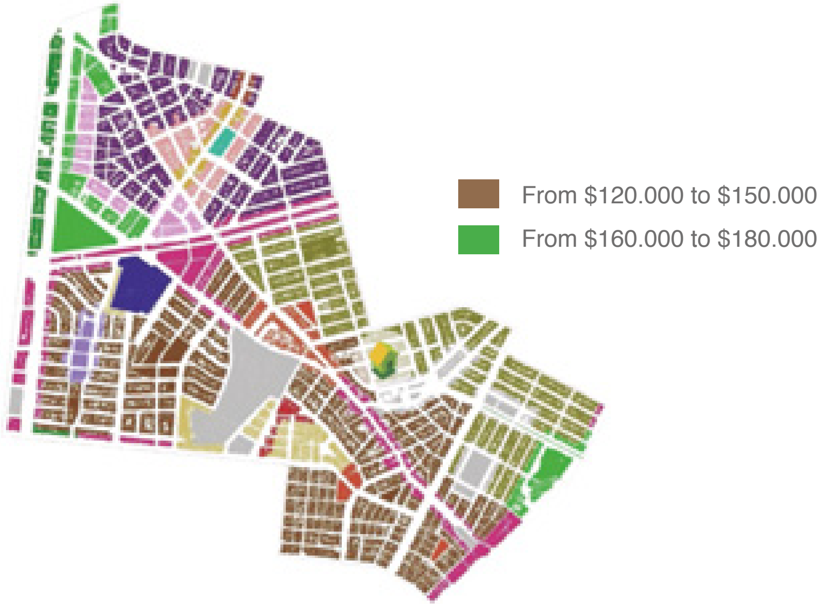


Figure 23
Economic activities and land prices
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Characteristic of the lot occupation

Single-family and multifamily buildings with 1 to 3 floors characterize "El Paraiso" neighborhood. These buildings have been modified over time to meet the demands of the district. Consequently, there are buildings with very small yards and in some cases without patios, creating an alteration of the landscape and affecting the environmental aspects of the neighborhood (Figure 24).

Figure 24
Lot occupation in "El Paraiso" neighborhood

Commercial activity

Commercial and trading activities are present mainly on the corners of the neighborhood due to the lack of parks and meeting points in the area. Therefore, people tend to gather in stores or in the front yards next to high pedestrian flows, which serve as meeting points. In consequence, these spaces became landmarks of commercial activity recognized by the population (Figure 25).

Figure 25
Commercial activity

Social aspects

Population per hectare

Table 1 shows statistical information about some of the neighborhoods that compose Commune 12. Among them, the numbers related to "El Paraiso" neighborhood are highlighted, showing that the population density per hectare is the lowest in the commune.

Table 1
Commune 12 statistics for year 2005

Code in the map	Neighborhood	m²	Hectares	Population	Housing	Homes	Overcrowding	Population density per hectare	Density of houses per hectare
1201	Villanueva	128968	12,9	3546	765	1002	1,3	275	59,3
1203	Eduardo Santos	103208	10,3	3633	763	977	1,3	352	73,9
1204	Alfonso Barberena	97670	9,8	2958	690	933	1,2	302,9	70,6
1205	El paraiso	151595	15,2	3506	741	900	1,2	231,3	48,9
1206	Julio Rincon	56186	5,6	1792	422	488	1,2	318,9	75,1
1209	12 de octubre	145288	14,6	5044	1006	1308	1,3	344,8	68,8
1211	Sindical	167197	16,7	4566	967	1237	1,3	273,1	57,8
1212	Bello Horizonte	40279	4	1326	289	394	1,4	329,2	71,7
Total		**890391**	**89,1**	**26371**	**5643**	**7239**	**1,3**	**303,4**	**65,8**
							Average		

Population analysis

A demographic analysis was conducted based on information provided by the census figures in Cali. The population at “El Paraiso” neighborhood aged between 0 to 19 years old is 1142 people; the population between 20 to 59 years old is 1936 people; and the population 60+ is 428 people. The total population in “El Paraiso” neighborhood was of 3.506 people by the year 2005 (Table 2).

Table 2
Age of the population in “El Paraiso” neighborhood

Neighborhood	Age group (years)															TOTAL
	0 a 4	5 a 9	10 a 14	15 a 19	20 a 24	25 a 29	30 a 34	35 a 39	40 a 44	45 a 49	50 a 54	55 a 59	60 a 64	65 a 69	70 o +	
1112	337	415	441	516	1311	1182	890	753	615	471	311	253	201	142	237	8075
1113	653	708	670	585	588	547	512	571	577	393	270	223	261	225	409	7192
1114	346	450	503	465	421	432	470	473	499	309	232	196	238	281	314	5629
1115	104	152	141	152	134	116	133	122	107	104	65	54	44	44	82	1554
1116	281	344	400	323	285	251	264	289	241	163	112	107	112	101	107	3380
1117	103	110	119	85	78	84	91	85	70	56	60	29	36	25	34	1065
1118	489	575	564	445	456	406	375	305	239	190	176	164	128	96	121	4729
1119	456	471	426	357	344	308	293	340	229	153	130	115	122	113	135	3992
1120	287	346	269	237	208	249	221	208	151	115	88	105	87	52	68	2691
1121	257	311	312	250	263	246	241	240	170	136	112	125	113	64	110	2950
1122	699	742	735	590	604	570	533	539	431	298	239	248	229	215	258	6930
1201	229	303	356	298	278	289	257	273	248	210	189	163	146	99	208	3546
1202	387	461	474	450	496	412	390	416	381	261	200	180	115	142	243	5008
1203	303	346	392	344	315	285	241	275	270	203	166	125	90	85	193	3633
1204	173	244	268	298	253	225	234	246	226	190	133	105	106	89	168	2958
1205	229	284	331	298	294	284	226	252	295	238	191	156	93	103	232	3506

Social problems

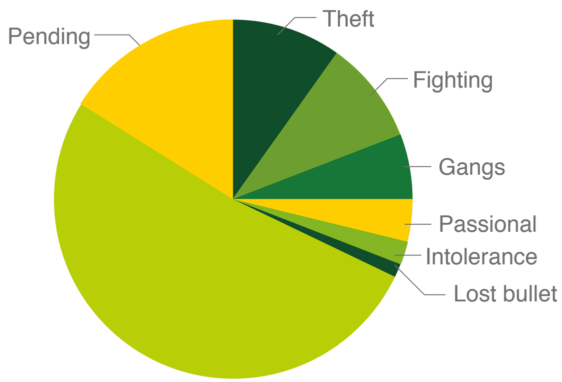


Chart 1
Main social problems at “El Paraiso” neighborhood

The population data, in terms of insecurity, show different variables. This information was studied and related to levels of education of the population; the highest percentage of crimes was crossed with ages and levels of study, resulting in greater insecurity in neighborhoods that have the highest deficits of student attendance. Commune 12 presents a high level of insecurity. The major violence problem presented in “El Paraiso” neighborhood is related to revenge, followed by pending, thefts, fights and gangs among others (Chart 1).

Environmental aspects

Wind and solar incidence

According to the wind and solar schemes, the morning winds go from east to west, while the noon winds from north to south. However, the winds during the night tend to go from south to north. As for sunlight, the morning sunrays reach the eastern facades, while the afternoon sunrays reach the western facades (Figure 26).

Tree coverage

Through field visits and aero photograph references, a survey of tree-layered areas was made (Figure 27); it was found that there is a lack of green spaces and tree coverage over the studied sector. However, there are trees in separating borders located in roads with major traffic flows.

Figure 26
Wind and sunlight schemes
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Figure 27
Tree coverage

Water channels

There are three rainwater channels in the area: the channel over de Autopista freeway, the channel near the “Ferrocarril” (railway) and the “Cañaveralejo” channel between “Calle 44” and “Transversal 28D” (Figure 28). Although a significant path of bushes and trees of various species accompany these channels, the areas are considerably polluted with trash and odors (Picture 2).

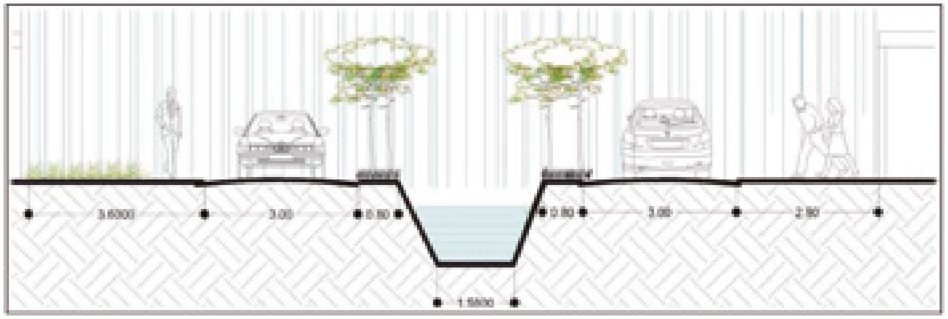


Figure 28
Section of the “Cañaveralejo” rainwater channel at “Sindical” neighborhood
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Picture 2
Pollution of different channels in the study area

Public space

Public space in the sector (Commune 12) as in the city is scarce. It is notorious that the existent proportion of public space is minimal taking into consideration the dimensions of the sector and its urban requirements (Figure 29). Many of the neighborhoods in the area urgently need to improve or to implement new public spaces. This could cover the population’s needs and could prevent the constant displacement of people that move to other city sectors looking to find such facilities. The MIHOUSE project icon is located in the Commune 12 map (Figure 29) where it is proposed to be constructed. The map shows all the public spaces available in the sector.

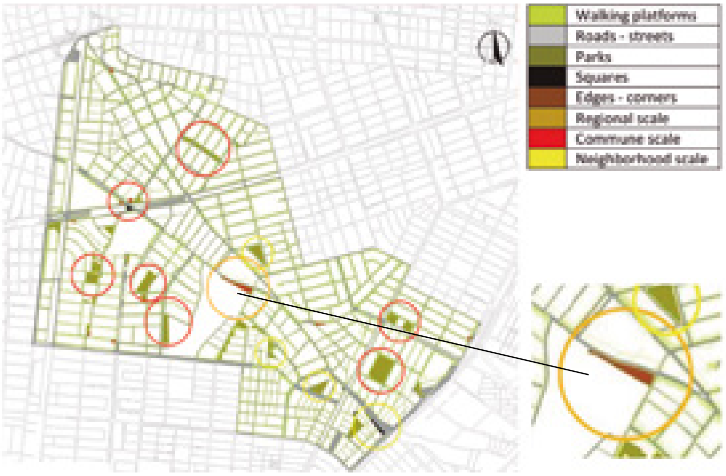


Figure 29
Public space availabe at Commune 12
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Figure 29 also shows a public space of regional scale in a corner between blocks. This corresponds to an area next to a prison (Picture 3). This pubic space is in good condition compared to others, because it has urban furniture, illumination, floor design and a bike path. However, the vegetation is scarce and the public space tends to conglomerate abundant informal vendors and people that gathers mostly during the weekends when the prisoners receive visits.

Picture 3
Available public space next to the prison located in Commune 12

Facilities

The most important facilities in the city of Cali were located in the map shown in Figure 30. A concentration of a diverse type of facilities accessible to people is appreciated in the western part of the city. There is also a concentration of higher education facilities (marked in blue) in the southern part of the city. This forces residents from the entire city to commute a long distance in order to receive education. It is important to notice that the eastern part of the city is the most populated; however, it is the one with fewer facilities. Our specific area of study (marked with dark gray) evidence no urban large-scale facilities at all.

One of the most alarming aspects is that Commune 12 has no security or health care facilities of mayor importance (Figure 31). This has increased the decaying conditions of its neighborhoods, which have abundance of crime, sale of drugs, and presence of gangs, among others. In contrast, small educational facilities (Picture 4) are widely found throughout the study area (Figure 31). However, these facilities are not enough to fulfill the educational needs of the people in the area because the student population is very high. There is also a high educational absence among the population.

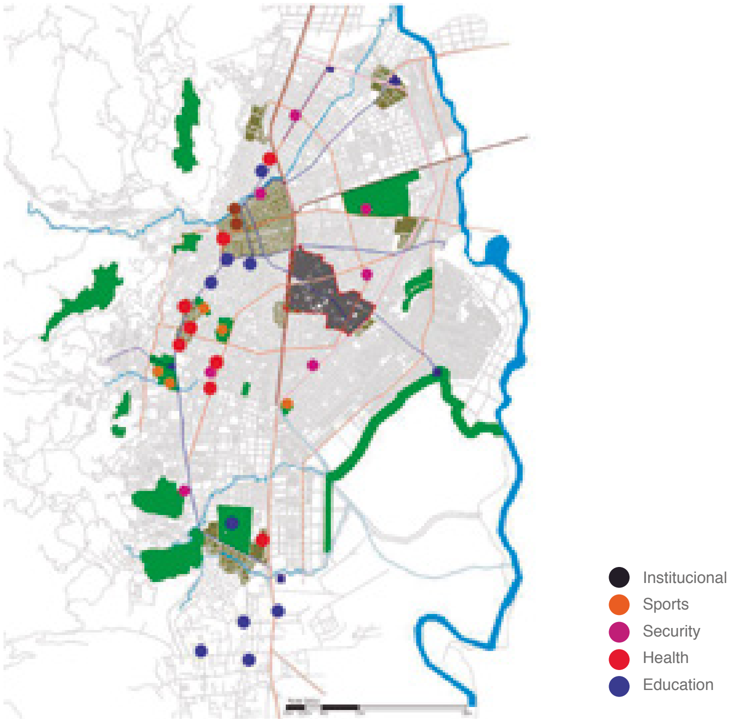


Figure 30
Map of Cali with facilities at urban scale
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Figure 31
Map of Commune 12 with available facilities
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Picture 4
Some educational sites at Commune 12

Mobility

The mobility system in the city is divided by interregional routes, which connect the city with the rest of the country. These pathways are generally old commercial roads or railways between towns, therefore, they have formal characteristics. These pathways that structure mobility, are generally boundaries or borders, which divide and determine areas within the city (Figure 32 and Figure 33).

Public transport

The MIO structural system is composed by the primary corridors or arteries previously mentioned: “Calle 5”, “Carrera 3”, “Carrera 1”, “Carrera 15” and “Troncal de Aguablanca” (Figure 34). Secondary arteries such as the “Autopista Sur-oriental” freeway, “Calle 13”, “Carrera 13”, and “Avenida 6”, among others, complement primary arteries. Tertiary corridors in streets at neighborhood scale feed secondary arteries and mobilize people to intermediate MIO stations. These intermediate sta-

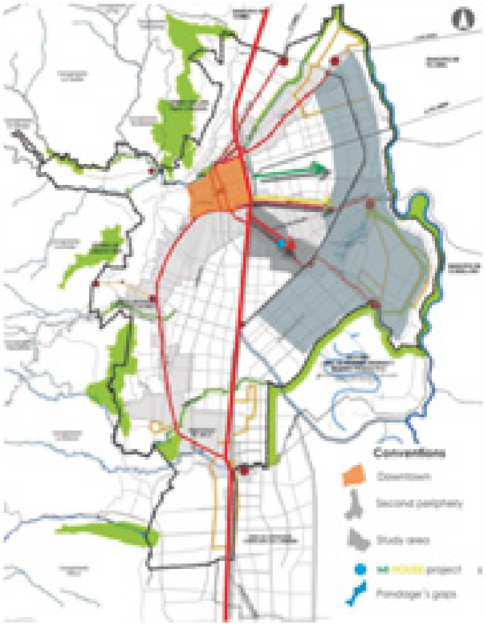


Figure 32
Cali´s mobility system

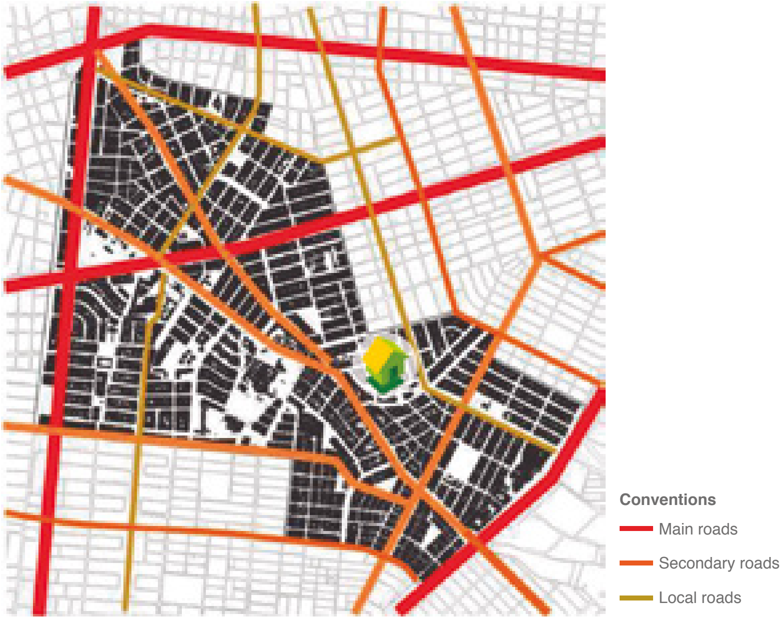


Figure 33
Commune 12´s mobility system
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

tions are located on corridor roads throughout the city. They also connect to other larger stations called header terminals that make part of the MIO structural system.

The study area (marked in gray in Figure 34) has access to two primary main MIO corridors (see red lines in Figure 35). One to the north at "Carrera 15", with three nearby stations outside of the area; and a second one, which is the "Aguablanca" main corridor, that crosses Commune 12 through its center and connects it with downtown and the eastern part of the city. This corridor provides the area with four MIO stations (see yellow triangles in Figure 35).

As previously described, the area has good coverage of public transport services, primarily with the MIO system that provides four stations inside Commune 12 and three more located nearby (Figure 35). The corridor routes are "Primitivo Crespo", "Santa Mónica", "Villanueva", and "Conquistadores". These integrate standard articulated buses and feeders circulating in some areas of the sector: the free MIO bus route that circulates over "Calle 44" (the yellow line in Figure 35), and buses that circulate only over the "Diagonal Autopista 19", "Calle 70" and "Calle 27" ("Aguablanca"). Figure 36 shows a common section of a street with a MIO station.

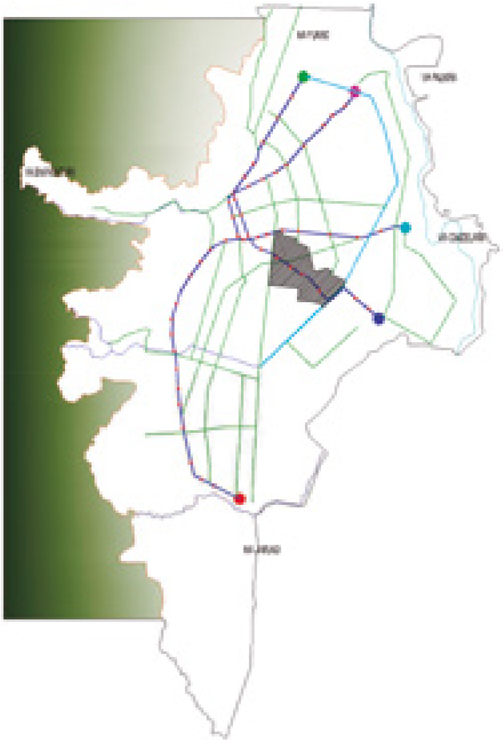


Figure 34
MIO structural system
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

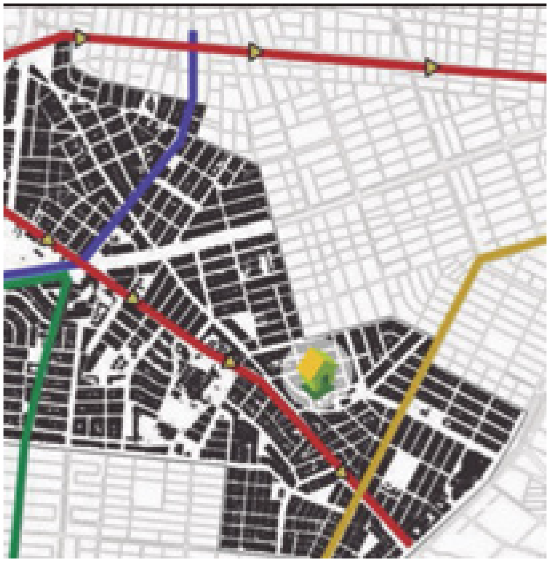


Figure 35
MIO routes available to Commune 12
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

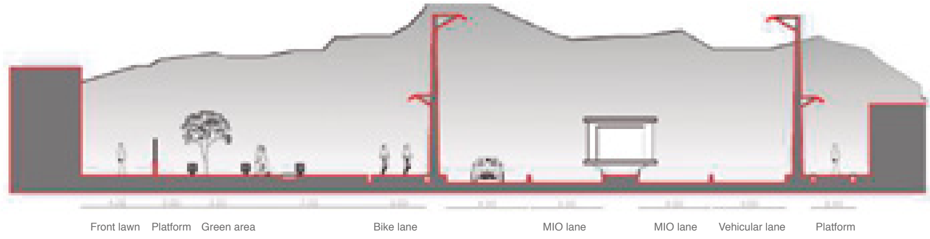


Figure 36
Common section of a street with a MIO station
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Sectorial problems

The study area is located at the transition between the city center and the eastern part of the city. This area plays an important role mainly because of its direct connection to the city of "Candelaria"; however, it is a decaying zone due to: 1) the abandonment of proximate neighborhoods, 2) the deteriorated major railway of interregional characteristics, and 3) the abandonment of many iron factories located nearby. This resulted in the oblivion and invasion of public space, which is a constant variable in the studied area. Another significant problem is the area´s proximity to the "Pondaje" lagoon, the Cauca River and the Cañaveralejo riverbed. These increase flood risks in addition to soil liquefaction (Figure 37). As for social

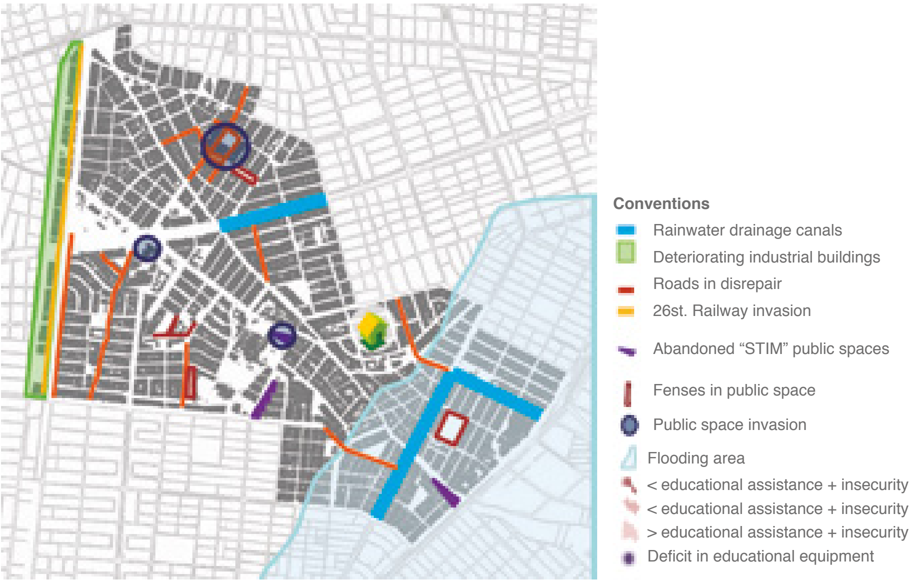


Figure 37
Sectorial problems (zoning issues)
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

aspects, the study area and its surroundings in the eastern part of Cali have an important index of violence. In Commune 12 is where gang crime is the highest and where young adults of 18 and older are not likely to attend college.

Sectorial opportunities

Mobility in the study area

The road system is articulated positively to structure a fluid and optimal mobility. This is conducive to the smooth access and exit of the area. It counts with neighborhood-scale roads connected to collector roads of different proportions and formal characteristics. These connect with primary structuring roads in the city that communicate with municipalities and districts, among others. There is a mass transit system in the "Aguablanca" corridor but there are projected more structural axes equipped with additional transport systems (Figure 38).

Low-density height

The scarce construction of tall buildings is one of the greatest potentials of the study area. The constructed surface has between one and two floors, allowing many possibilities for redensification and ways of intervention (Picture 5).

Figure 38
Mobility in the study area
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

Picture 5
Images of the low-density height in the study area
Source: Builes, H., Contreras, F, Ocampo. A., Póveda, D (2013).

The MIHOUSE urban proposal

Authors: Margarita María Villalobos Ayala (teacher)
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General description

Figure 39
Location of MIHOUSE proposal in the study area

The urban proposal presented by MIHOUSE is developed in the real context of "El Paraiso" neighborhood in Cali, which provides a local representation of the problematic situation of social housing in Colombia and Latin America. This problematic consists in the large deficit of quality housing options for low-income populations, plus the scarceness of proper land conditions for their location and development.

MIHOUSE considers that a social housing solution of quality is not an isolated product. It should contribute to the cities´ sustainability, which is guaranteed with a balanced mix of residential, commercial, governmental, recreational, industrial and institutional facilities (Figure 39). "*The location of households should facilitate its inhabitants the access to basic services, public spaces and recreation. They should not be just a shelter, but a city that permits its access to developing opportunities*". Therefore, MIHOUSE proposes to take advantage of urban areas going through deteriorating processes by providing them with a sustainable housing solution and public spaces that could reverse the deteriorating dynamics into those of renovation and re-densification.

Groups of dwellings forming 4 to 5 story buildings surrounded by public common areas are the components of the MIHOUSE project. The group of buildings can be replicated to conform a housing set adaptable to different places, density requirements, and types of urban blocks (Figure 40). Thus, it could vary in height and number of dwellings.

The housing set is composed by 30 buildings (with 4 to 5 floors each) grouped around 8 parks with different uses (parks for recreational activities, landscape contemplation, among others) and 4 small squares (Figure 40 and Figure 41).

The proposed density can vary depending on the needs. It can have between 128 dwellings per hectare in 4 to 5-storey buildings, to 150 dwellings per hectare with 5-storey buildings. Buildings with more than five floors are not recommended because they require elevators thus increasing the project costs.

The proposal also contains two facilities that complement the residential use: a childcare and a mini-market. Additionally, it is possible to develop productive units in some of the apartments located on the first floors of the buildings, which can be used as service facilities or commercial stores to supply the neighborhood's needs (Figure 42).

Public spaces

The MIHOUSE project highly values all the possibilities for the inclusion of public spaces because they provide inhabitants with areas for landscape contemplation, for socialization and for recreational activities, which should be accessible to all the population. Additionally, autochthonous trees were included in parks and green areas because they will promote the local avifauna and keep the city´s

Figure 40
MIHOUSE adapted to an existing urban block

Figure 41
Aerial view of MIHOUSE urban proposal in “El Paraíso” neighborhood

environmental corridors. Figure 43 and Figure 44 show the location of the urban spaces and native trees. The amount and description of each species is found from Table 3 to Table 10.

Figure 42
Location of complementary facilities in a MIHOUSE urban set

Figure 43
MIHOUSE proposal for public spaces

Figure 44
Inclusion of native trees in MIHOUSE urban proposal

Table 3
Number of trees and species to be included in the MIHOUSE urban proposal

Proposed species	# of trees	Diameter of the crown	Total tree coverage
Guayacán Carrapo tree	10	7	84
Carambolo tree	8	4,5	36
Madroño tree	11	5	140
Chitato tree	16	15	150
Guamo tree	20	6	36
Total	**65**		**446**

Table 4
Zancona palm specifications

Common name	
Zancona Palm	
Scientific name	
Syagrus sancona	

Height	30 m
Diameter of the crown	3 m
Diameter of the trunk	0,50 m
Root	Deep
Leaf type	Feathery
Flower type	Not present
Fruit	Yellowish ellipsoid

Justification
It serves as a distant refence. Nesting place for birds.

Care	
Seeding	2.00 m height distance of not less than 3 meters sowing within species.
Irrigation	Every day for the first month.
Fertilizer	In roots and leafs during the first 2 months of planting. Then every 2 months in the roots.
Prunning	Perform careful prunning to give the desired tree silhouette.

Table 5
Guayacán Carrapo tree specifications

Common name	
Guayacán Carrapo	
Scientific name	
Bulnesia carrapo	

Height	15 m
Diameter of the crown	7 m
Diameter of the trunk	0,40 m
Root	Relatively deep
Leaf type	Paripinnate
Flower type	Yellow
Fruit	Not present

Justification
Used to decorate the space. Nesting place for birds.

Care	
Seeding	1.00 m height distance of not less than 3 meters sowing within species.
Irrigation	Every day for the first month of planted.
Fertilizer	In roots and leafs during the first 2 months of planting. Afterwards only every 2 months in the roots.
Prunning	Perform careful prunning to give the desired tree silhouette.

Table 6
Corozo palm specifications

Common name
Corozo Palm
Scientific name
Acrocomia aculeata

Height	15 m
Diameter of the crown	3 m
Diameter of the trunk	0,12 m
Root	Not aggressive, not superficial
Leaf type	Plumosa
Flower type	Not present
Fruit	Globose yellowish green

Justification
It serves as a distant refence. Nesting place for birds.

Care	
Seeding	0.50 m height planting distance of not less than 1 meter from the same species.
Irrigation	Every day for the first month and then space it seeding.
Fertilizer	In roots and leafs during the first 2 months of planting. Then every 2 months in the roots.
Prunning	Perform careful prunning to give the desired tree silhouette.

Table 7
Carambolo tree specifications

Common name
Carambolo tree
Scientific name
Averrhoa carambola

Height	4 m
Diameter of the crown	4,5 m
Diameter of the trunk	0,12 m
Root	Deep
Leaf type	Elliptic
Flower type	Purple
Fruit	Carambolo

Justification
Used to decorate the space. Nesting place for birds.

Care	
Seeding	2.00 m height distance of not less than 3 meters sowing within species.
Irrigation	Every day for the first month and then space it seeding.
Fertilizer	In roots and leafs during the first 2 months and then every 2 months in the roots.
Prunning	Perform careful prunning to give the desired tree silhouette.

Table 8
Madroño tree specifications

Common name
Madroño tree
Scientific name
Calycophyllum candidissimum

Height	18 m
Diameter of the crown	5 m
Diameter of the trunk	0,30 m
Root	Deep
Leaf type	Ovate
Flower type	Greenish white
Fruit	Madroño

Justification
It serves as a distant refence. Nesting place for birds.

Care	
Seeding	Every day for the first month and then space it seeding.
Irrigation	Every day for the first month and then space it seeding.
Fertilizer	In roots and leafs during the first 2 months. Then every 2 months in the roots.
Prunning	Perform careful prunning to give the desired tree silhouette.

Table 9
Chitato tree specifications

Common name	
Chitato tree	
Scientific name	
Muntingia calabura	

Height	15 m
Diameter of the crown	Dense and wide crown
Diameter of the trunk	0,20 m
Root	Deep root
Leaf type	Obovate
Flower type	White petals and yellow stamens
Fruit	Chitató

Justification
Used to decorate the space. Nesting place for birds.

Care	
Seeding	2.00 m height distance of not less than 3 meters sowing within species.
Irrigation	Every day for the first month and then space it seeding.
Fertilizer	In roots and leafs during the first 2 months. Then every 2 months in the roots.
Prunning	Perform careful prunning to give the desired tree silhouette.

Table 10
Guamo tree specifications

Common name
Guamo tree
Scientific name
Inga codonantha

Height	22 m
Diameter of the crown	6 m
Diameter of the trunk	0,50 m
Root	Buttresses up to 1 m in diameter
Leaf type	Morus alba
Flower type	Calix green and reddish white stamens
Fruit	Noy present

Justification
Used to decorate the space. Nesting place for birds.

Care	
Seeding	2.00 m height distance of not less than 3 meters sowing within species.
Irrigation	Every day for the first month and then space it seeding.
Fertilizer	In roots and leafs during the first 2 months of planting. Then every 2 months in the roots.
Prunning	Perform careful prunning to give the desired tree silhouette.

Accessibility

MIHOUSE helps in the integration of public and collective means of transport mostly for 3 reasons: firstly, to ease traffic problems; secondly, to facilitate the movement of people by aiding to surpass any social or economic barriers; and thirdly, to help keep in acceptable levels the air pollution and CO^2 emissions produced by different types of vehicles.

In consequence, MIHOUSE urban project takes advantage of its privileged and strategic location near public transport corridors. This provides an excellent road connectivity and an easy access to the MIO public transportation system. Furthermore, there are enough areas for vehicles in the urban proposal, according to current regulations. This is complemented by alternative means such as walking and cycling paths, which promote a healthy lifestyle (Figure 45).

The mentioned vehicles for families living in MIHOUSE will only approach vehicular isles located at the delimiting streets, avoiding contact with internal pedestrian paths. Accesses to bikes are through the peripheral bike paths towards a main pedestrian axis. Inside the urban block, the approximation to the housing units is only through a pedestrian path system (Figure 45 and Figure 47).

Figure 45
MIHOUSE proposal for urban mobility

Figure 46
Integration of public and collective means of transport

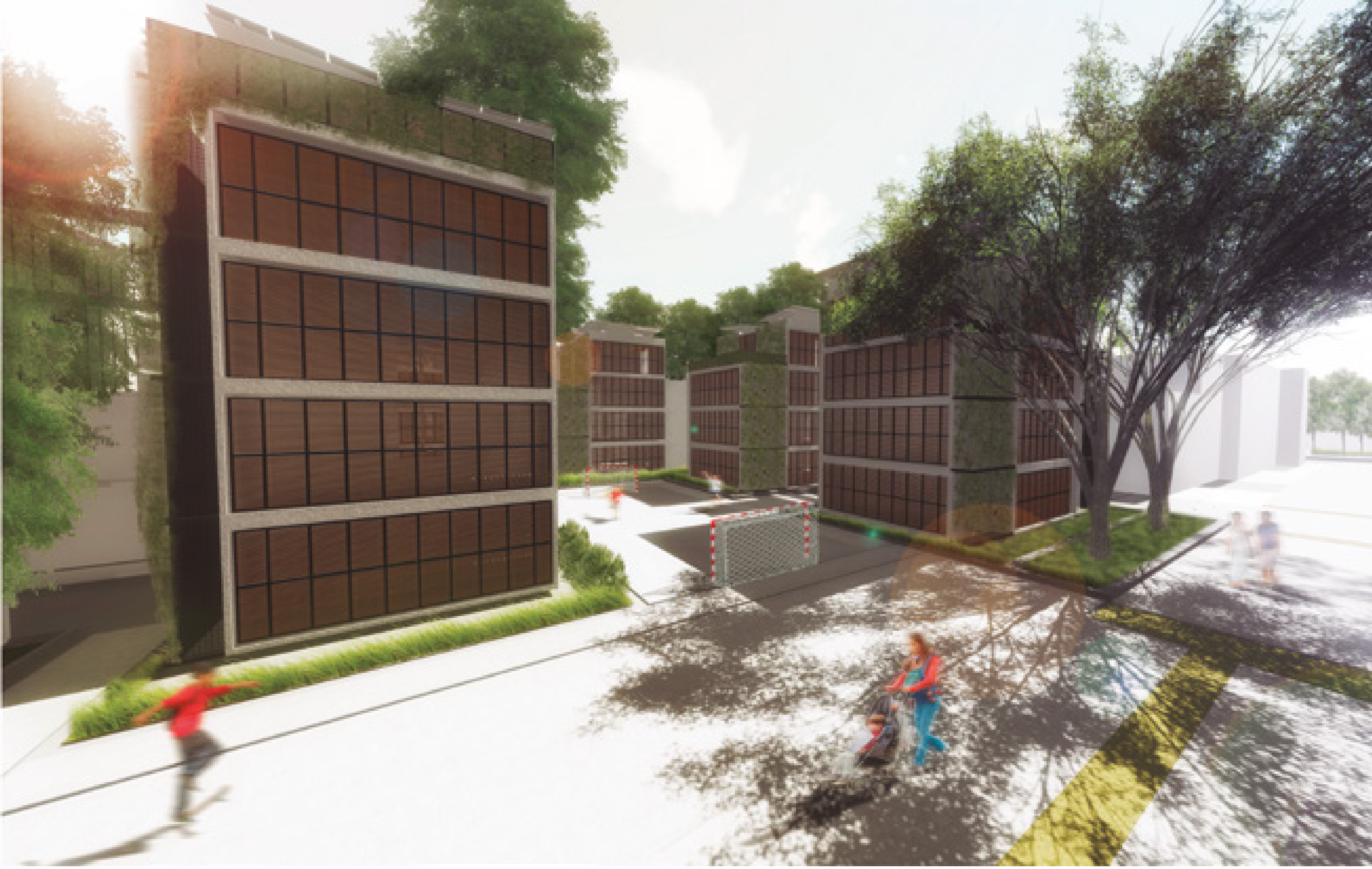

Figure 47
MIHOUSE urban proposal includes walking and cycling paths

Architectural design of the MIHOUSE prototype

This page has complementary content AR

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Jessica Andrea Rojas Benavides (student)
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Why is it called MIHOUSE?

MIHOUSE means “Multi Intelligent House Using Solar Energy” and is a set of housing units that conform an urban whole. These housing units are the synthesis of different intelligences that technically resulted from the interdisciplinary work done by the team of two universities: San Buenaventura Cali and Autónoma de Occidente. The technical results cover urban, social, environmental, economical, innovative, sustainable and architectural aspects related to the use of solar energy as a source of power in a household for low-income families in tropical countries, and its low environmental impact.

General description

The MIHOUSE prototype constructed at the Solar Villa corresponds to the fifth floor of a 5-story building from the urban proposal. The decomposition of the prototype allows its industrial production and prefabrication. Each prototype is composed by four structural tables (Figure 54), which provide the spatial conformation of each dwelling.

The fundamental principle of MIHOUSE relies on the idea of flexible spaces within the prototype for the various activities carried out by a family of maximum five (5) members, therefore the spaces can be modified according to the changing needs of the family. The first four floors of each building have the same spatial and structural conformation based on (4) main tables (Figure 54), however, one of the tables of the fourth floor becomes the ground of the orchard proposed on the fifth floor, which is the MIHOUSE prototype constructed at the Solar Villa. In this orchard is possible to plant products for consumption such as species of easy handling and care. In addition, MIHOUSE evidences a high commitment to the environment by having a permeable envelope that allows a high flow of ventilation and high permeability to the outside, creating a strong relationship and transparency to the immediate context (Figure 48).

Figure 48.
Renders of the MIHOUSE prototype at the Solar Villa

Module flexibility

The MIHOUSE prototype constructed at the Solar Villa consists of three (3) volumes (the prefabricated tables). The remaining central space fulfills the function of articulator because it is the main circulation axis, which connects the spaces where the different activities are developed. The surrounding volumes are flexible spaces, therefore, people can determine the functions of each space: where they want to place the dining room, the living room, the bedrooms and the productive area, according to how many people share an apartment: if it's a single person, a family, a couple with children or extended family (Figure 49).

There is also a movable furniture system that vary the spatial organization (Figure 49) in an easily and fast way without having to perform any civil works that imply costs in time and money. The proposed furniture is the result of an interdisciplinary work, in which the following aspects were taken into consideration: the multifunctional flexibility, the modularity, the ease of use, the scale, the materials and the viable supplies.

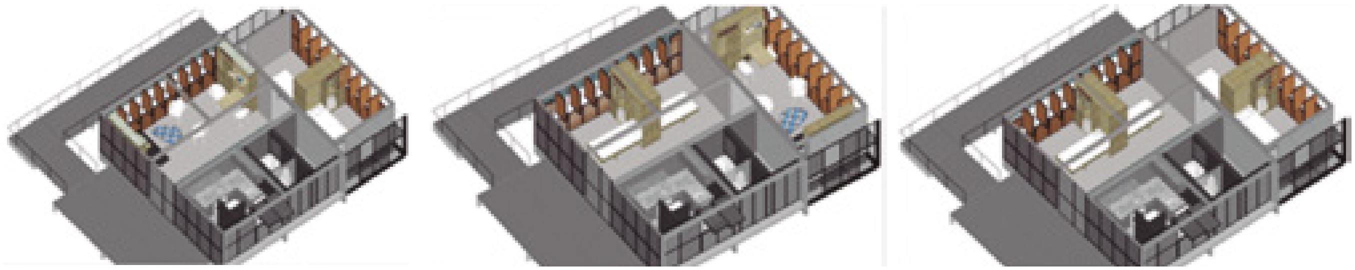

Figure 49
Modularity and flexibility of the MIHOUSE prototype

Exterior design

Both the MIHOUSE urban scale proposal and the small housing prototype constructed at the Solar Villa use housing materials that pose simplicity and minimalism. This combines innovation with tradition, as natural materials produced in the region are incorporated through technological and industrialized processes.

It is important to mention that in the overall design, trees, parks and community gardens were merged in the urban design, as well as vegetation incorporated in private orchards in each housing unit and facades in the architectural design (Figure 50). In these private orchards people can produce consumable goods for its own family or for selling in the local community, serving as a strategy for the family to gain additional income and to foster food security. These gardens are raised on large decks of 100% recycled plastic wood that replace vegetal wood. This has led to a significant reduction in the indiscriminate felling of forests, since wood is replaced by plastic post-consumption wood, contributing towards the planet preservation.

The gardens implemented at MIHOUSE are a contribution to the sustainability of the overall project. They also depend on the rich nutrient compost derived from the organic waste generated at the homes of people living in the buildings. These gardens can produce native medicinal plants, vegetables and fruits if planted with the aforementioned substrate. Native plants are not extent of predators and pests found in the region, therefore, in their care is recommended a treatment with chili to eliminate potentially harmful agents and nutrients through composting. Adding fertilizers and chemicals for growth will not be needed to strengthen the roots, leaves and fruits.

The use of native species brings advantages because there is no need to create structures such as greenhouses to promote the proper growth of the plants and they will only need to be watered once or twice a week.

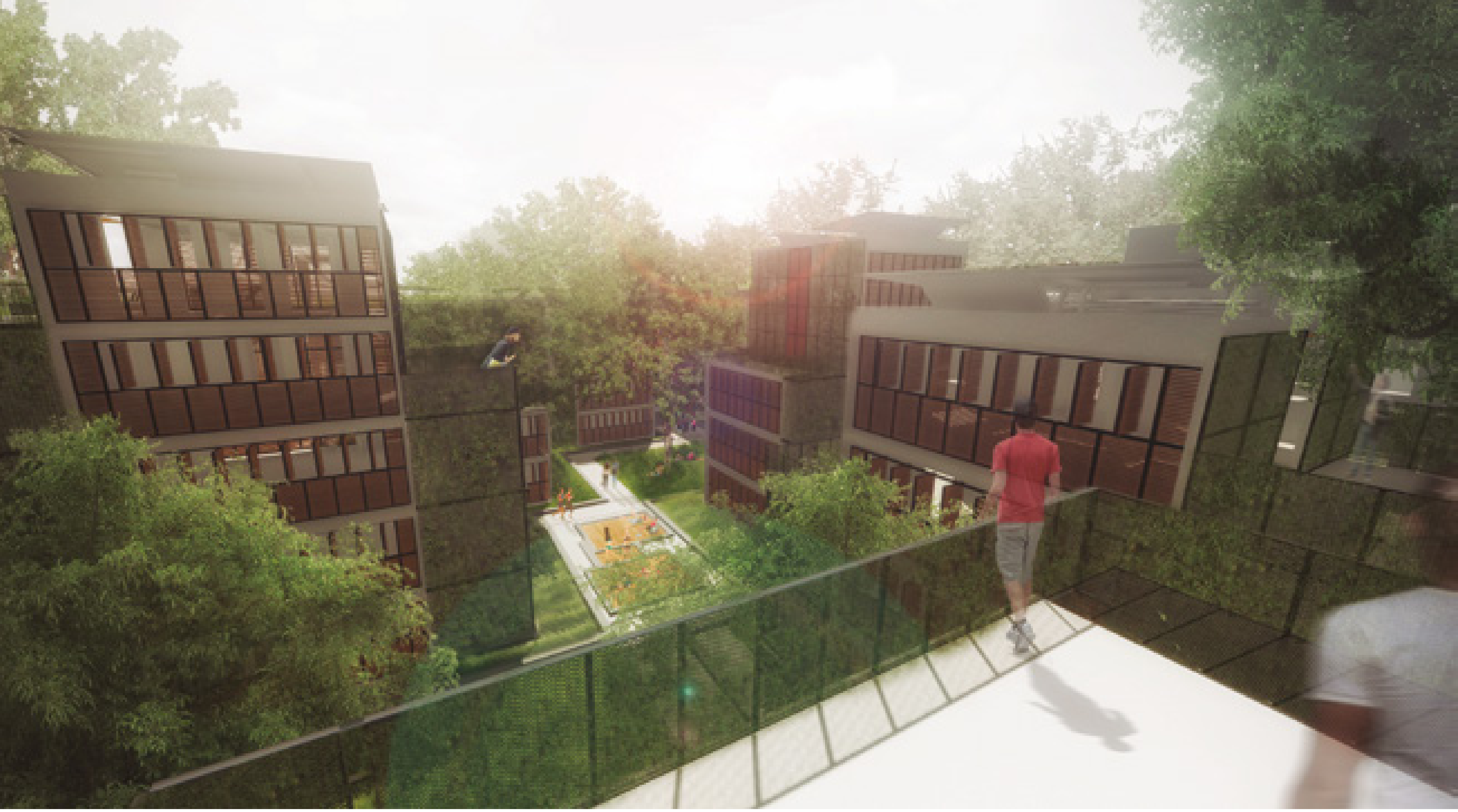

Figure 50
Render of external and internal vegetation

Interior design

The MIHOUSE proposal includes the following concepts in the interior design: flexibility, dynamics, spatial organization and multi-functionality.

The use of three (3) different structural tables allows the adaptation of the spaces according to the inhabitant's preferences (Figure 49). Two (2) of the structural tables fulfill the need of bedrooms, living and dining rooms, responding to the concept of social housing by supplying the required rooms for five (5) people. These two (2) structural tables allows the internal dynamism and multi-functionality because the space can be adapted by generating, for example, a choice of two bedrooms plus a living room and dining room, a choice for four bedrooms, or a choice for one room plus one study, a living room and dining room. As for the third structural table, it contains fixed spaces: the kitchen and two bathrooms. These are not flexible as the areas located in the other two (2) structural tables. However, one of the two bathrooms can be used as a closet that can then be turned into a bathroom facility with shower, toilet and hand wash.

Figure 51
Flexible interior design

As for the interior atmosphere, the concrete finish in the walls allows a fresh and harmonious space with wide view to the different accommodations and the appreciation of indoor flexibility. The concrete finishes also produce unsaturated areas with less vulnerability to aesthetic obsolescence. In relation to the used furniture, its design is based on the same principles and handles materials such as wood, which adds to a comfortable and natural space. The color palette, keeps the principles of minimalism of the structure, making this a clean and bright space.

Natural lighting design

The lighting design uses natural and artificial light to fulfill the apartment's illumination needs. Due to Cali´s latitude and longitude position in the globe, it is possible to harvest high solar radiation values averaged between 4.5 kW/m2 and 5 kW/m2 according to weather data stations and the Colombian solar radiation atlas. This creates a great scenario to take advantage of solar power, which means that during a regular sunny day, peaks of solar radiation could reach 1000 W/m2. This helps to promote saving energy strategies that reduce energy consumption by using daylight provided by the radiant energy of the sun throughout the day. To do this, MIHOUSE uses windows that allow the entrance of sun light to meet the illumination needs during the day, while it uses an efficient LED light system during the night. The chosen LED light system went through a careful selection of low consumption appliances. It is important to mention that the location of the buildings and the location of the constructed prototype at the Solar Villa also have an incidence in the amount of solar radiation and heat received.

Sketches of the natural illumination in the MIHOUSE prototype are found on chapter 6, simulating the entrance of daylight through the windows. These windows help to avoid the direct solar radiation that heats the house. Figure 62 to Figure 69 show the natural illumination passing through the prototype windows during six different times of the year: in June and December, at 10 am and 3 pm, during cloudy and clear sky days.

It is also important to notice that the last floor of each building and the constructed prototype at the Solar Villa count with skylights in the ceiling below the metal roofed structure (Figure 52). These skylights help to reduce the solar entrance at different hours. This is because of the protection tilt towards west and because skylights present an asymmetric performance, being more efficient on the afternoons. Skylights geometry reduces 39% and 67% of the solar entrance between 8:00 and 10:00 hours, respectively. During the afternoon, the solar entrance is reduced by a 71% at 16:00 and a 100% at 14:00 hours.

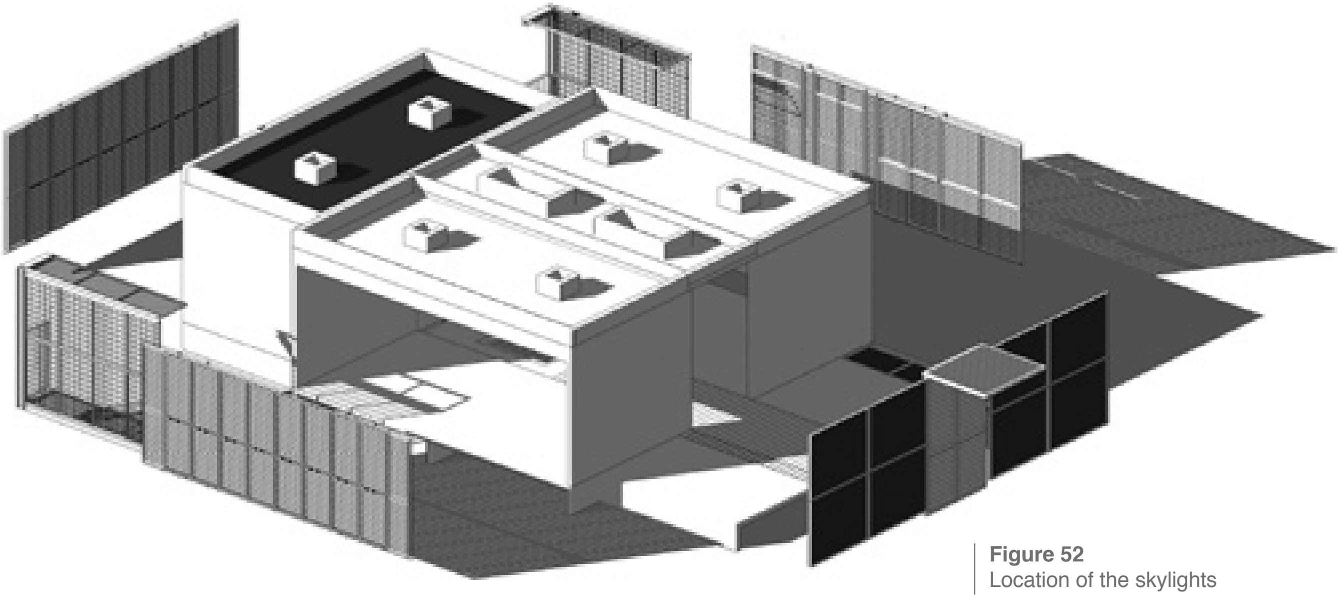

Figure 52
Location of the skylights

Engineering and construction of the MIHOUSE project

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Juliana Alexandra Muñoz Lombo (student)
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Structural design and complementary components

The city of Cali has a vulnerable seismic condition because it is located in the western region of Colombia, which is over the so-called "Ring of Fire" (Figure 53). This area is worldwide distinguished for its high probability of having major earthquakes. Consequently, it requires the construction of buildings with high resistance to such natural events.

The proposed constructive system for the MIHOUSE project is based on the prefabrication of pre-stressed concrete structural elements. This system, which originated in the process of post-war reconstruction, is recognized by its advantages in the construction of mass housing and for its reduced costs. This system has also been widely used in many parts of our country because it provides a safe structural solution for areas constantly affected by earthquakes.

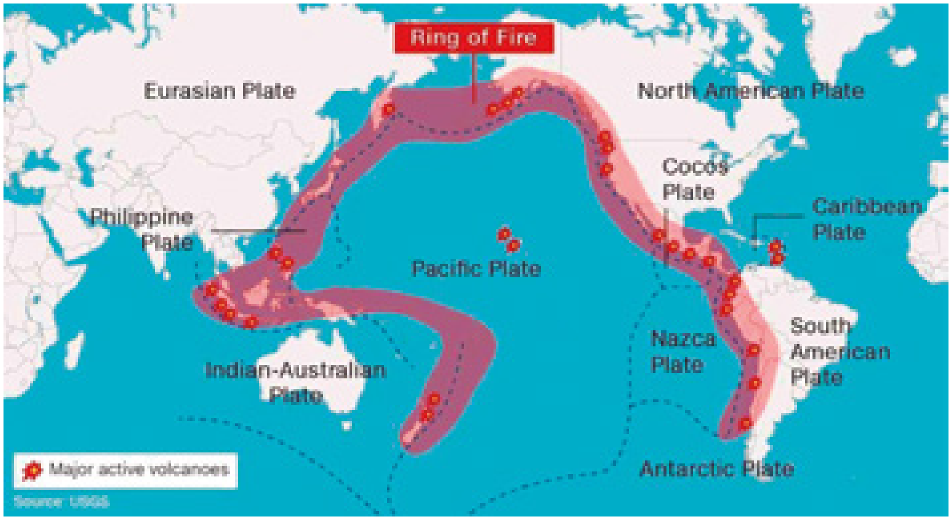

Figure 53
Ring of Fire
Source: http://www.geologyin.com/2018/01/the-ring-of-fire.html

The chosen materials and the principles of constructive and structural efficiency allows the MIHOUSE building to be shaped primarily with two prefabricated modules of pre-stressed concrete (the “main table as shown in Figure 54 and the “central table” as shown in Figure 55). These are conveniently positioned and assembled together to define the interior spatiality of each housing unit depending on the number of floors required for the technical and economic feasibility of the project.

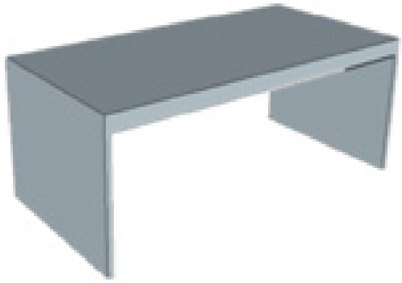

Figure 54
Main table

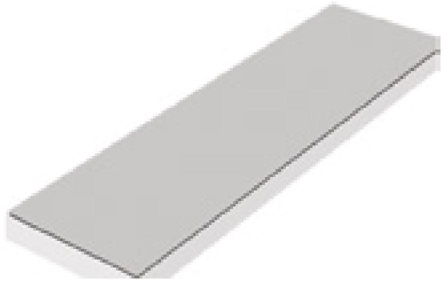

Figure 55
Central table

Resting on a foundation of reinforced concrete plate designed according to the type of terrain that apply in each case, the main structure of the building is resolved with a stack of these basic structural modules, linked together by mechanical fasteners that provide and ensure its comprehensive action to support vertical loads and horizontal seismic forces. Along with a perfect assembly of the constituent parts, this system excludes the need of drying the joints, which is one of the most critical points in traditional construction.

The following sequence show the assembly process of the “main tables” and “central tables” which piled up can conform the proposed 5-story building (Figure 56). This construction process is very clean, highly efficient and helps to avoid construction delays.

The wall lengths resulting in each orthogonal direction of the structural plan generate a high regularity of the building in response to earthquake resistance. This structure is symmetrical in its center of mass and center of rigidity; therefore, it provides a high reliability in accordance to the rules required by the Colombian Earthquake Resistant Building Regulations NSR-10.

A local firm expert in the design and construction of prefabricated concrete assessed the MIHOUSE structural proposal and earthquake resistance qualities. This

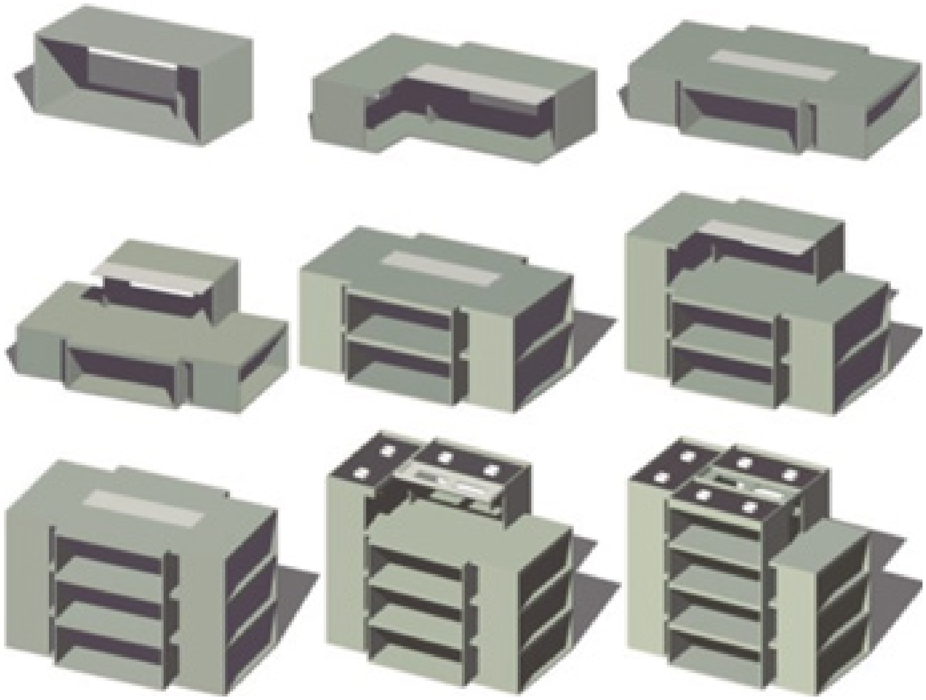

Figure 56
Structural assembly process

firm also provided the technical possibilities for the construction of the concrete modules and supported its construction process at the Solar Villa. Based on the firm´s professional experience in the local environment, it is possible to say that the construction method proposed is viable financially and could be highly competitive in the market of sustainable social housing.

An aspect to highlight is the attractive finishes that the precast concrete can generate when using a carefully designed formwork. In the MIHOUSE project, an effective control over the foundry processes was needed because the skin of the structure was going to remain exposed. This concrete used for the structure and for the skin of the building is part of the aesthetic goal of the MIHOUSE urban project and adds to its technical and financially viability by reducing the final cost of the building because no paints are needed to cover concrete surfaces.

Additionally, the final volume of the building is composed by the integration of smaller parts (Figure 57) that allow spatial flexibility. This enables a visually attractive set of full and empty plans and the possibility to generate multiple variations in the external façade of the building, thereby enriching the urban proposal. While it is true that the functional requirements of each module in response to its use vary according to the internal program needs of each housing unit, they only generate slight variations in the overall construction, which remains essentially composed by the two basic structural modules (main tables and central tables).

Non-structural elements (Figure 57) of different materials were used according to their embedded sustainable features and functional requirements. These elements are to be assembled with dry mechanical anchors to the main structure of the building, altering as little as possible its structural behavior.

Non-structural elements include the windows made of steel and plastic timber and internal drywall and super board divisions (which have a lighter weight compared to traditional walls made of bricks). These divisions contain the electric, sewage and hydric systems. All of these materials are manufactured locally and some of them are made of recycled raw materials, which contribute to the overall energetic evaluation of the proposal. These non-structural components adapt to the possibilities of spatial flexibility, which is an important characteristic of the MIHOUSE project, while drywall and super board walls permits the easy access for the maintenance of electric, sewage and hydric systems.

Moving up to the last floor (Figure 58), the concrete structure is covered by a light metal structure assembled with supporters of compatible materials. This structure carries the photovoltaic panels that generate 100% of the energy needed in the building. This light structure also serves as a visual and compositional architectural

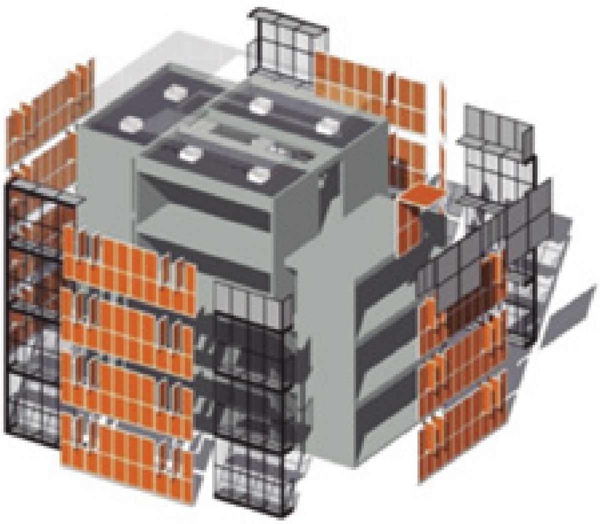

Figure 57
External elements assembled to the main structure

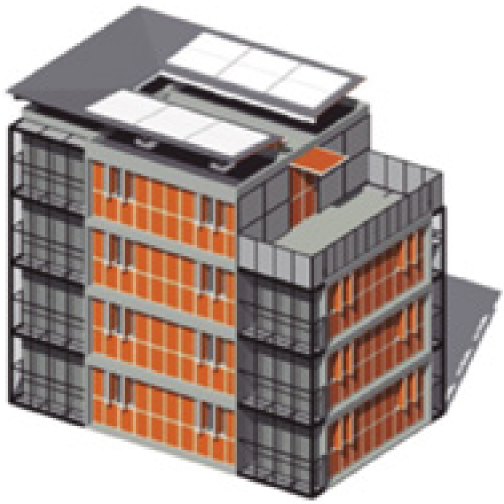

Figure 58
External appearance of the building

element that helps for thermal protection by generating shade. Additionally, it creates an air chamber between it and the concrete ceiling and helps in the collection of rainwater that is afterwards used for different purposes.

External circulation and vertical accesses that allow the entrance to the housing units are also prefabricated and adhered to the building. The union of three buildings and its vertical and horizontal circulations is considered in the urban proposal as a basic unit. This basic unit adhered to other basic units, conform the entire urban proposal.

It is important to mention that the MIHOUSE prototype at the Solar Villa follow most of the structural and constructive aspects mentioned before, however, since only the last floor of the building was constructed instead of the 5-story building, exceptions and adaptations were required. The most significant change in order to respond to the requirements of the contest was the use of three “main tables” and one “central table” with only 50 cm height for the base, resting directly over some metal plates on the ground. This low height tables transmitted the loads of the prototype to the ground just as the “main tables” of the fourth floor would transmit the loads to the third floor and subsequently to the ground. The rest of the pre-stressed concrete elements and indoor elements constructed in the MIHOUSE prototype at the Solar Villa preserve the real dimensions of the elements proposed for its large-scale construction in a real case scenario.

The construction process at the Solar Villa

Due to the short time available for the installation of the prototype in the Solar Villa, there are three basic points in which the MIHOUSE team agreed in order to be successful:

- If it is possible, the MIHOUSE prototype must be assembled and disassembled previously to its assembly at the Solar Villa, with the aim of allowing the team to rehearse and achieve the synchrony required to avoid construction delays, accidents and unforeseen eventualities.
- According to their possibilities, all of the components of the MIHOUSE prototype must be prefabricated and previously assembled.
- Only dry assemblies are allowed, meaning that no mortars, concrete or similar will be used.

In accordance with these points, the construction process of the MIHOUSE prototype is the following:

Corresponding with the technology of precast reinforced concrete, the parts that compose the principal structure of the prototype will be previously casted in a cellar with the use of a metal formwork, and afterwards moved and assembled at the assigned lot at the Solar Villa. These parts have been named “main tables” (Figure 54) and the “central tables” (Figure 55), and will be joined through high resistance mechanical anchors. The adequacies of the lot´s terrain as well as the low weight of the prototype, will allow the team to use a superficial foundation consistent of steel plates that distribute the weight of the structure to the previously compacted ground. Each piece weights around 15 tons and will be supported by three lineal bearings. The eventual seismic effects will be dissipated by the slide of this solid concrete box supported on the steel plates. It is to emphasize that this only applies in the construction of the prototype and not in the construction of the entire building, which should be sufficiently embedded with its foundation.

After the installation of the main structure and its access ramp (activities that will require specialized workforce, transport equipment and special cranes), the team will proceed with the assembly of the other parts that compose the MIHOUSE prototype (Figure 59). This will be done by the different working teams conformed by decathletes (faculty advisors and students) whom will count with a previous training to install and assemble the components. The first group of decathletes will be responsible for mounting the metal structure of the roof, which will be pinned to supporters over the top slab. This structure will afterwards carry the solar panels. Simultaneously, inside of the housing unit, other groups will manage the assembly of the different equipment and facilities required. Initially, that will imply the installation of the module with water facilities composed by the bathrooms and

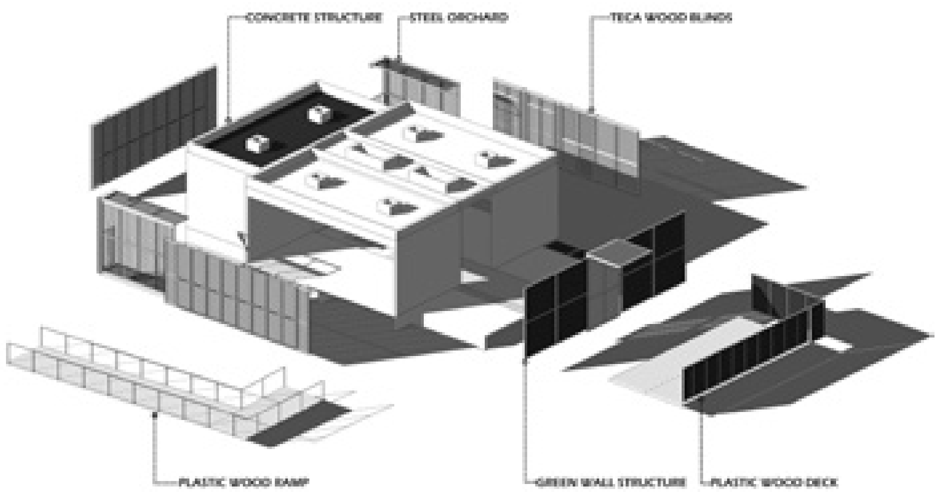

Figure 59
Some of the components to be assembled during the construction process

kitchen with its hydraulic and sanitary parts. In some cases, these parts will be located at the top slab and in other cases hidden below the false floor in the central part of the prototype. Other group of decathletes will manage the installation of fixed enclosures such as windows and internal modular divisions. The additional metallic structure on the façade that will support the proposed vegetation will also be assembled. Finally, depending on previous group arrangements, decorative elements are to be installed as well as the furniture and everything else needed for the jury evaluation (Figure 60).

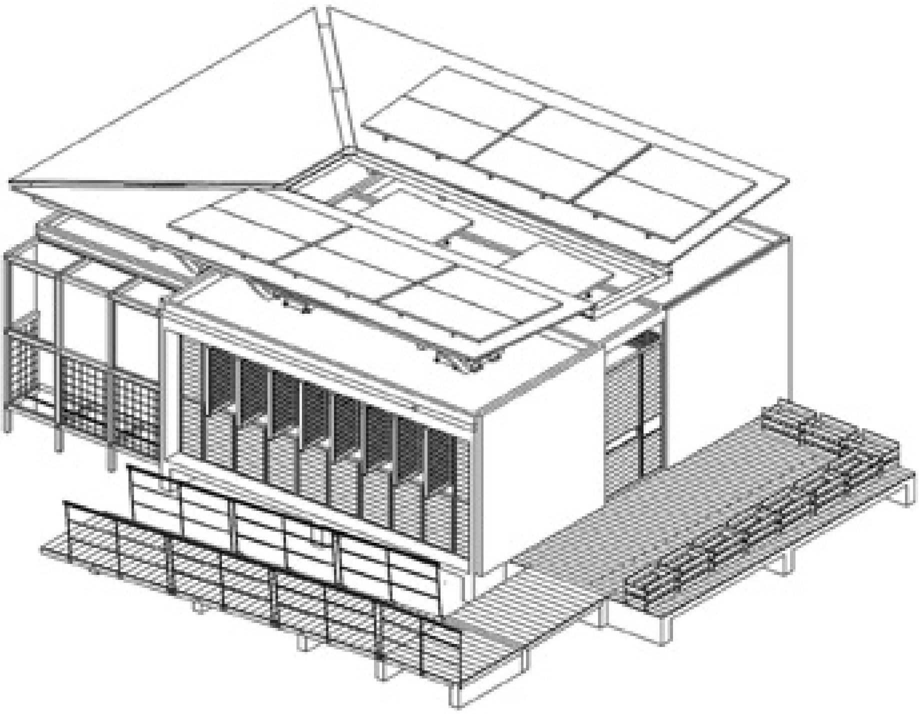

Figure 60
Finished prototype to be exposed at the Solar Villa

Innovative aspects of the MIHOUSE project

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General innovative aspects

The following are some general innovative aspects that the MIHOUSE project include:

- The urban and architectural designs are flexible, adaptable and bioclimatic.
- It includes home gardens that will supply with food products that add to the household´s income, while being green protected environments.
- It proposes new ecologic materials with enhanced mechanical properties in its construction.
- Promotes de use of recycled materials and regional products.
- It is energy efficient due to the use of solar photovoltaic panels that supply the energy required to satisfy the demand of the houses. It is possible to sale the surplus to the electric national grid.
- It achieves around 23% of drinking water savings by collecting rainwater that will be channeled to underground storage tanks.
- The rainwater harvesting provides the water supply for green areas and residential gardens.
- There will be a reduction of solid waste for final disposal (approximately 6.54 ton/month) by incorporating strategies for solid waste treatment.
- Proper areas for the separation, classification and storage of ordinary, organic and inorganic waste are included in the urban proposal.
- Composting areas to treat organic waste that will later be used as fertilizer in the gardens are included in the urban proposal.
- The prefabricated elements of the structural system allow a high efficiency in the construction and the fulfillment of construction norms.
- Technological apps have been created to help the inhabitants reduce their energy consumption.

Specific innovative aspects incorporated in the urban design

From the first sketch, the MIHOUSE team incorporated innovative and sustainable aspects to the project´s urban design ¡Error! No se encuentra el origen de la referencia.. It was important to create an energy efficient urban housing project that could integrate its dense areas with green open public spaces. Such consideration adds to the contemplation of the environment and promotes the social integration of the inhabitants. It was also taken into consideration the use of water and its treatment, and the care for waste management and disposal, aspects that are scarcely studied in the construction of conventional housing proposals.

In terms of density, MIHOUSE project contains 150 living units per hectare. These dwellings are surrounded by green open spaces that permit different social and recreational activities that help in the construction of community life and well-being (Figure 43). This was considered because the MIHOUSE team believes good neighborhoods provide safe areas for the permanence of children and adults and the contemplation of natural resources. This is the reason why native tree species where incorporated (Figure 44), in addition to the fact that this helps in the conservation of local flora and fauna that maintain green urban corridors. Composting areas were also included and open spaces for outdoor activities (Figure 61).

MIHOUSE proposal is composed by elements of different sizes: there are blocks, sets and groups of buildings. As we put together these elements, in-between spaces are created. Both occupied and empty spaces are regulated by a modular system that organizes their positions. We can say that the urban proposal is conceived from smaller parts that can be copied, joined and organized, creating outdoor spaces that can be used as parks in-between buildings, as well as creating internal spaces that can be used as mini markets, childcare facilities, training spaces, among others (Figure 43). Also regulated by this modular grid, there is a reserved area for waste storage and other facilities in strategic areas of the project.

Driveways and parking areas were located guarantying accessibility but at the same time giving priority to pedestrian circulation throughout the project (Figure 45). These circulations paths make the project permeable and safe since the inhabitants will be continuously walking between the buildings or observing from their homes.

Specific innovative aspects incorporated in the construction process

MIHOUSE prototype at the Solar Village corresponds to the fifth floor of one building from the urban complex. During the innovative construction process of the housing

Figure 61
Render of public spaces within the MIHOUSE urban proposal

prototype, prefabricated elements are considered, keeping the same material of the structure used for the urban complex but making the necessary recalculations for a single unit. This allows the assembly of MIHOUSE in a record time of 10 days, which is the permitted time at the Solar Villa. As for the different parts and pieces, they are to be assembled preferably with dry connections such as bolts, screws, etc., as it would be in the real building. The construction of the prototype requires active collaboration from all team members who develop synchronized activities to achieve the effective assembly on this huge “LEGO”.

The construction industry can reduce its environmental impact by using local materials and industrial waste transformed into new construction materials. Therefore, the MIHOUSE proposal incorporates innovative local technological advances that take in consideration the life cycle of the materials used for construction, and technologies that provide alternatives to conventional materials. Some of the innovative materials developed at USB for MIHOUSE, improved conventional products developed on the construction sector and help in the reduction of urban heat islands:

- Permeable concrete: It is a solid material, which allows 100% of the passage of water. This characteristic is due to its specific design, which has the mechanical properties of a traditional concrete. It also has anti-slip properties, greater surface area, less expansion of the slab and is cheaper by 35% compared to conventional concrete. These properties make permeable concrete an innovative material in Colombia.
- Lightweight concrete with coal stones: The lightweight concrete, as traditional concrete, is a compound of aggregates, cement and water. The difference is its lower density and strength. Given this, the innovative product calculated for MIHOUSE is the lightweight concrete with coal stone, which can be used as structural concrete with low density. Using this kind of concrete in the construction of the MIHOUSE project will reduce the structure´s weight in a 20% without reducing its mechanical strength. This innovative aspect is important for the transportation and installation processes of the concrete tables. The lightweight concrete also has a high thermal insulation capacity which makes it a necessary material for buildings in warm areas. This product is also environmentally friendly because it uses aggregates that come from the waste of the paper industry, which makes the cost of this material cheaper compared to the cost of traditional concrete, both in production and in the installation.

Although both materials were highly innovative, due to the limited time for constructing at the Solar Villa, traditional concrete was used for the construction of the final structural tables. However, the overall urban proposal was conceived to use the mentioned innovative materials because they are part of the bioclimatic design strategies that help in the energy balance, heat transfer and heat flow from the outside to the inside of the building. Additionally, the costs of the structure results cheaper and lighter without risking its strength and resistance.

General innovative aspects related to water management

The MIHOUSE urban proposal seeks for the following main aspects related to an efficient water management: the exploitation of rainwater, the reuse of gray water and the reduction in the consumption of drinking water for non-potable uses.

As previously mentioned, each building has a metal roofed structure. This structure helps in the collection of rainwater that can subsequently be used for different purposes both in the residential unit and in the urban proposal. At urban scale, the collected rainwater can serve for irrigating green areas, parks, community crops and orchards. In the residential unit, the collected rainwater can be used for non-potable uses such as household cleaning, watering the plants or home gardens and for the first flush of sanitary tanks.

As for the gray water resulting from doing laundry, showering and the washing machine, it can be used for toilet flushing. This water is treated by using a grease trap system and a wetland, where it is stored previously to being taken to toilet tanks. The process is natural, innovative an economic. Both the rainwater collection system that allows the use of free rainwater and the gray water treatment proposed, help to reduce the overall drinking water consumption, making it an innovative aspect in the MIHOUSE project.

General innovative aspects related to energy efficiency

The MIHOUSE proposal had to be since the beginning an energy efficient, comfortable low-income home. This fact challenged the MIHOUSE group because it was understood that an extremely energy efficient home, required innovative technologies such as highly efficient solar cell modules, efficient lighting systems and modern low-consumption appliances:

Use of solar panels

The high energy efficiency required was obtained by following an organized methodology for designing and selecting economic photovoltaic solar modules with higher power ratios but with less area than similar modules, and more efficient electronic technologies to convert and adequate the DC signal from the panels to the house, producing higher energy values in the useful area. The total solar electric PV system consists of 544 Canadian 310 watt panels for a total peak power of 168kW placed on a roofed system. This system is connected to the electronic subcomponents that connect the solar power to the living unit. This system is large enough to supply the living unit with enough power during daytime for three days without sunlight. In consequence, MIHOUSE´s solar photovoltaic system was designed for meeting the energy demand and to produce surplus energy that could maintain charged batteries.

The MIHOUSE project also incorporated the usage of grid interactive inverters, charge controllers and batteries. It means that this system will use its own produced electricity and additionally, it will also be able of selling the surplus (excess) energy to the city´s grid at a reasonable price, making the system sustainable over the time. Subsequently, this urban complex will be ready to sell energy to the national grid as soon as the new Colombian Renewable Energies Law 1715 from May 2014 announces the trading price. This law promotes the installation and integration of renewable energies into the electrical network of the National Regulator Commission-CREG.

After all the ideas, researches and decisions taken during many meeting hours, the team designed an efficient project in terms of solar power generation and consumption. Therefore, the MIHOUSE prototype can demonstrate to the visitors of the Solar Village the state of art in photovoltaic solar technologies integrated as architectural elements in low-income households that bring benefits to people living in tropical contexts.

Use of natural light

To increase energy efficiency and reduce power consumption, sun radiation is used to illuminate naturally. This is free and available throughout the day. However, using this source of natural and clean energy needed to take into consideration the following aspects:

Large windows. They allow daylight by diffusion and reflection of sunlight into the interior. They must be taken into account during the building design process unless the living unit is permanently in zones with very high temperatures, thus direct sunlight would create high interior temperatures.

Direct sunlight in interior working areas must be avoided.

The potential use of natural light must be considered and analyzed with the purpose of coordinating the time hours in which it is available and the time hours in which artificial lighting devices will be used instead, according to the sun schedule at the place where the building is to be located.

The equipment selection used to control artificial and natural lighting should add to the energy efficiency strategy of the home and prevent air conditioning systems.

The levels of radiation of natural light and its lasting time (or duration periods) have to be clear.

Interior lighting should consider the following objectives:

- Maximize light transmission through window glass (it is measured per unit area of window).
- Check the clarity contrast, especially between windows and walls.
- Minimize veiling glare on work surfaces, resulting from direct sun light in the upper windows.
- Minimize the daytime heat during sunny days, using eaves or umbrellas.

Use of LED lighting

The MIHOUSE project uses LED lights because they are brighter and consume up to 90 percent less energy than conventional lighting methods. LED light is efficient and the energy is not wasted in the form of heat as it happens in traditional bulbs. Normally, incandescent bulbs have 10 lumen per watt (lm/W) efficiency while LED have 90 to 110 lm/W. This is more efficient than incandescent or fluorescent light. Additionally, LED bulbs work for more than 10.000 hours, which make them cheaper in long term and more environmentally friendly because they do not use gases in its interior that can pollute the environment. Finally, they have electronic devices easy to replace and reuse.

The selection of LED luminaires for MIHOUSE implied a comparison of available LED technologies, LED brands, the lifetime of the luminaires, the light inputs, the efficiency, the temperature, the color of the light and the product guarantee. From the consumer´s side, it was previewed the use of LED lights, high efficient microwaves, and low consumption appliances that would not reduce the families´ comfort represented on the use of items such as the internet connection, LED-TVs or sound systems.

Use of energy efficient appliances

The MIHOUSE team carefully selected efficient home appliances taking into consideration the needs of each space in the housing unit. This was done by checking the energy efficiency-rating label (Table 11) of every appliance and by choosing only the ones classified with letter A or B, which are the codes given to home appliances that have energy savings of 45% and 25%.

Table 11
Energy efficiency rating label

Energía Fabricante Marca Modelo/Tensión (V)	Lavadora ABCDEF XYZ (logo) IPQR/220	Indica el tipo de electrodoméstico Indica el nombre del fabricante Indica la marca comercial o logomarca Indica el modelo del aparato y la tensión con la que funciona normalmente 220
Más eficientes A B C D E F G Menos eficientes		La letra indica la eficiencia energética del electrodoméstico
Consumo de energía (kWh/ciclo) (Dependiendo de los resultados de un ciclo de lavado normal de tejidos de algodón a 60º)	XY, Z	Indica el consumo de energía en kWcicle
Eficiencia de lavado A: más elevada G: más baja	ABCDEFG	La letra indica la eficiencia de lavado
Eficiencia de secado A: más elevada G: más baja Velocidad de centrifugado (rpm)	ABCDEFG 1.000	La letra indica la eficiencia de secado Indica la velocidad de centrifugado
Capacidad de lavado (kg) Capacidad de agua (l)	Y,Z YZ	

Sustainable aspects of the MIHOUSE project

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General sustainability aspects of the MIHOUSE project

MIHOUSE project focuses on achieving a balance between the three pillars of sustainable development: the economy, the society and the environment. The environmental component is included transversally in all the activities, designs, plans and processes carried out in the MIHOUSE urban proposal. Simultaneously, the social and economic aspects are oriented to guarantee food security, the affordability of a high quality social housing project and the inclusiveness of the population through the generation of job opportunities for the production, management and marketing of crops cultivated in communitarian and private gardens. An example that combines the three previously mentioned sustainability aspects is the transformation of organic solid wastes produced by the families in MIHOUSE, which could be composted, later on marketed and used as fertilizer in gardens, allowing the inhabitants to have job opportunities within their area of residence.

Additionally, the MIHOUSE design is a dynamic and sustainable solution for real neighborhood conditions in the city of Cali, Colombia and for tropical countries due to the fact that it can be adapted to different terrains in cities with similar climatic conditions. MIHOUSE is also an affordable and innovative solution for deteriorated neighborhoods. In the specific context of “El Paraíso” neighborhood, the buildings included a high density of 128 living units, however more buildings could be attached in additional hectares if the willing is to expand the neighborhood to productive purposes. Furthermore, the design includes generous green environments in spaces as parks and community areas that complement the comfortable, flexible, progressive and productive living unit along the time.

Considering sustainable principles, an integrated water management plan was designed, in which rainwater collection allows the inhabitants to consume less potable water because, as with the use of gray water, it will be reused for cleaning, watering the plants and for toilets tanks, among others. For the integrated solid waste management, the creation of a small company to manage the community’s residues is proposed. Likewise, MIHOUSE takes advantage of the Sun as a free energy source using a solar photovoltaic grid-connected system with storage capacity. This system will produce and use its own electrical energy and will be able to sell the excess of captured energy to the national grid, making the system sustainable over the time. All of these savings and synergies proposed by the MIHOUSE project aims to convert it into a promoter of positive and lasting impacts on cities, especially in contrast to conventional unsustainable social housing projects.

MIHOUSE also adds to the preservation of natural resources because it considers key aspects stated in the Resolution 0549 of 2015 from the Colombian legislation, which cares for sustainable construction and water and energy savings in buildings. Thus, MIHOUSE will be the first project to achieve sustainability among all of the social housing projects in Colombia if it gets massively constructed after the Solar Decathlon contest. Further aspects related to the sustainability of the MIHOUSE project are:

The bioclimatic strategies

According to the climatic conditions of the city of Cali, Colombia, several major passive design strategies are available to promote environmental comfort to users of residential environments. Some of the strategies include the use of sunscreen openings, the use of natural ventilation and the incorporation of facade systems (materials, walls and covers) to ensure the control of heat transfer into the environment (Chart 2 and Chart 3).

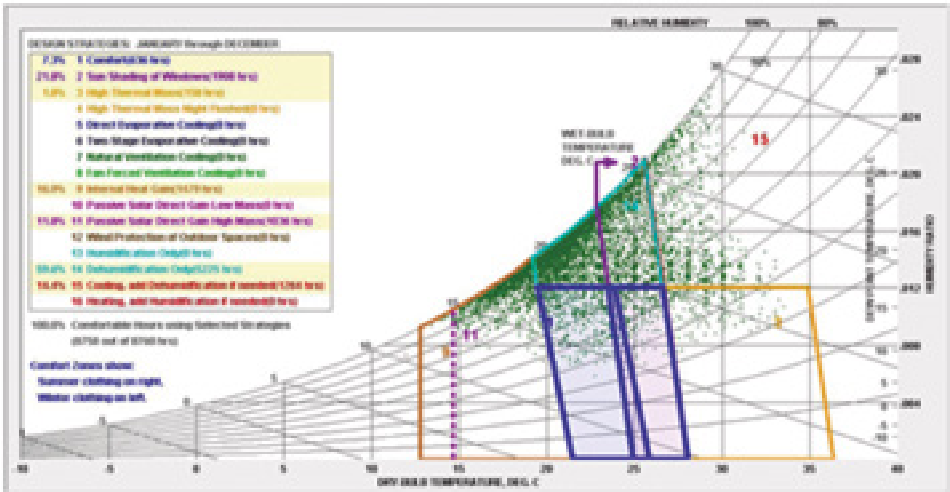


Chart 2
Design strategies to favor thermal comfort.

Design strategies according ASHRAE Standard 55 and Current Handbook of Fundamental Model. Chart generated with the Climate Consultant 6.0 BETA program.

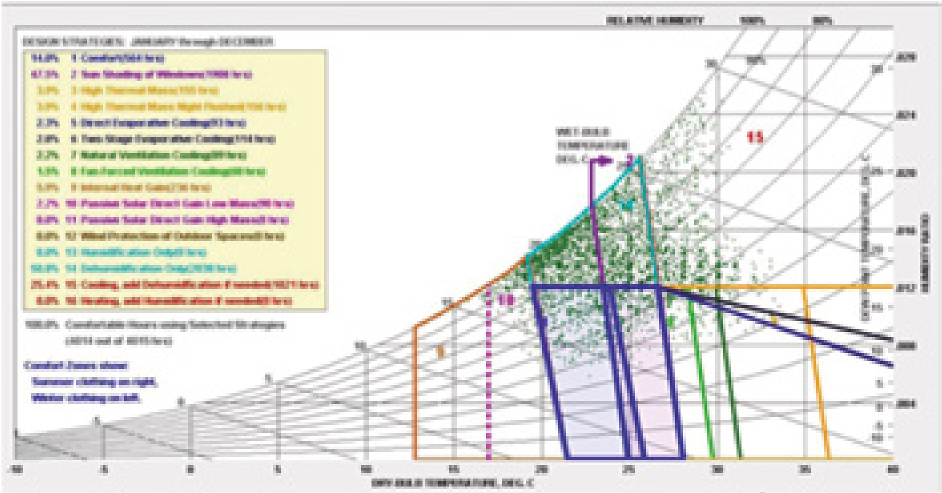


Chart 3
Design strategies to favor thermal comfort between 7h and 17h

Design strategies according ASHRAE Standard 55 and Current Handbook of Fundamental Model. Chart generated with the Climate Consultant 6.0 BETA program.

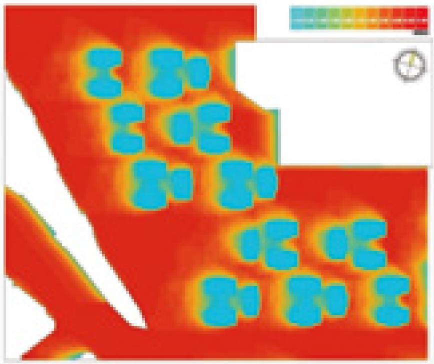
The bioclimatic aspects at urban scale

From the bioclimatic point of view, a proper urban proposal located in the city of Cali, Colombia, should consider elements for shadow generation and the use of natural ventilation paths with sitting or resting areas. Using the ECOTECT program, different simulations were ran to make a diagnosis of aspects related to sunlight and natural ventilation in MIHOUSE´s urban proposal.

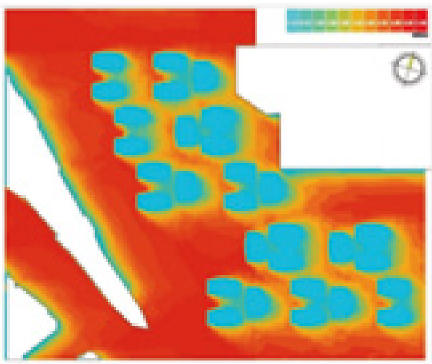
With regard to sunlight, the images below show exposure to direct sunlight on a grid of points located at ground level. The cyan color blocks correspond to the buildings, which are areas with no sunlight incidence. The ranges in orange and red show over 2.5 hours on average per day (morning and afternoon) of exposure to direct sunlight (Picture 6 and Picture 7). The results served as reference for a proposal of forestation of areas and footpaths.

Regarding urban ventilation, the positioning of the buildings in the urban proposal allows the ventilation along the entire lot. This is because the wind passes through gardens, fixed points, orchards and all the spaces between buildings. The wind flows both at pedestrian level and at upper levels. Picture 8 shows the natural ventilation flow through the urban project.

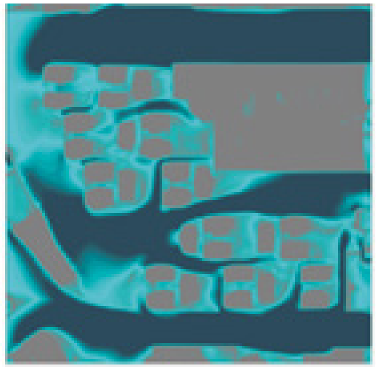
MIHOUSE urban proposal includes the provision of autochthonous trees specially selected according to the local natural conditions (see Table 3 to Table 10). Computer simulations of every selected specie were performed using the ECOTECT software in order to identify the potential shadow to be generated by the trees. The



Picture 6
Areas in the urban proposal with exposure to direct sunlight (morning)

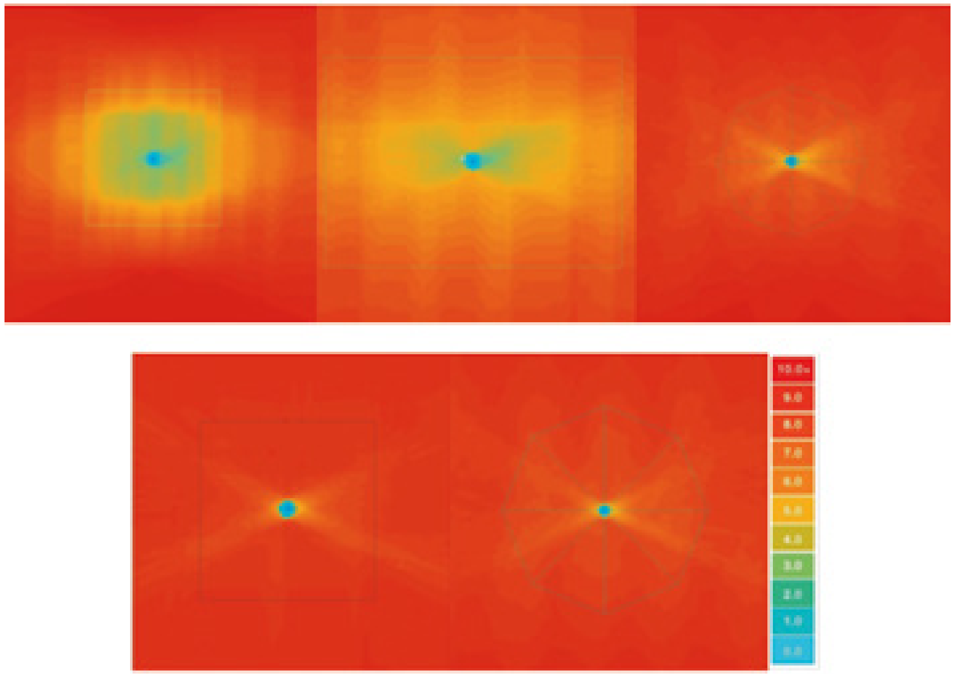


Picture 7
Areas in the urban proposal with exposure to direct sunlight (afternoon)



Picture 8
Ventilation flow through the MIHOUSE urban proposal

results of the simulations of species show the average hours of exposure to direct sunlight on a grid of points located on the floor during a day, just under the tree (**Picture 9**). The simulation results are shown in a graphical scale of 0 to 10 hours.



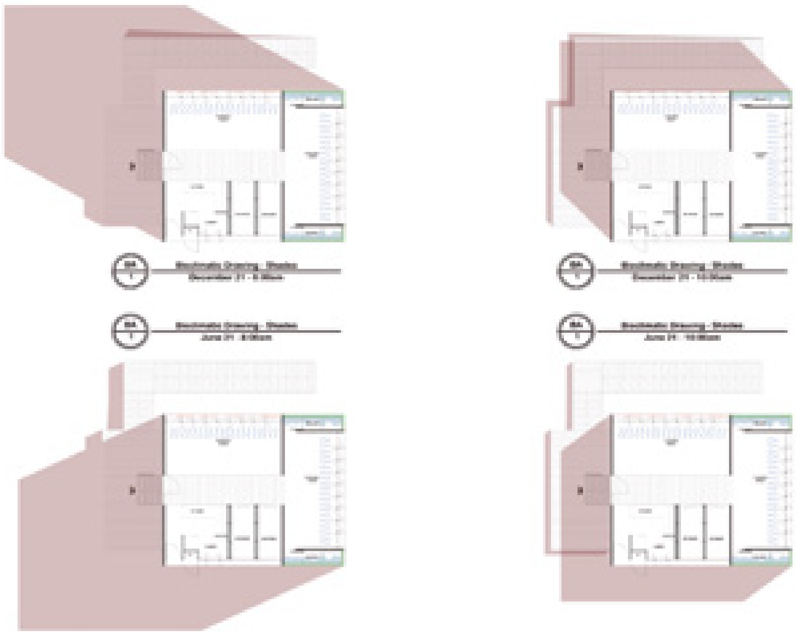
Picture 9
Simulation of the potential shadow generated by the selected species of trees

The first two simulations show 2 species of trees that could produce a larger shadow compared to the shadow produced by the other 3 species. This means that people can walk or sit beneath the shade of these 2 species feeling less of the impact of direct sunlight.

The results together with the recommendation of available species, served as inputs to design the ideal grouping of trees for paths, corners and parks, among others, in the MIHOUSE urban proposal. The shadow potential of the selected species also aimed to contribute to the thermal comfort of the urban area where the project is located.

The bioclimatic aspects of the MIHOUSE prototype

Picture 10 is a representation of how bioclimatic aspects as sunlight and ventilation affect the MIHOUSE prototype at the Solar Villa during the months of December and June, more specifically on the 21st of those months, at 8:00 am and 10:00 am. It is shown how the projected shade differs drastically, meaning that during the mornings in December the exposure to sunlight is higher in the eastern and southern facades, while the northern and eastern facades are more exposed during the month of June. In both cases, the ventilation flows seems to remain constant.

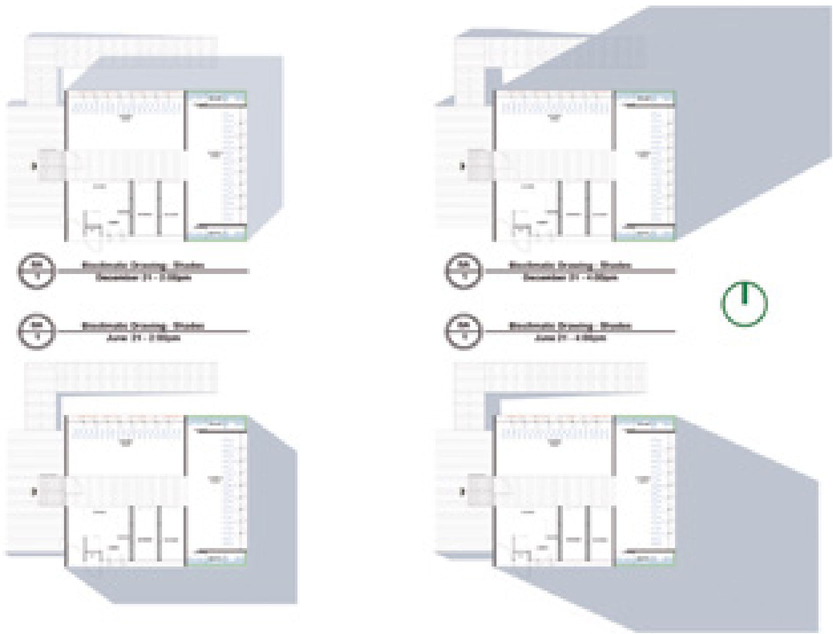


Picture 10
Shade and ventilation projections (December and June 21st, at 8h and 10:00h)

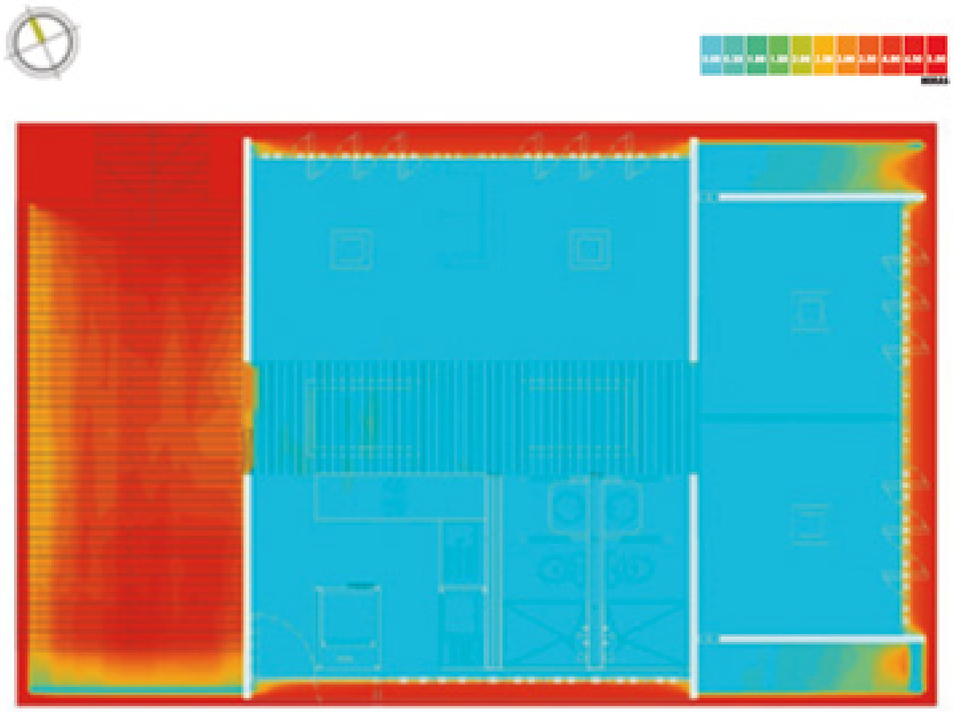
Picture 11 represents how sunlight and ventilation affect the MIHOUSE prototype at the Solar Villa during the months of December and June, more specifically on the 21st of those months, at 2:00 pm and 4:00 pm. It is shown how the projected shade differs drastically, meaning that during the afternoons in December the exposure to sunlight is higher in the western and southern facades, while the northern and western facades are more exposed during the month of June. In both cases, the ventilation flows seems to remain constant.

The sunlight exposure of the MIHOUSE prototype was also explored through computer simulations with the ECOTEC software with the purpose of achieving a desired performance in relation to the solar incidence. These simulations calculated the daily average hours of exposure to direct sunlight for every day of the year between 07h and 17h, departing from a grid of dots arranged at floor level. In Picture 12, the prototype areas highlighted in cyan represent areas with no exposure to direct sunlight, while the areas highlighted in the range of orange and red, represent the areas within the prototype, which are excessively exposed to direct sunlight.

In response, shutters and vegetation were included in the façades to mitigate solar radiation throughout the year. In consequence, the heat gained by solar radiation is not significant in the simulation model. This represents an ideal condition obtai-



Picture 11
Shade and ventilation projections (December and June 21st, at 14h and 16h)

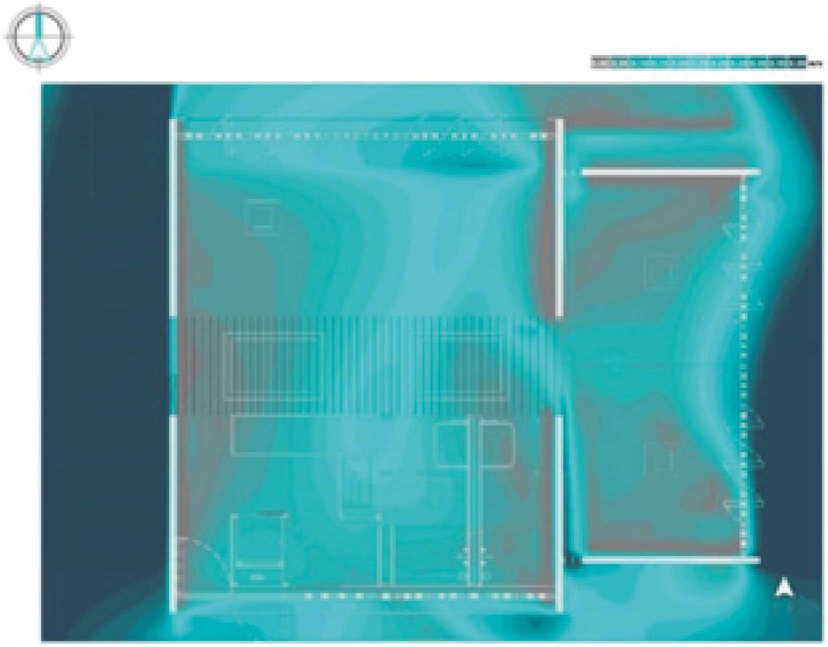


Picture 12
Average of hours of exposure/day to direct sunlight (all year between 7h and 17h)

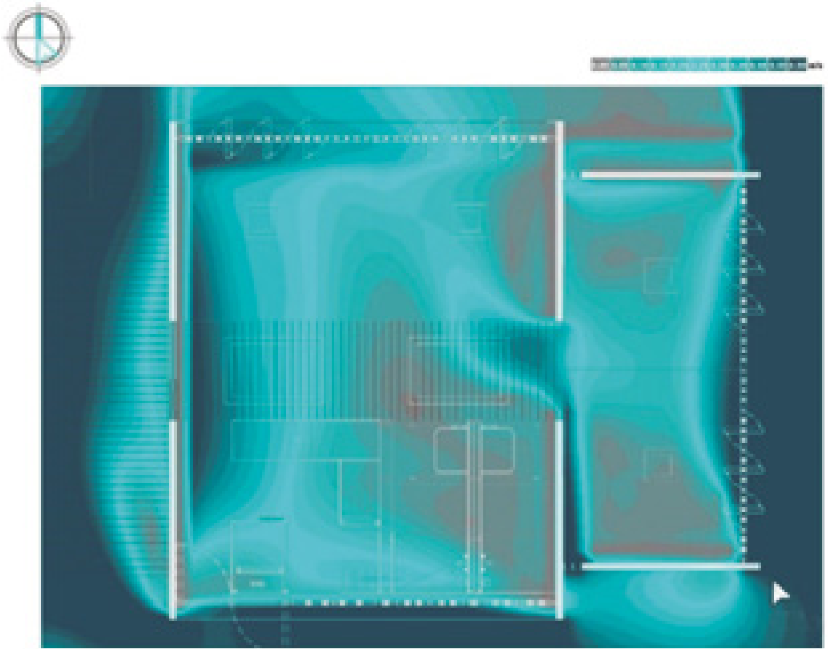
ned in terms of control of external heat gains by solar radiation, according to the climate calculations in Chart 3, which mentions that 47.5% of the time, thermal comfort can be promoted with the sun shading of windows.

Regarding the use of natural ventilation, in order to evaluate the use of wind currents, computer simulations were performed using the plug-in in the ECOTECT CFD software. An average speed of 2 m/s was considered and different directions according to the time of day: early morning (south), morning (southeast), afternoon (northeast) and night (northwest). Picture 13, Picture 14, Picture 15 and Picture 16 (in plain view) show the distribution of the wind scale colors (dark blue represents the maximum speed, light blue represents low speed and grey represents null) at a height of 1.5 m.

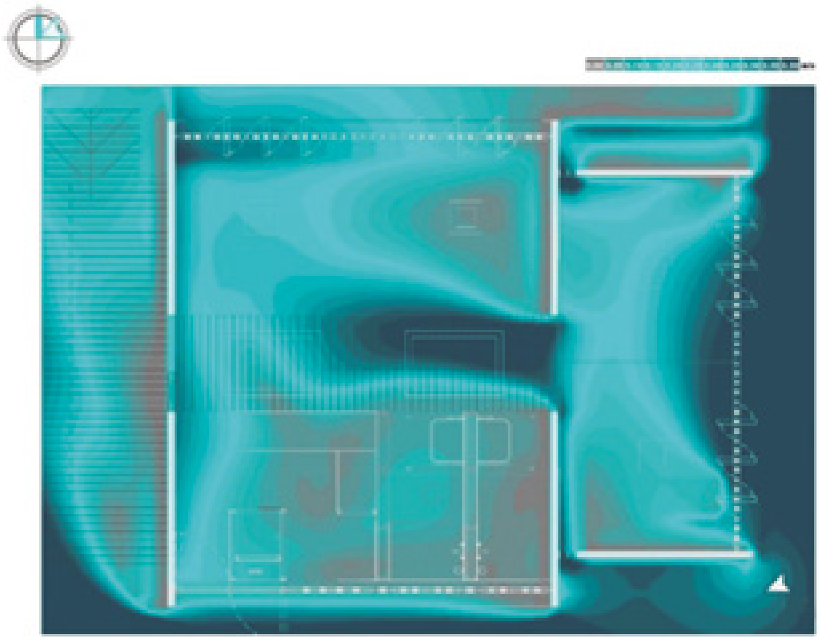
During the morning and evening hours, internal wind currents have lower speed than during the afternoon; this represents a desirable situation that reduces the possible sensation of heat registered in the afternoon due to temperature peaks and heat accumulation gained throughout the day.



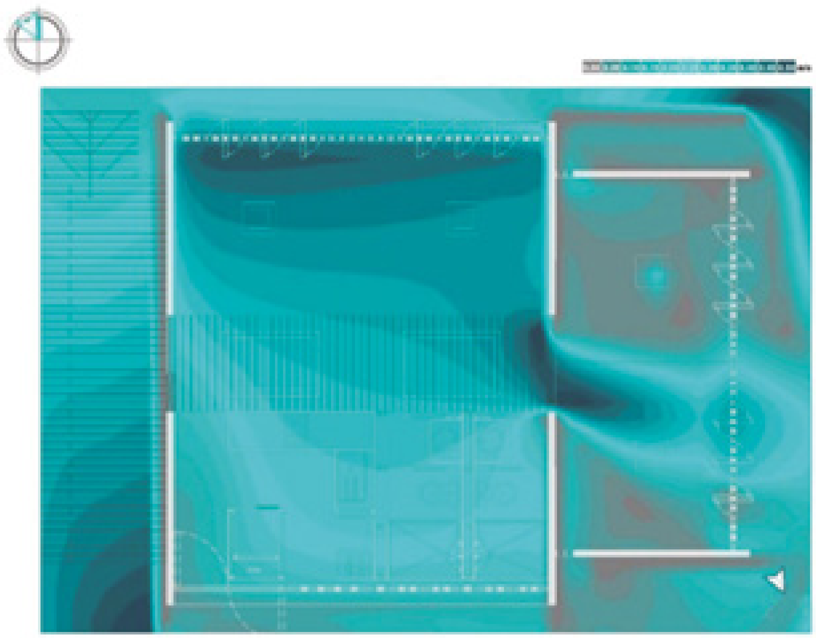
Picture 13
Use of natural ventilation during the early morning



Picture 14
Use of natural ventilation during the morning

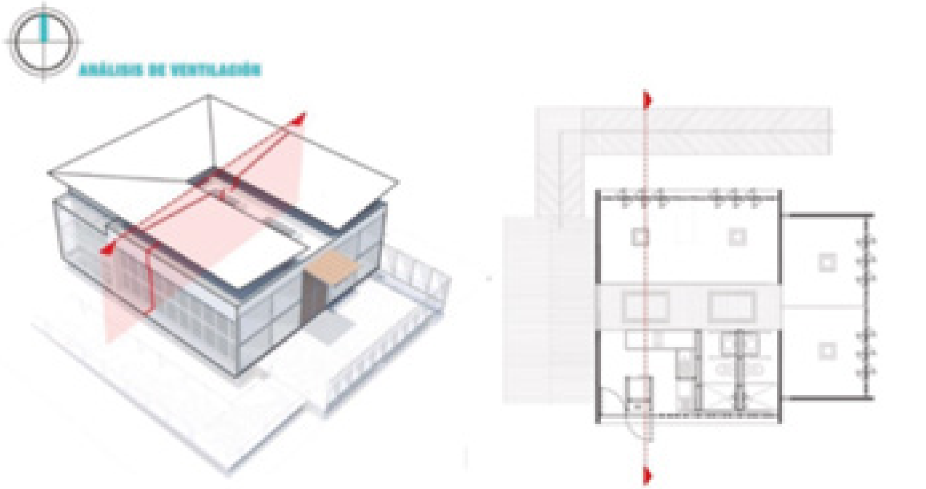


Picture 15
Use of natural ventilation during the afternoon

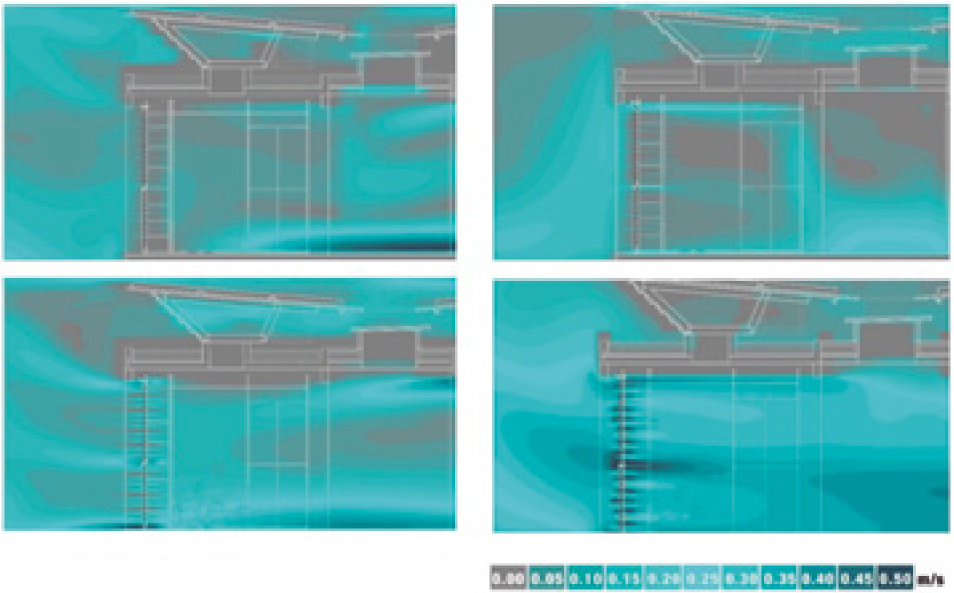


Picture 16
Use of natural ventilation during the night

Subsequently, the analysis of the elevation of the ventilation was done using a section of the prototype (Picture 17 and Picture 18):



Picture 17
Section for the analysis of ventilation

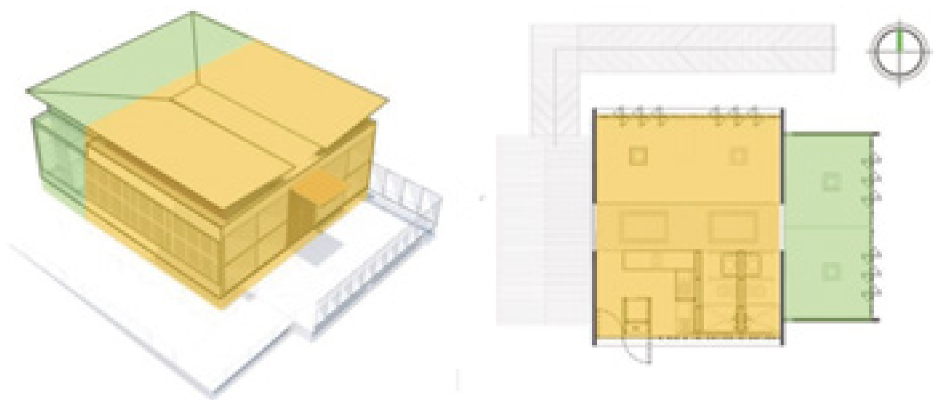


Picture 18
Section view. Natural ventilation flows through vertical and horizontal openings

The compositional system of the MIHOUSE prototype generates a sheltered space; however, this does not limit indoor-outdoor relationships. In consequence, the wind leaks inside through a facade system that sieves and regulates its access, enabling the air changes and assisting the extraction of hot air. This interaction with the outside is possible thanks to the shutters and vegetated windows installed on vertical surfaces, and to the upper openings in the roof (see skylights in Figure 52).

The thermal behavior inside the MIHOUSE prototype was calculated using a table developed by Dr. Eduardo González. This table takes into consideration different aspects of the building such as the volume, the thickness of materials and their specifications, the openings in the facades and roofs, the internal heat gaining's, among others. It also considers aspects of the context where the project is located, such as weather conditions, average temperature, average temperature difference, solar radiation on site, etc. Once gathered all this information it was possible to calculate the heat balance that determined the needed temperature to provide comfort. For MIHOUSE, the resulting temperature for comfort was set at 25.2°C, which is the maximum indoor comfort temperature for warm tropical cities as Cali. Furthermore, the table also helped to determine the average temperature inside the prototype, making possible its comparison with the desired comfort temperature.

For the implementation of the calculations previously described, it was necessary to divide the space within the prototype in two sub-spaces (Picture 19): the yellow area, where the access, kitchen, bathrooms, main corridor and living room are located (Area 1); and the green area, where two rooms are located (Area 2).



Picture 19
Zoning for heat balance calculations

Results for Area 1

Shutters cover a significant percentage of the facade of this area, which allows the passage of wind while limiting the entry of sunlight. These two effects are the most efficient way to avoid overheating in the interior of the prototype. Another result is the air exchange rate of 12 r/h, which permits an excellent air quality, meaning that the volume of air is renewed 12 times during an hour. Additionally, having a double roof (composed by a metal roofed structure over a concrete structure), allows the formation of an air chamber that efficiently absorbs the heat transfer from outside to the inside.

Chart 4 shows a comparison between the outside temperature (see "Exterior"), the comfort temperature (see "Confort"), and the temperature in Area 1 (see "Edificio"). It is clear that the maximum temperature of "Edificio" is quite close to the maximum temperature of "Confort" (only 0.4°C above). In turn, the average and minimum temperatures of "Edificio" are lower than the average and minimum temperatures of "Confort", ensuring that the interior environment of area 1 will be comfortable. It is important to note that when it comes to housing, the most important thing is to ensure comfort in places where the permanence is high, such as in social areas, which is a met objective in the MIHOUSE prototype.

The building already has protection from direct sunlight, has good ventilation and a comfortable indoor temperature. However, in case the indoor temperature needed to be lower, a passive system of radiated cooling could be implemented

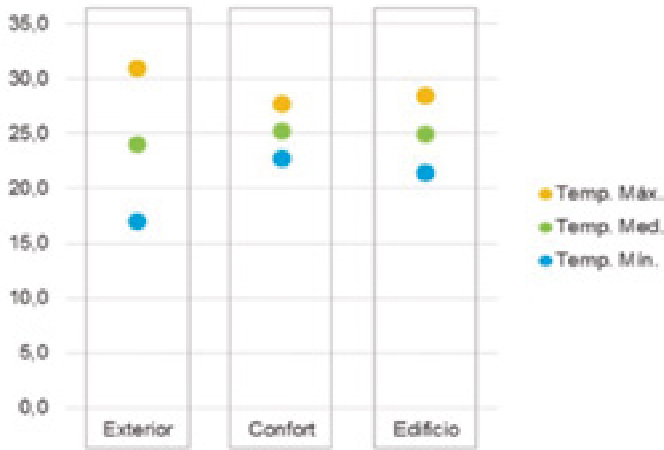
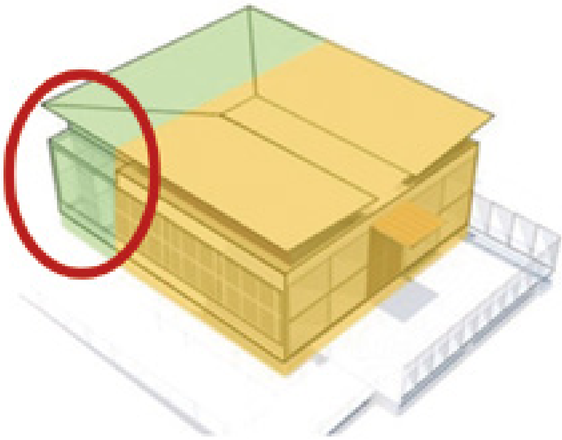


Chart 4
Comparison of external, comfort and indoor temperatures for Area 1

on the roof. This would be possible, as indicated by Eduardo Gonzalez strategy (2002), with a thin layer of water on the deck that will help to cool the indoor environment.

Results for Area 2

Area 2 has small balconies attached to each of the rooms. These balconies are external to the rooms and are connected to them with shuttered doors of similar conditions to the shutters used for the windows. These balconies are known as “jaulas” in Spanish or “cages” in English, because they are delimited by a light vegetated metal structure that gives the appearance of a cage (Picture 20).



Picture 20
“Cages” or “Jaulas” made of a light vegetated metal structure

These “cages” have a dual function: providing a space for growing small plants and vegetables, and allowing the growth of a vegetated permeable wall that absorbs the heat and solar radiation while letting the passage of the constant ventilation. Such considerations were useful to protect the concreted walls adjacent to bedrooms and to benefit the indoor thermal comfort.

In consequence, for Area 2, heat balance calculations with two different situations were made: when the doors to the “cages” of the northeastern and southeastern corners were opened and when they were closed. This differentiation was taken into consideration because either if they were opened or closed, it would affect the possibility of maintaining a constant flow of ventilation. Chart 5 shows that when the shuttered doors of the cages were open, the maximum indoor temperature (see “Edificio”) is equal to the maximum comfort temperature (see “Confort”); while the average and minimum temperatures remain lower than the average and minimum temperatures of comfort due to the ratio of apertures for ventilation.

In the case of having the doors closed, Area 2 increases its temperature. This happens because there is a smaller ration of apertures for ventilation, preventing the constant flow of air. Chart 6 shows that the maximum and average temperatures for Area 2 (see "Edificio") are 1.4°C and 0.4°C respectively, above the maximum and average temperatures of comfort (see "Confort"), while the minimum is below. While there is a very high difference to ensure that the temperature of Area 2 is always kept below the optimum maximum confort range, there is an evidenced need to have doors with some degree of porosity to allow the passage of air. In consequence, shuttered doors with the same geometry and openings of the shutters for the windows were included to maintain the crossed ventilation and to decrease the indoor temperature even is the doors were closed.

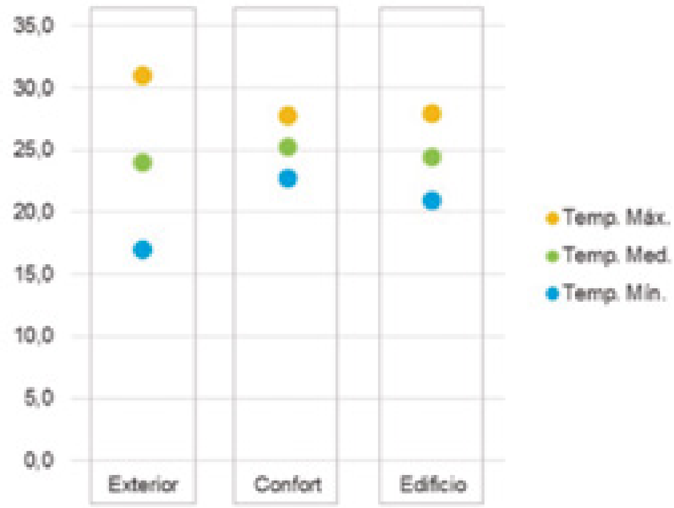


Chart 5
Comparison of external, comfort and indoor temperatures for Area 2 (opened doors)

In order to verify the entrance of natural illumination to the MIHOUSE prototype, computer simulations were performed using the DIVA plugin (Figure 62 to Figure 69). The results show that when the shutters are open, the facades system allows sufficient admission and adequate distribution of natural light into the prototype. Additionally, a daylight autonomy analysis shows that almost the entire floor area has day lighting levels higher than 300 lux during 50% of time.

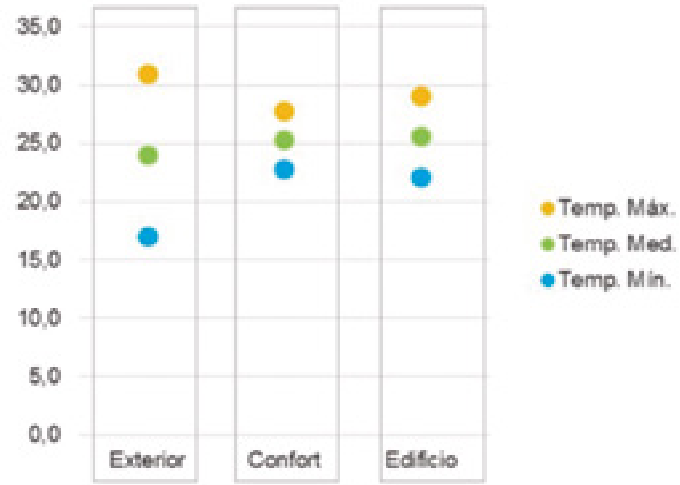


Chart 6
Comparison of external, comfort and indoor temperatures for Area 2 (closed doors)

Figure 62
Natural illumination (cloudy day in June 21 at 10 am)

Figure 63
Natural illumination (cloudy day in June 21 at 3 pm)

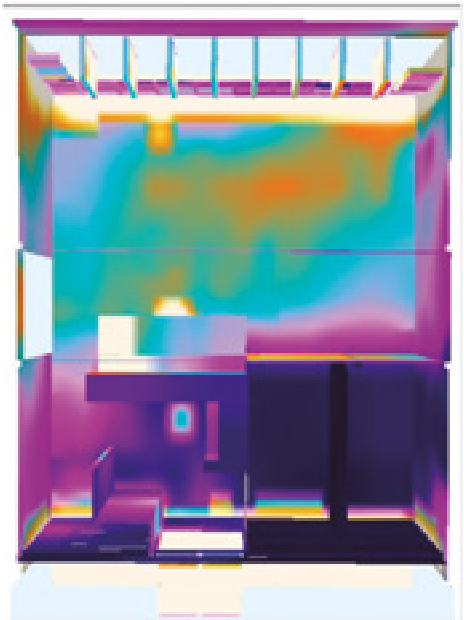


Figure 64
Natural illumination (clear sky day in June 21 at 10 am

Figure 65
Natural illumination (clear sky day in June 21 at 3 pm)

Figure 66
Natural illumination (cloudy day in December 21 at 10 am)

Figure 67
Natural illumination (cloudy day in December 21 at 3 pm)

Figure 68
Natural illumination (clear sky day in December 21 at 10 am)

Figure 69
Natural illumination (clear sky day in December 21 at 3pm)

Affordability of the MIHOUSE project

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Urban-economic aspects of low income housing

According to studies conducted by the Ministry of Housing, City and Territory and the National Planning Department of Low Income Housing (Vivienda de Interés Social-VIS, by its name in Spanish), the social housing in Colombia must meet the quality standards of appropriate housing and it´s design and construction must ensure the sustainable use of natural resources. The quality of these dwellings is based on the needs and economic possibilities of the people considering the number of household members that will benefit from the project, the daily tasks undertaken in the homes, and the efficient use of energy within the framework of human and social sustainability.

In Santiago de Cali, the problems related to a shortage of housing and land scarcity affected the development of housing projects in socio-economic strata 2 and 3, and lead to the development of low income housing on the outskirts of the city and neighboring municipalities. This fact is still accelerating the growth of the city, the construction of housing in unsuitable areas that lack basic services and in unstable land not apt for construction, which in the end, affect different aspects of the quality of life of the residents. Examples are the increase in transport costs, travel times and difficulty to meet basic needs like employment, education, health, among others.

Housing deficit in Cali

The Housing Strategic Plan Study for Cali carried out by Camacol and the Municipal Urban Renewal Company -EMRU (by its name in Spanish)- shows the growing quantitative housing deficit in the city which increases between 9.000 and 10.000 housing units per year. The housing deficit in 2015 was projected to reach 129.659 homes. On the other hand, the number of new homes built does not meet the estimated annual demand for housing. The study shows that the annual supply stands at 3.300 units, leaving about 7.000 households without a dwelling unit (Table 12). The large proportion of housing shortage (mostly in the poorest areas of the city), occur in Priority Interest Housing (Vivienda de Interés Prioritario, VIP) and in Social Interest Housing (Vivienda de Interés Social, VIS) (Table 13).

Table 12
Projection of the housing deficit in Cali according to CAMACOL

<table>
<tr><th colspan="7">Projection of the housing deficit</th></tr>
<tr><th rowspan="2">Types</th><th colspan="5">Year</th><th rowspan="3">Total</th></tr>
<tr><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td>Deficit for new homes (strata 1, 2 and 3)</td><td>9.478</td><td>9.550</td><td>9.621</td><td>9.692</td><td>9.764</td></tr>
<tr><td>Total cuantitative home deficit (Camacol)</td><td>103.413</td><td>109.942</td><td>116.544</td><td>123.220</td><td>129.659</td></tr>
<tr><td>Projection of DANE finished vis units</td><td>3.308</td><td>3.308</td><td>3.308</td><td>3.308</td><td>3.308</td><td>16.504</td></tr>
</table>

Table 13
Distribution of the housing deficit for VIP and VIS housing

%	Type of housing	2011	2012	2013	2014	2015	Total
73%	Basic unit - VIP	7.300	7.300	7.300	7.300	7.300	36.500
27%	Homes / apartments - VIS	2.700	2.700	2.700	2.700	2.700	13.500
100%	Total	10.000	10.000	10.000	10.000	10.000	50.000
							38,56%

According to Table 13, only 13.500 housing units were developed for VIS housing from 2011 to 2015, while 36.500 were built for VIP housing during the same period. Together they sum 50.000 new homes, which responds only to a 38.56% of the total quantitative home deficit for 2015 shown in Table 12. This means that the shortage in housing construction needs an urgent solution.

Market analysis

After learning about the housing deficit in Cali, it was essential to identify and investigate the affordable housing projects currently offered in the city in 2015 (Table 14), in coherence with the type of housing that MIHOUSE is proposing: social interest housing (VIS) for people in socioeconomic strata number 2). The purpose of this comparison was to recognize aspects that create market positioning by identifying the strengths that differentiate the project from others. Based on the analysis of the market, 14 housing projects coincided with the typological features and amount of square meters offered by MIHOUSE. Relying on this, the average cost per square meter could be determined in order to estimate a position in the market.

Table 14
Social interest housing (VIS) projects offered in Cali in 2015

Project's name	Total units	Construction area	Sale value	M^2 sale value	Average
Mirador campestre- South west Cali	180	48,6 m^2	$ 77.531.000	$ 1.595.288	
Jardin de las vegas- Valle del lili Cali	220	59,90-61,49 m^2	$ 90.466.740	$ 1.507.779	
Naranjos	324	62,38 m^2	$ 91.100.000	$ 1.460.404	
Ambar-Valle del lili Cali	260	59,82-61,01 m^2	$ 95.174.142	$ 1.591.009	$ 1.538.620
K-108 nogal-Pance bocha	400	63,18 m^2	$ 126.900.000	$ 2.008.547	
Fuentes de la bocha -Pance bocha	192	72,2 m^2	$ 129.800.000	$ 1.797.784	
Kerato del viento-North of Cali	96	59,39-113,62 m^2	$ 132.018.400	$ 2.237.600	
Oasis de la bocha-Pance bocha	224	63,22 m^2	$ 132.900.000	$ 2.102.183	
San rafael-valle del lili cali	256	64,96 m^2	$ 135.339.000	$ 2.083.421	
Montiel-Sur Cali	60	53,30 m^2	$ 136.981.000	$ 2.570.000	
Laurel - Jamundi	184	69-83,35 m^2	$ 146.460.000	$ 2.122.609	
K-108 teka-Pance bocha	160	70,34-72,35 m^2	$ 149.700.000	$ 2.128.234	
Prados de san agustin- North of Cali	178	69,93 m^2	$ 149.882.000	$ 2.141.171	
San gabriel-Valle del lili Cali	320	70,23 m^2	$ 157.928.000	$ 2.248.726	
Santa catalina-Valle del lili Cali	128	75,84m^2	$ 161.775.000	$ 2.133.109	
Palmeras de la bocha -Pance bocha	256	70,65-80,91 m^2	$ 164.300.000	$ 2.325.548	
Portal de la alameda-Pance bocha	144	70.84 - 75.68 m^2	$ 167.667.177	$ 2.366.843	
Parques de la bocha -Pance bocha	192	83,82 m^2	$ 167.200.000	$ 1.994.751	$ 2.161.466
Bonanza-Jamundi	3948	36,70-60 m^2	$ 41.000.000	$ 1.117.166	
Ciudadela terranova-Jamundi		63,21 m^2	$ 64.000.000	$ 1.012.498	
Paseo de la Italia-Palmira		68.84 m^2	$ 70.700.000	$ 1.027.019	
Casas del saman		82,44 m^2	$ 86.987.000	$ 1.055.155	
Caña real		71,18 m^2	$ 90.800.000	$ 1.275.639	
Oasis de la italia		105.38 m^2	$ 91.330.000	$ 866.673	
Alborada-Jamundi		72,2 m^2	$ 94.700.000	$ 1.311.634	$ 1.095.112
Malibu		105.38 m^2	$ 107.300.000	$ 1.018.220	
Punta del este -Pance bocha	160	72,03-81,13 m^2	$ 157.002.000	$ 2.179.675	$ 1.600.000

The MIHOUSE project proposes a strategy to make both citizens and the association of homebuilders aware of the importance of re-densification and provides a model for future projects in social housing in the city, improving the quality of life for residents. As a pioneering project for re-densificated and rehabilitated areas, MIHOUSE´s goals is to attract building construction companies to develop new VIS, VIP or low-cost projects and commercial units in the Commune 12. This would allow a socio-economic development that would lead to a greater valuation of the area, thus the inclusion of large business infrastructures might change the landscape of this part of the city.

Study about the variables in the area

Characteristics of the area

"El Paraíso" neighborhood is located in the Commune 12 on the east side of the city. Regarding the stratified social system, this neighborhood is included in the stratum 2. In this area, the building height management is between 1 to 3 stories and 13 out of 15 blocks are primarily residential areas with a reduced industrial, educational services and additional services. The uses, population, homes and housing statistics in the analysis of this study may show the trend in the area. Additionally, a market research data analysis involving statistical data, show the behavior of households in stratum two (2) regarding the supply and demand for housing.

Uses of areas by socioeconomic status

The predominant housing dimensions in Cali range from 60 m^2 to 85 m^2 according to the studies carried out by CAMACOL. The socio-economic class in "El Paraíso" neighborhood is stratum 2. The dimensions of the housing units in this area correspond to the ones reported by CAMACOL. There are different reasons for these housing dimensions by stratum. The main reason for reduced housing dimensions in the lower strata is due to the lower cost of housing. People living in areas located in strata 4, 5, and 6 have the opportunity to get new homes over 85 m2. Source: CAMACOL

The educational level of the household head

In most cases, the heads of the household in stratum 2 have completed secondary school (41,9%) and a medium-low percentage of heads have done technical studies (5,6%), but they do not have the opportunity to complete higher levels of education (technology studies, undergraduate or postgraduate courses) (Chart 7). This suggests that the income of the head of the household in "El Paraiso" is low, which only allows them to have a housing unit in stratum 2.

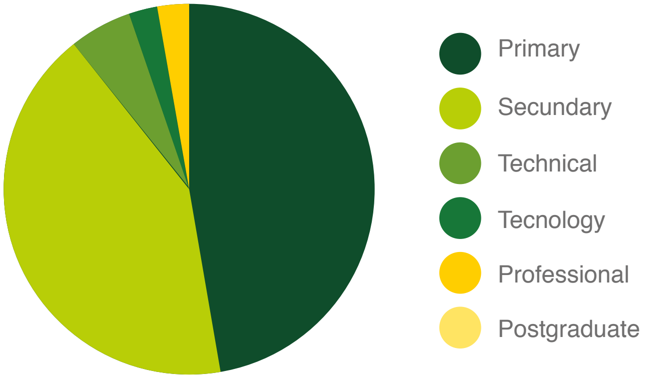


Chart 7
Education level of the head of the household

Source: Graphic made from Dane information, census in 2005 .

As for the social characteristics, the figures show that 37.3% of household heads in stratum 2 is devoted to the informal self-employment, while 31.7% are construction workers / employees, 14.5% are retired, 11.2% is engaged in household chores, while the remaining percentage are employers, unemployed and students (Table 15). This situation suggests low incomes and the need to establish an education policy for the lower strata. The independent workers in this stratum carry out informal jobs while this type of workers in the high strata enjoy the benefits of formal employment. Source: CAMACOL

Table 15
Principal activity of the household head

Principal activity of The house head	Socioeconomics stratum						Total
	1	2	3	4	5	6	
Independent worker	32,3%	37,3%	31,7%	34,9%	40,6%	43,2%	35,6%
Employee/worker	42,5%	31,7%	24,3%	21,1%	32,2%	41,7%	30,7%
Retired	5,4%	14,6%	21,3%	30,3%	20,0%	6,5%	17,0%
Employer	0,5%	0,6%	1,6%	2,0%	3,3%	4,3%	1,8%
Unemployee	3,2%	4,0%	3,6%	1,3%	0,0%	0,7%	2,7%
Home offices	14,0%	11,2%	13,4%	8,6%	2,8%	2,2%	10,0%
Student	0,0%	0,3%	0,2%	0,0%	1,1%	0,7%	0,4%
Others	2,2%	0,3%	3,9%	2,0%	0,0%	0,7%	1,8%
Total	100%	100%	100%	100%	100%	100%	100%

Incomes and expenditures per household

Table 16
Incomes and expenditures per household. Source: CAMACOL

Stratum	Total income per family		Total expenditures per family	
	Average income	SMMLV	Average expenditure	SMMLV
1	$ 1.161.827	1,9	$ 611.785	1,0
2	$ 1.439.855	2,3	$ 695.995	1,1
3	$ 1.667.487	2,7	$ 1.029.498	1,7
4	$ 2.674.349	4,3	$ 1.388.009	2,3
5	$ 4.307.418	7,0	$ 2.930.778	4,8
6	$ 8.596.112	14,0	$ 3.460.850	5,6
Total	$ 2.600.551	4,2	$ 1.369.265	2,2

Based on the CAMACOL data, the total household income in stratum 2 is 2,3 SMMLV which is 7 times lower than the expenditure in a high-income household in stratum 6 (Table 16). The average household's expenditures and surplus income, after expenses show that households in stratum 2 could afford a housing unit of around 60 million pesos (Table 17). This results coherent with the analyzed variables of the stratified social system and educational level, which indicated that the households located in "El Paraíso" neighborhood, could afford new housing units of 60 million Colombian pesos (Vivienda de Interes Social or "VIS) plus subsidies.

Table 17
Costs of VIP, VIS and No VIS vs the monthly payment

Type of housing	Housing value	Value of mortgage credit	Approximate monthly payment	Fees	Years
VIP	Under 43.120.000 COP	30.000.000 COP	Between 590.19 and 661.461 COP	60	5
VIS (between 43.120.000 pesos and 83.160.000 pesos)	63.100.000 COP	44.170.000 COP	Between 596.124 and 708.497	96	8
	83.100.000 COP	58.170.000 COP	Between 513.872 and 683.671	180	15
No VIS housing	120.000.000 COP	83.000.000 COP	Between 677.969 and 891.531	240	20

Source: Semana magazine-October 2014

Users

The type of housing provided by the MIHOUSE project has been designed using quality parameters estimating different household types. Therefore, three types of housing units are designed according to the needs of different social-economic strata, which generates a social mixing that involves people who usually live outside of the city.

The main factors that have led to the current poor quality of social housing units has been the change of social structure in recent years, the high increase in population and the shortage of land for the projects. Generally, the VIS households are composed by large families, young couples (with or without children), elderly and families with at least one member with reduced mobility. Most of these families cannot afford a house due to their low incomes. Therefore, the government develops these projects through housing subsidies and joint financing programs for urban renewal to cover the expenses of the cost of social housing.

Population and housing trends

Commune 12, where “El Paraíso” is located, presents a declining population growth; the exponential growth rate between 1993 and 2005 was 1.11%. However, there is an opposite tendency in “El Paraíso” neighborhood, which –in between the inter-census period- showed a negative rate of -0.87%, which it is not the lowest in Commune 12 (Table 18). The housing deficit, the supply reduction and the low affordability of the demand in the neighborhood is one of the main causes of the population decline. Besides, the zoning change from residential properties to commercial use is another aspect that reduces the population.

Table 18
Exponential growth rate of the population

Exponential growth rate of the population			
Neighborhoods in Commune 12	1993	2005	TCEXP
Villanueva	4210	3546	-1,43%
Asturias	5301	5008	-0,47%
Eduardo Santos	4137	3633	-1,08%
Barrio Alfonso Barberena A	3067	2958	-0,30%
El Paraíso	3893	3506	-0,87%
Fenalco Kennedy	1571	1845	1,34%
Nueva Floresta	21253	20448	-0,32%
Julio Rincón	2422	1792	-2,51%
Doce de Octubre	4351	5044	1,23%
El Rodeo	13617	13004	-0,38%
Sindical	4550	4566	0,03%
Bello Horizonte	1381	1326	-0,34%

Regarding the concentration of population in the commune, 5.26% of the total population is concentrated in “El Paraíso” neighborhood. This percentage remains almost constant in the period 1993-2005 (Table 19).

Table 19
Distribution of the population in the neigborhoods of Commune 12

Neighborhoods in Commune 12	Porcentual participation (commune)					
	Year 1993			Year 2005		
	Population	Homes	Families	Population	Homes	Families
Villanueva	6,04%	5,36%	6,07%	5,32%	5,26%	5,45%
Asturias	7,60%	7,02%	7,43%	7,51%	7,22%	7,52%
Eduardo Santos	5,93%	5,08%	5,99%	5,45%	5,25%	5,31%
Alfonso Barberena A	4,40%	4,70%	4,38%	4,44%	4,75%	4,53%
El Paraíso	5,58%	5,63%	5,46%	5,26%	5,10%	4,89%
Fenalco Kennedy	2,25%	2,43%	2,18%	2,77%	2,99%	2,89%
Nueva Floresta	30,47%	32,00%	30,38%	30,67%	32,09%	30,94%
Julio Rincón	3,47%	3,82%	3,36%	2,69%	2,90%	2,65%
Doce de Octubre	6,24%	6,15%	6,21%	7,56%	6,92%	7,11%
El Rodeo	19,52%	18,83%	19,78%	19,50%	18,89%	19,83%
Sindical	6,52%	6,85%	6,64%	6,85%	6,65%	6,73%
Bello Horizonte	1,98%	2,14%	2,11%	1,99%	1,99%	2,14%
COMMUNES TOTAL	45,24%	39,88%	46,14%	39,33%	39,50%	43,13%

Housing market analysis and opportunities for house-holds in stratum two in “El Paraíso” neighborhood

The analysis of demand in stratum 2 shows the following information: 727 is the number of households that afforded a housing unit in this stratum in 2013, which is about 10% of total homes sold in the city. This number of homes is very low considering that the demand for the lower strata is about 10.000 units.

Table 20
Annual sales Source: CAMACOL

Anual sales (units)				
Types	2010	2011	2012	2013
Stratum 2	1899	327	305	727
STRATUMS TOTAL	8529	8704	6586	7459

Table 21
Dissatisfied housing demand in 2014 by price rate

Building home price		Dissatisfied housing demand in 2014 by price rate		
Thousands of pesos	SMMLV	Efective demand	Available offer	Dissatisfied demand
<30.800	<50	481	0	481
30.800-43.120	50-70	1442	4	1438
43.120-61.600	70-100	2404	263	2141
61.600-83.160	100-135	2404	188	2216
VIS		6,731	455	6,276
83.160-104.720	135-170	**2404**	162	2242
104.720-128.128	170-208	962	116	846
128.128-144.760	208-235	481	272	209
144.760-165.704	235-269		283	198
165.704-184.800	269-300	1442	350	-350
184.800-206.360	300-335		275	1167
NO VIS		6,731	**2,702**	4,029
TOTAL		13,462	3,157	**10,305**

The current housing supply in Cali does not meet the demand for the households that can buy a home as it is shown in **Table 21**. This is because there is 10,305 households that have the resources to buy a home but they cannot find one. Only 2,702 households that can manage to afford one.

As mentioned previously, households in stratum 2 can afford a housing unit $60 million COP. CAMACOL study shows about 2,404 households in Cali have the financial resources to purchase a home, but they do not find the needed housing supply.

Urban proposal

MIHOUSE responds to the problems of social housing and housing deficit, through awareness and the development of strategies that take the needs as a priority and the quality of life of the user. It also responds to the needs of re densification, promoting the development of housing in height in the city, thus raising 150 sustainable living units in the deteriorated area of “El Paraíso” neighborhood (Figure 70). Thanks to the urban proposal, urban furniture, public space and recreation areas are included to improve the quality of life of the inhabitants of the sector and of those who become the final users. MIHOUSE is an initiative to generate positive changes in the city from the social, economic and environmental points of view.

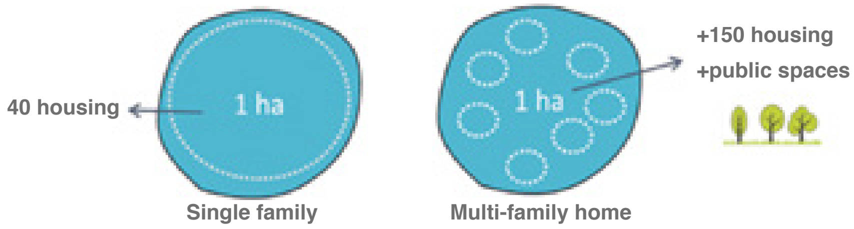


Figure 70
Re densification proposal

Thanks to the location of the project, it encourages the use of public transportation while reducing the environmental impact caused by the transportation of people to areas with social housing currently located in the outskirts of the city and surrounding municipalities. Additionally, since it has a sustainability concept, it reduces the environmental impacts produced by homes thanks to:

- The collection of rain water
- Saving of 23% in the consumption of drinking water
- The correct use of gray and waste water
- The production of clean energy through solar panels to supply electricity consumption
- The use of waste through recycling and composting

Derived from the previous items are some economic benefits for the users, such as the decrease in spending on public services and the productivity of the homes which allows the household to receive additional incomes thanks to the agriculture and trade that arises on the first floors, among others.

The urban and architectural design is flexible, adaptable, includes bioclimatic strategies that makes it adaptable to cities in tropical countries and adds to the quality of life of its users and to the environment.

The distinguishing features that collect the three concepts of sustainability (social, environmental and economic) places the MIHOUSE project in a privileged position because such aspects are not currently covered by other social housing projects in the country.

Product specifications

The MIHOUSE project responds to the market for social housing. An analysis allowed the team to identify important aspects that characterize this type of housing in the market. MIHOUSE is an attractive project for buyers thanks to its environmental, social and economic aspects.

This project covers a large market because it has two kinds of housing (VIS and not VIS), which are classified in 3 housing types (Table 22): Type 1 with 81 m2 which includes a small area for a market inside of the housing unit, Type 2 with 63 m2 and Type 3 with 45 m2. The three comply with the characteristics of social housing.

Table 22
Three types of apartments available in the MIHOUSE project

Type	# Of apartments	Apartment area
Type 1	90	81
Type 2	41	63
Type 3	19	45

Since this type of housing is the least offered at national level but the one with the highest demand, the objective of the MIHOUSE project is to offer a high quality alternative in the market, were the advantages and benefits of sustainable housing are fundamental. It is also an objective, to create a sense of awareness and belonging in the final user, which is whom in the daily use of the housing unit, will allow the optimal use of natural resources and the one to put into action the strategies created in the project for achieving energy efficiency.

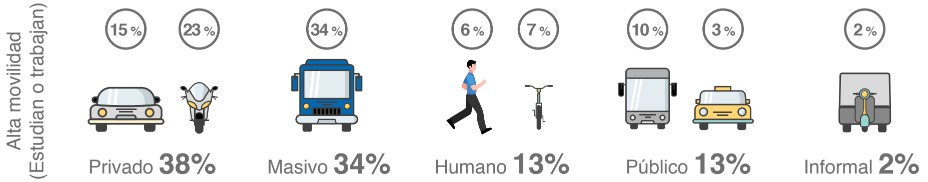
Transport and mobility

Santiago de Cali is the third largest city of the Republic of Colombia. Likewise, it is the third most populous city in the country with 2´369, 829 inhabitants. 47% of the population (the ones mobilized during the days of work or school), use public transport as their primary means of transport. From them, 34% are users of the integrated mass transport (MIO), while 13% are users of traditional public transport. On the other hand 38% has private transportation (23% uses motorcycles while 15% uses cars). Additionally, 13% use non-motorized means (7% uses bikes while 6% walks). An additional 2% says to use informal transportation (Chart 8).

In average, each resident has an estimated of 2.0 travels per day which are mostly in week-days between 7 and 8 am, and between 6 and 7 pm.

The structure of mobility in Santiago de Cali is composed of seven routes that gives order to the city: "Avenida Ciudad de Cali", Avenida Circunvalar", "Calle 5ta", "Avenida Simón Bolivar", "Calle 26" (the old railway line), and the "Autopista Sur Oriental" (Picture 21).

Chart 8
Distribution of daily commutters



The roads pass through urban areas in the city, which is divided into 22 communes, which subsequently divide into 249 neighborhoods (Picture 21). Linked to this division of areas is the distribution of social strata, which is classified as high, medium and low strata.

According to the "Cali Cómo Vamos" survey in 2014, people from the lower strata takes an average of 41 minutes to commute to their places of study or work; people in a medium strata takes 38 minutes; and people in a high strata takes 30 minutes. In consequence, people from the lowest strata spends more time commuting to work or study.

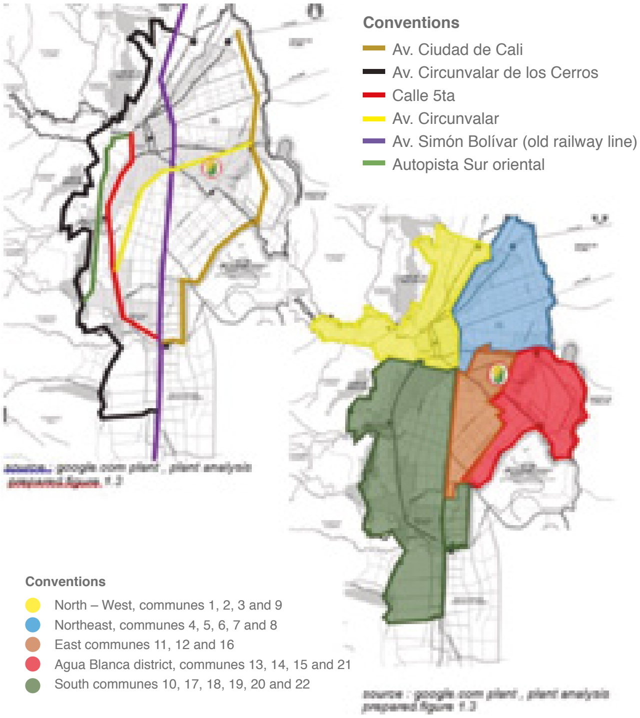
One of the benefits of the MIHOUSE project is its location in Commune 12, in the eastern part of the city, which has an adequate transport network near to different business centers.

The MIHOUSE project promotes the use of alternative transportation -like cycle paths- to improve the infrastructure of mobility. It also proposes sustainable ideas, which create the opportunity to reduce traffic in the city and the high rates of $CO2$, CO (carbon monoxide) and nitrogen oxides, which are the ones that contribute to the pollution of cities.

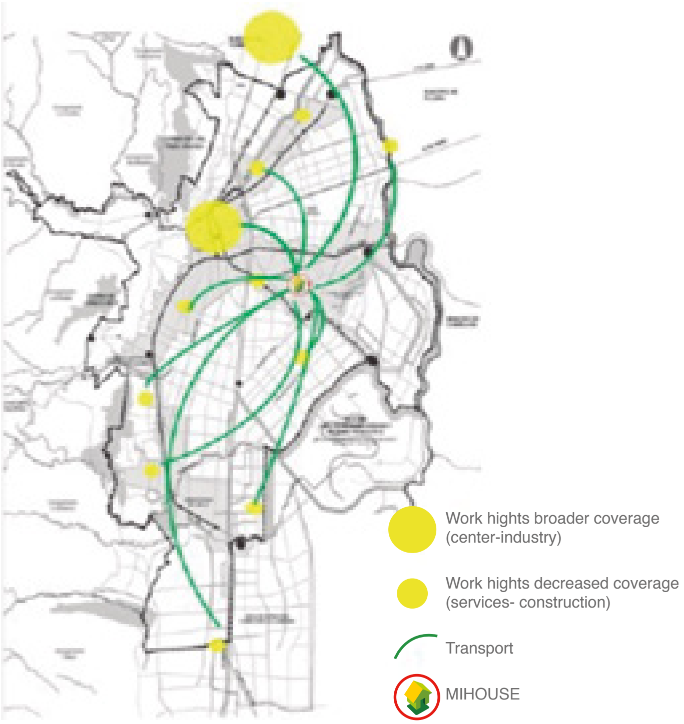
Economic benefits of the MIHOUSE proposal

Rain water savings

The MIHOUSE project has 960 m^2 of green areas in private orchards, parks and urban gardens, which require two liters of water per each square meter per day. This means that 1,920 liters of water are needed for sustaining these areas per day. However, since there is a design for collecting rain water, there is a projected savings of 8.4% of the demand for potable water, which would contribute to a decrease of 161,28 liters of drinking water. In consequence, the use of rain water, means there are savings of drinking water and as a result, economic savings for the MIHOUSE urban complex and for their users.



Picture 21
Transport and mobility in Cali



Picture 22
Different business centers in the city of Cali

Table 23
Savings by using rain water.

	Residential complex without use	Mihouse residential complex
Consumption for irrigation (m^3/day)	1,92	1,76
Monthly consumption (m^3)	59,52	54,56
Rate (\$/m^3)(*)	1.415,22	1.415,22
Monthly cost ($)	84.233,89	77.158,25
Annual cost ($)	1.010.806,68	925.899

The project also counts with a system that would provide up to 320 liters of water rain to each dwelling located on the upper floors of each block by means of two elevated storage tanks; taking into account that the net for a family of four are from

523,406 (l/family-day) according to the Administrative Department of planning of Cali to the year 2014, the consumption of drinking water would reduce 61,13%, when the tanks are at their maximum capacity, generating a saving of $452,8 against a 740,6 $ that would pay for daily consumption. This saving validates the importance of the use of water from precipitation for the use of common activities such as irrigation, domestic, and for demonstrating the sustainable development policies driven by the MIHOUSE project.

Grey water

Grey water management is done in two collection tanks located underground and below the green areas. They have grease traps followed by a tank that hosts the coagulation and flocculation; afterwards, the water distribution is done through pumps, taking the treated water to each apartment.

“El Paraiso” neighborhood is currently supplied by the municipal utilities company called EMCALI, which handles a single rate of $1.145,71 of sewerage per m3 in stratum 2 (EMCALI, 2015). The calculated values of production of water for each apartment and at the urban level can be seen in the following table, which demonstrates the feasibility of the project from a resource saving perspective.

Table 24
Grey water produced (housing unit and urban scale)

M^3 of grey water produced in Housing	M^3/day of grey water Produced at urban level
0,405 m^3/day	56,7 m^3/day
12,15 m^3/month	1701 m^3/month

There will be the following savings (Table 25) assuming 5 people per dwelling, in coherence with the mentioned rate in Table 24:

Table 25
Savings (housing unit and urban scale)

Savings in pesos in housing	Savings in pesos at urban level
$13.920	$1’948.853

Solid waste

Taking into account the number of people and number of apartments in the project, the following table shows the amount of waste that will be generated by a residential unit.

Table 26
Amount of waste produced by a housing unit

Category	Stratum %		% Amount of waste	Amount of waste (kg)	Type of solid waste	% Of solid waste per typo
	1	2				
Food	61,3	61,9	0,616	116,27	Organic	0,65
Garden	4,31	2,26	0,033			
Paper	2,75	3,13	0,029	8,96	Recyclable	0,05
Carton	1,87	2,25	0,021			
Bags and packaging	6,72	7,08	0,069	17,74	Recyclable	0,1
Plastic	2,86	3,14	0,03			
Metal	0,94	1	0,01	5,51	Recyclable	0,03
Glass	2,19	2,02	0,021			
Rubber and leather	1,56	1,38	0,015	30,71	Ordinary	0,17
Textiles	2,82	2,28	0,026			
Wood	0,68	0,93	0,008			
Ceramic	0,99	2,18	0,016			
Bones	0,32	0,31	0,003			
Toilet tissue	8,3	8,91	0,086			
Other	2,38	1,24	0,018			
Total			1	179.20		

Within the MIHOUSE project was projected the use of different types of waste, which is managed in an environmentally safe manner. The following table shows the quantities and values (weights) of waste that will be produced:

Table 27
Amount of waste to be exploited

Type of waste	% Of sw Per typo	Amount of waste (kg/day)	Water Recovery	Use Value	Use Value
Organic waste	0,65	110,38	-	-	
Paper and carton	0,05	8,96	250	2240	67.200
Bags and plastic packaging	0,1	17,74	300	5322	159.660
Metal	0,01	1,79	200	358.4	10.752
Glass	0,021	3,76	80	301.06	9.031
Total				8221.45	246.643

Utilization of organic waste: quantity and cost

Organic residues will be produced by the composting process, making use of two autonomous systems of composting of 3,000 litres, i.e. two composters referenced SAC-3000 from the company EARTHGREEN. According to EARTHGREEN, for every kilogram of organic waste separated and taken to composting, it is obtained 0.4 to 0.5 kilograms of compost for green areas, gardens, orchards and organic fertilizer, with a market value ranging between $120,000 to $180,000 pesos / ton through the use of organic waste.

Energy

He is the comparison between the project and a normal House, where the benefits of the use of solar energy is shed.

Table 28
Analysis and comparative light

Quantity		Loads	Hours per day	Energy rate for stratum 2 (C)	Power W	Luminous flux Lm	Luminous Efficacy (Lm / W)	Total energy kWh / day	Monthly Energy kWh	Lighting bill payment	power W	Luminous flux Lm	Luminous Efficacy (Lm / W)	Monthly Energy kWh	Lighting bill payment	Total energy kWh / year
Kitchen	3	24 H2o Kitchen	4	229,59	4	300	75,0	0,048	1,44	$330	60	760	12,67	0,72	21,6	$ 4.959
	2	Luminarie LED Kitchen	4	229,59	19	1550	81,6	0,152	4,56	$1.046	100	1650	16,50	0,8	24	$ 5.510
Hall	2	Luminarie LED Hall	6	229,59	19	1420	74,7	0,228	6,84	$1.570	100	1650	16,50	1,2	36	$ 8.265
	3	24 H2O Hall	6	229,59	4	300	75,0	0,072	2,16	$ 495	60	760	12,67	1,08	32,4	$ 7.438
Dining room	2	Luminarie LED dining room	6	229,59	40	1420	35,5	0,48	14,4	$3.306	100	1650	16,50	1,2	36	$ 8.265
Bath	2	Luminarie LED Bath	2	229,59	8	680	85,0	0,032	0,96	$ 220	60	760	12,67	0,24	7,2	$ 1.653
Living Room	1	LED luminaire Living Room 1	5	229,59	19	1420	74,7	0,095	2,85	$ 654	100	1650	16,50	0,5	15	$ 3.443
	1	LED luminaire Living Room 2	5	229,59	19	1420	74,7	0,095	2,85	$ 654	100	1650	16,50	0,5	15	$ 3.443
									36,06	$ 8.279					187,2	$ 42.979

The lighting in MIHOUSE characterizes the power, luminous efficiency and energy consumption of each luminaire. Values in yellow indicate social housing energy consumption (Table 28).

In table 29, the column identified as “Payment on invoice for consumption” totals the monthly energy costs derived from the use of electrical appliances. Therefore, the MIHOUSE´s lighting costs an average of $8,279 Colombian pesos per month, while the average of a common house is $42,979 Colombian pesos. This occurs because MIHOUSE has the advantage of using LED lighting and an innovative lighting system called 24H2O. In this way, MIHOUSE is 80% more economic in terms of lighting. This is considering the rate in the month of January 2015 in the city of Cali, Colombia in strata 2.

Table 29
Consumer appliances in a MIHOUSE

Quantity	Loads	Voltage V	Power W c/u	Hours a day	Total energy kwh/day	Monthly energy Kwh	Payment on invoice for consumption of electrical appliances (colombian pesos)
1	Blender	120	370	0,5	0,185	5,55	1,274
1	31 lbs washing machine	120	693	0,25	0,17325	5,1975	1,193
1	222l fridge	120			0	0,82	188
1	TV led 22’	120	30,4	8	0,2432	7,296	1,675
1	Cell charger	120	12	3	0,036	1,08	247
1	Computer HP Pavilion 500-245la	120	300	2	0,6	18	4,132
1	Microwave	120	800	0,25	0,2	6	1,377
1	Stove	120	1300	2	2,6	78	17,908
1	Dvd	120	10	1,5	0,015	0,45	103
Total payment invoice							28,100

TOTAL monthly energy bill in a MIHOUSE:

In table 29 can be appreciated the electrical parameters of every appliance, the intensity of use and the average monthly energy cost: $28,100 Colombian pesos. In consequence, the total payment for electricity would be: lighting bill + payment of invoice for electrical appliances = $8,279 + 28,100 = $36.379 Colombian pesos.

Table 30
Conventional house

Quantity	Loads	Voltage V	Power W c/u	Hours a day	Total energy kwh/day	Monthly energy kwh	Payment on invoice for consumption of electrical appliances (colombian pesos)
1	Blend	120	370	0,5	0,185	5,55	1,274
1	Washing machine	120	550	0,25	0,1375	4,125	947
1	222L fridge	120			0	0	
1	Led 22’ TV	120	30,4	8	0,2432	7,296	1,675
1	Cell charger	120	12	3	0,036	1,08	247
1	All in one computer	120	65	2	0,13	3,9	895
1	Microwave	120	800	0,25	0,2	6	1,377
1	Stove	120	1000	2	2	60	13,775
1	Dvd	120	10	1,5	0,015	0,45	103
Total payment invoice							20,295

Tarifa extract energy 2: 229,59

TOTAL monthly energy bill in a conventional house:

The total payment for electricity in a conventional house would be
= $42,979 + $20,295 = $63,275.

The invoice difference between a MIHOUSE and a conventional house is $26,895 Colombian pesos per month. The annual difference would be $322,750 Colombian pesos (about 120 USD per year).

Affordability

The project derives from the need to offer an alternative housing solution for populations in strata 2 and 3 in the city of Santiago de Cali. In consequence, it contributes to the state policy that aims for the decrease of the housing shortage. Additionally, this policy aims to consider alternatives that mitigate the environmental impact derived from energy consumption and waste. Furthermore, due to the city's excessive growth that causes high urban costs and a great impact in transportation, the approach taken with the MIHOUSE project was considered an urban renovation plan. This idea is proposed to be developed at "El Paraíso" neighborhood, considering augmenting its density and demolishing the houses that are deteriorated and misused.

The project aims to create new opportunities and dwelling options for large families, young couples, workers and students. Therefore, the area is projected with parking lots, bicycle lanes, pedestrian paths, orchards and public spaces adapted for children, young people, adults and seniors. The proposed urbanism creates meeting points where inhabitants may carry out different activities (Table 31). Urban facilities such as mini markets and social rooms have also been considered, where the inhabitants of the project will be trained on how to use the different innovative systems applied to their apartments and on how to grow vegetable gardens. These spaces can be used according to the needs of the community.

Public spaces will be illuminated with LED lighting. Vehicle and pedestrian roads as well as bicycle lanes are also considered since hazard is high in the area. Regarding the construction of the public spaces, the connection between private and public areas is one of the main principles, besides height densification.

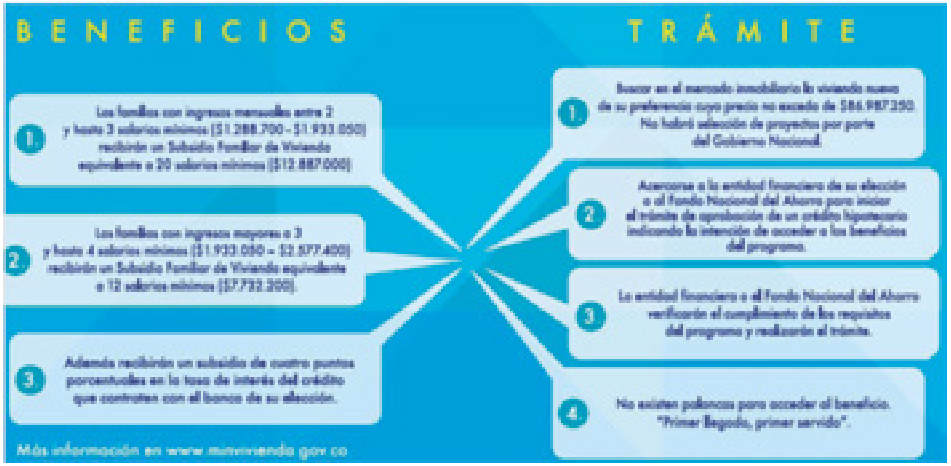
It is understood that there will be some conflicts between local communities and those interested in relocating within the project when demolishing existing households. Therefore, a plan was previously considered for the MIHOUSE proposal, since it is important to bring together those who are going to live in the block. Consequently, the government will act as an intermediary in order to fulfill this alliance.

Table 31
Areas for public recreation in the MIHOUSE urban proposal

Description of the intervention	M^2 area	Cost	Total cost
Total demolition	8132,44	$ 25.000	$ 203.311.000
Equipment	392	$ 650.000	$ 254.800.000
Green areas	2808	$ 15.000	$ 42.120.000
Hard zones	4005	$ 85.000	$ 340.425.000
Orchards	317,24	$ 75.000	$ 23.793.000
Parks	282,2	$ 130.000	$ 36.686.000
Court	271	$ 290.000	$ 78.590.000
Parking	697,25	$ 310.000	$ 216.147.500
Squares	71	$ 180.000	$ 12.780.000
Total public space	16.976,13 m^2		$ 1.208.652.500

The national government already has a program called “Mi Casa Ya” (translated as “My House Now”) (Picture 23, Picture 24, and Picture 25), which consists on helping Colombian families purchase a house. This program was integrated to the urban proposal since it is directed to the households with income between 2 and 4 times the minimum wage (USD$443[1] - USD$885); the government will subsidize them with the house’s down payment, if it is valued between 70 times and up to 135 times the minimum monthly wage (USD$15.495 to USD$29.882). Besides, the government will subsidize the credit’s interest rate offered by the bank of their choice.

1. These values in USD correspond to October 13th’s exchange rate: USD $1 = COP $2.911 (Year 2015).



Picture 23
“Mi Casa Ya” brochure (side 1)
Source: Ministry of Housing, “My house now” brochure

Picture 24
"Mi Casa Ya" brochure
Source: Ministry of Housing, Brochure "My house now"

Ultimately, the proposal is affordable thanks to the help of the government and public bodies since they offer the necessary elements so that a family in this sector or socioeconomic strata is able to get a comfortable, sustainable and productive home.

Cost reduction strategy

The architectural project is the result of several studies addressed to the reduction of residual, costs and consumption. The designer's knowledge and society's expectations, traditions and needs are considered as external factors, whereas both, knowledge of history and materials that can be used in the area, are considered as internal factors. The quality of the product, design and construction are taken into account in the design process, as aspects that guarantee quality. A preliminary economic parameter was developed in the urban project, considering the input from utilities, subsidies and government benefits, since a satisfactory profit is not reached due to the project's costs and expenses, as you can see in Table 32. This leads the MIHOUSE team to find solutions so that projects like these are affordable for lower socio economic stratas.

Table 32
Cost and utility

Total cost and utility	
Direct costs	$ 16.442.772.175
Indirect costs	$ 3.032.212.937
Lot costs	$ -
Comercial costs	$ 1.542.015.781
Administrative expenses	$ 255.070.279
Total costs	$ 21.272.071.174
Total sale costs	$ 23.188.207.248
Use gross	$ 1.916.136.073

Table 32
Cost and utility

Contributions	
Lot cost	$ 5.600.758.000
Emcali contributions	$ -
Total contributions	$ -
Income tax 38%	$ 728.131.708
Net income	$ 1.188.004.365
% UTILITY	5%

The MIHOUSE team also tried to ensure a follow up to the sector's regulations, such as structure, design and material parameters, providing people and property safety. Therefore, the objective was to provide moderate-price housing. The program is part of a neighborhood's revitalization process, which includes an intervention to a hectare[2] block. The block comprises 150 apartments with three different types of areas. See Table 33 and 34.

Table 33
Types of appartments

Types of apartments	
Number of apartments type 1	90
Number of apartments type 2	41
Number of apartments type 3	19
Aparment area type 1	81 m^2
Aparment area type 2	63 m^2
Aparment area type 3	45 m^2

Table 34
Apartment values

Apartment Value					
Apartment	Area in M^2	Total apartment cost	Apartment benefits	Subsidy	Maximum mortgage
Type 1	81	$ 175.078.746	$ 110.156.923	$ 110.156.923	$ 77.109.846
Type 2	63	$ 136.172.358	$ 85.677.607	$ 72.790.607	$ 59.974.325
Type 3	45	$ 97.265.970	$ 61.128.291	$ 48.311.291	$ 42.838.804

It is worth noting that not all of the apartments can be subsidized with the total cost of the apartment.

2. 1 hectare = 2.47 acres.

Labor costs in the housing complex

An economic study of the market was carried out in the city and in the chosen area for the urban project, creating a parameter based on social housing referents already built in the city. Employed design, techniques and materials were sought in the study. As the team was dealing with social housing, costs were the main focal point. The MIHOUSE intervention will provide decent housing with new technologies, which will help people to have an income in their homes. It was important the need of having a moderate pricing, due to the socio economic strata the project is aiming. The construction program is part of a process of urban renovation in a low-income neighborhood. The project comprises 150 apartments with three different areas: 81m^2 (871 ft2), 63m^2 (678 ft2) and 45m^2 (484 ft2).

Features of the buildings

After analyzing the studies carried out by Camacol Valle (Colombian Chamber of Construction), the team understood the current situation lived by dwellers in Commune 12 regarding their social and housing conditions. For this reason, MIHOUSE's re densification objective arises from the housing shortage in this sector of the city of Cali. Today, "El Paraíso" neighborhood is inhabited by large families, young couples, workers and students, who will be relocated in the project. The interior spaces can be personalized and adapted to any type of user and his/her needs, thanks to the housing's flexible features.

The team´s main interest was to foster residents' maximum use of their housing, as well as it is in the countryside. In addition, to allow them to have the opportunity to get economic, social and environmental benefits from the spaces offered by the dwelling, such as the vegetable garden. Additionally, to provide them with development opportunities, and a space for small shops – in the case of the apartments on the ground floor. Therefore, MIHOUSE becomes both environmentally and economically sustainable, providing income for its residents.

Based on the market study carried out by the team, it was established a 30% down payment credit for each appartment, as a general installment credit rule. Besides, being considered as a social housing project, MIHOUSE suggests a subsidy plan over 70% of the appartment´s total costs so that people can afford a place to live without paying for rent.

Furniture proposal

The interior design provides the opportunity to develop a versatile and efficient alternative regarding the use of furniture and space. The furniture of the apartments has been designed keeping in mind the maximum use of materials, avoiding their waste. Regional products were used, promoting the local market and decreasing the materials' transportation and the resulting pollution.

It was necessary to use industrial products in order to match the regular functioning needs of the kitchen, such as oven, fridge, stove, etc. The design was based on the transformation of the concept of common furniture and as decorative elements; the challenge was to mix functionality, ergonomics, versatility and aesthetics with the human being's daily needs. The aim was a design that contributed to social rehabilitation through multiple pieces of furniture that allowed meeting the different configuration needs within the property without turning to civil works.

The building process

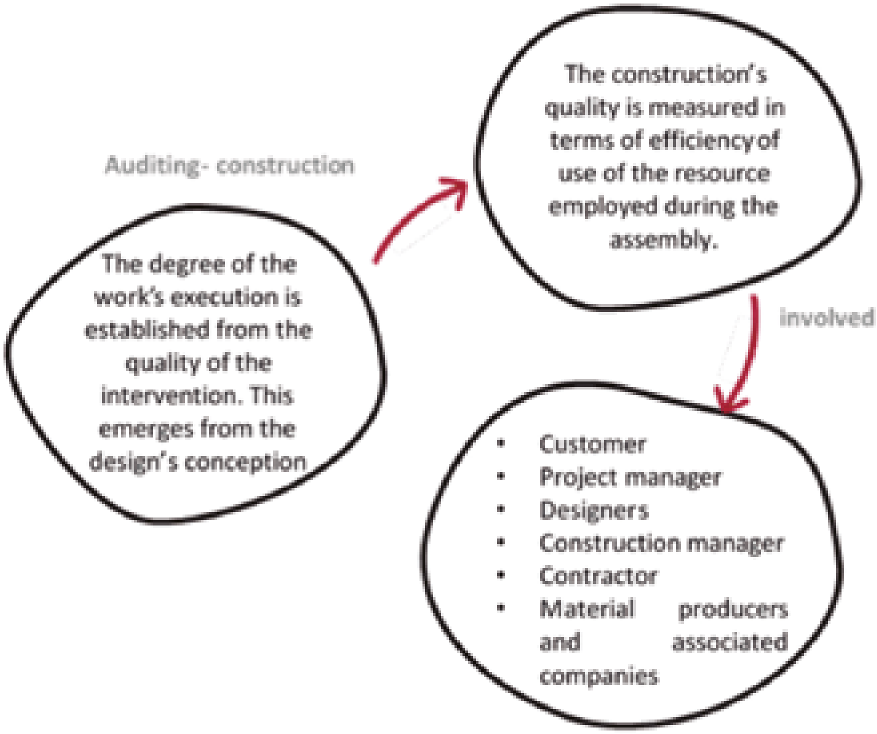
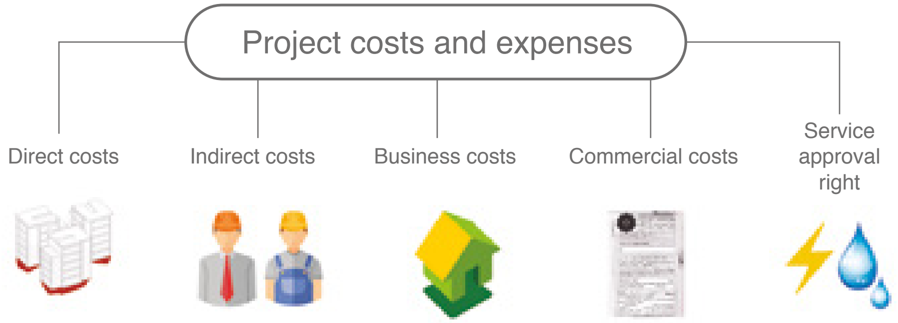


Figure 71
The building process

Feasibility and sales plan

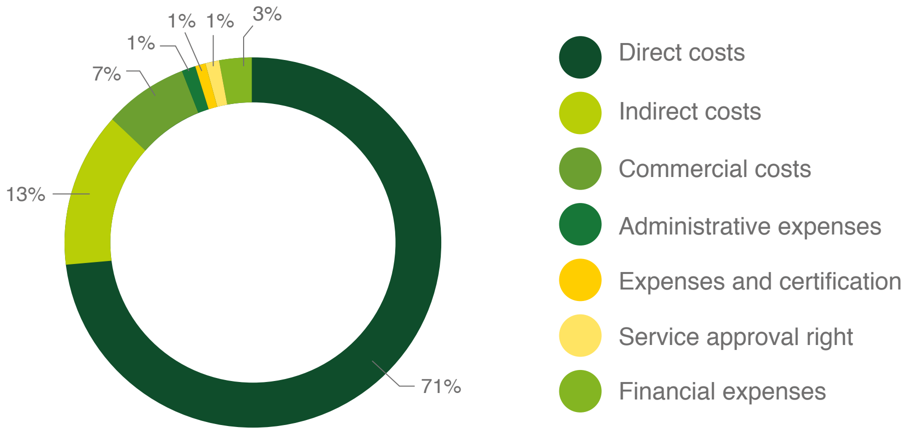
For this phase of the urban project, we did an economic analysis departing from its costs and expenses. See Figure 72.

Figure 72
Project costs and expenses



With the objective of making the development of this project viable and departing from real and determinable facts, it was identifiable through the urban project´s costs and expenses calculations (see Chart 9), the need to provide economic solutions such as the contribution to public services, subsidies and government benefits for making MIHOUSE an accessible project to the users. This was due to the fact that the proposed appartments do not correspond with the characteristics of an average one, but to those with constructive and sustainable advantages.

Chart 9
Total costs and expenses



As you can see in Chart 10 for the urban development, the project was divided into four phases with the purpose of making feasible selling and constructing the project taking into consideration its scale. Subsequently, a timeline was proposed which helped organize the phases of the project in a way that we could take advantage of the efficient constructive system while overlapping consecutive phases. The estimation of the total construction resulted in 40 months.

Each of the phases of the project was estimated with a pre-sales, sales, construction and post-sales stages.

Month 1-5	Month 6-10	Month 11-15	Month 16-20	Month 21-25	Month 26-30	Month 31-35	Month 36-40
Time line 40 months							
Design month 1-12		Stage 1. Month 13-28					
			Stage 2. Month 17-33				
				Stage 3. Month 21-37			
					Stage 4. Month 25-40		

Chart 10
Project phases

- Design: 12 months
- Phase 1: 16 months
- Phase 2: 17 months
- Phase 3: 17 months
- Phase 4: 16 months

These four phases are to be developed in 40 months.

In each phase it was identified an independent feasibility goal, which indicated the number of apartments to sale in order to start the construction. With this, a sales plan emerged for each type of housing, which allowed us to define the order and income objectives such as the initial payment (from the buyers), the subsidies (from the government) and the loans (from the banks).

Apartment	Apartment cost	Credit bank	Subsidy	Initial fee
Type 1	$ 175.078.746	$ 122.555.122	Not applicable to apartment type 1	$ 52.523.624
Type 2	$ 136.172.358	$ 95.320.651	$ 12.877.000	$ 40.851.707
Type 3	$ 97.265.970	$ 68.086.179	$ 12.877.000	$ 29.179.791

Thanks to the sales plan, it was identified the length of time needed for the buyers to pay each apartment, which corresponds with the end of its construction. This process concluded in a final document in which it was obtained the relation between the income (corresponding to the sales of the apartments) and the expenses (corresponding to the constructive costs, indirect costs, commercial costs and administrative expenses). The relation between the income and the expenses resulted in the cash balance and the monthly-accumulated amount during the 40 months of sales and construction of the project. This will define the moment during the construction to resort to a financial credit. The first credit is meant to be of $800´000.000 Colombian pesos while the second one of $2´000.000.000, for a total loan of $2´800.000.000 Colombian pesos with an annual interest rate of 9%.

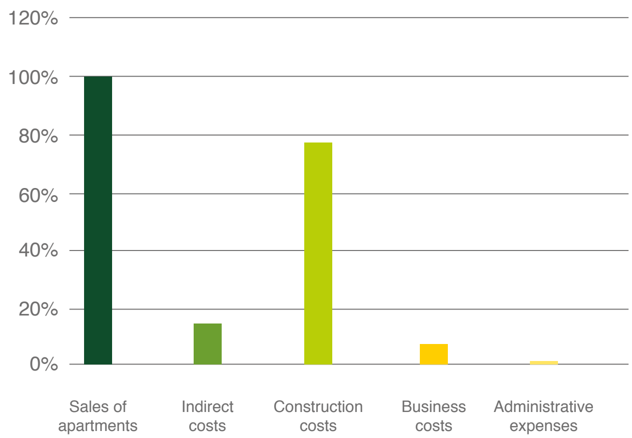


Chart 11
Income and expenses

As the result of the progressive sales strategy, an accumulative active was generated that would permit starting in advance each construction phase, allowing each phase to be sold in an average of 6 months and constructed in an average of 10 months. This research and its process allowed us to project MIHOUSE in a real context for its elaboration and construction, which at the end, will generate a 5% utility of the project´s total cost, without this being the main objective, since MIHOUSE gives priority to the social, environmental and economic aspects of its clients.

Table 35
Projected income

MIHOUSE
PROJECTED INCOME STATMENT

	YEAR 0	YEAR 1	YEAR 2	YEAR 3	Total	
TOTAL REVENUE		349.627.589	10.102.381.593	12.756.005.501	23.208.014.683	
- INDIRECT COSTS		451.603.554	1.416.093.551	1.238.518.065	3.106.215.170	
- CONSTRUCTION COSTS		-	9.390.275.908	7.052.593.842	16.442.869.750	
GROSS PROFIT		- 101.975.965	- 703.987.866	4.464.893.594	3.658.929.763	
- ADMINISTRATIVE EXPENSES		102.028.112	76.521.084	76.521.084	255.070.280	
- SELLING		189.375.435	641.709.269	708.204.451	1.539.289.156	
OPERATIVE UTILITY		- 393.379.512	- 1.422.218.220	3.680.168.059	1.864.570.327	
FINANCIAL EXPENSES LOAN 1		-	60.706.283	21.329.235	82.035.517	
FINANCIAL EXPENSES LOAN 2				52.500.000	52.500.000	134.535.517
INCOME BEFORE TAXES		- 393.379.512	- 1.482.924.502	3.606.338.824	1.730.034.810	
TAX PROVISION		- 98.344.878		901.584.706	432.508.702	
NET PROFIT		- 295.034.634	- 1.482.924.502	2.704.754.118	1.297.526.107	5,59%
FREE CASH FLOW OF PROJECT						
- INVESTMENTS	-$ 5.600.758.000					
+ LOAN						
NET PROFIT		- 295.034.634	- 1.482.924.502	2.704.754.118		

Conclusions

MIHOUSE is the sustainable housing solution to deteriorated neighborhoods existing in numerous tropical cities around the world. MIHOUSE departs from a housing unit designed for a family, which can be replicated in a large-scale neighborhood project in order to be inhabited by a community. This urban-architectural project is provided with innovative technology, infrastructure facilities, economic viability and the conditions to develop the social capital of its inhabitants. These characteristics make MIHOUSE the perfect setting for a sustainable society.

If the main issues that deteriorate the planet´s natural resources and ecosystems were explored, it would be possible to list the exponential annual population growth, poor urban planning, an imbalance in the distribution of wealth, lack of education, malnutrition, pollution and waste, inefficient buildings, a human ecological footprint that exceeds the carrying capacity of the earth, among others. MIHOUSE has taken into consideration all these characteristics in order to respond to the increasing need of an economic and social development, allied with initiatives to diminish environmental impact, especially in growing cities in tropical countries. In this way, the MIHOUSE project proposes the renovation and densification of old deteriorated neighborhoods instead of using new land areas in the urban limits to respond to the growing urban population.

It is to highlight that the specific urban area where MIHOUSE is proposed, corresponds to a socioeconomic strata level 2, which means that the household income averages 2.3 monthly minimum wages (around $1´439.855 Colombian pesos -COP- or $454 USD). According to the "Estudio Plan Estratégico de Vivienda para la ciudad de Cali", done by Camacol and the "Empresa Municipal de Renovación Urbana EMRU", around 6.731 households in this strata and with this income level have the possibility to buy a house up to 60 million COP or $18.915 USD. However, the city is not able to offer enough houses to supply this demand.

In consequence, MIHOUSE is presented as the proposal that helps to counteract the housing shortage and the project to make available favorable social and economic solutions that come together to provide potential buyers with more sustainable ways of life. Therefore, it is possible to say that MIHOUSE is a sustainable house for sustainable people due to the following facts:

- Each house is architectonically designed to be flexible, which means that the family that inhabits it will be able to modify it according to its cultural background without investing a lot of money. It also means that the internal spaces are resilient to changes in time, weather if the family inhabiting it is composed by a single couple or a couple with children or living with the extended family. This flexibility allows the habitat appropriation and having more dynamic personal and productive relations thanks to internal and external spaces that relate productive aspects (in orchards and productive gardens in scale), with spaces of permanence and with terraces for socializing. This is complemented by the bioclimatic conditions of the house, which provides ventilation and a climatic comfort that is related to a more energy efficient house.

- MIHOUSE allows families to have their own urban gardens, which reduces the dependency on products brought from far distances and reduce CO2 emissions caused by transportation. By growing their own vegetables, species and fruits, the families will be able to designate their income to satisfy other needs and will be able to sale the surplus production of their gardens to their neighbors at specific areas in the urban proposal. In this way, every household will have an economic inclusion that will decrease unemployment, will have an additional income, and will prevent malnutrition.
- MIHOUSE motivates the use of bikes and promotes walking, avoiding the use of cars at the interior of the urban proposal. This helps in the reduction of CO2 emissions to the environment, allows the protection of pedestrians and the enjoyment of public spaces. It also prevents obesity by promoting exercising and generates spaces that are articulated with nature allowing an environmentally friendly recreation.
- The constructed space will have communal areas destined to educational purposes in order to increase people´s knowledge on topics that will promote self-employment. In these areas, courses about recycling, the generation of organic products and byproducts, how to make the maintenance of gardens, orchards and the infrastructure, how to start a home business, among others, are meant to be offered. This will help shape the neighborhood, which is an inescapable part of our culture, and will potentiate the concept of community and cooperation. These activities will also be beneficial to unemployed people, for those who could not access educational programs and for those how are retired.
- The people that will benefit at a MIHOUSE home will learn how to use wisely the drinking water, how to reuse rain water, and how the construction system works in order to reuse used water. They are also going to be able to separate organic and inorganic waste, will be more effective when it comes to recycling and will be able to compost and reuse organic waste, putting in practice simple environmental principles of having circular processes and reusing nutrients.
- The MIHOUSE habitat is designed departing from the environmental tropical conditions which are determining for the synergy between comfort and the total efficiency of environmental factors. The incidences in the population will be visible because by having less impact of the radiation due to its design and

location, the environment will be fresher and healthier. The thermal behavior of the house is optimized by crossed ventilation and by the use of materials culturally rooted.

- MIHOUSE tries to depend on solar energy in order to copy nature. In this way, the inhabiting families will be more sensitive to learn about new technologies, will be guided to reduce their energy consumption, to use improved and more efficient appliances, and will be more aware of daily routines that can help reduce unnecessary energy losses.

Being all these aspects presented at the Solar Decathlon Latin America & the Caribbean 2015 in the city of Cali – Colombia during the month of December, groups of recognized international juries evaluated the 16 prototypes constructed at the Solar Villa of Universidad del Valle.

Given the results, the proposal presented by the MIHOUSE team achieved the following awards: first place in Sustainability and second place in Architecture, Urban Design and Affordability, Engineering, Innovation and Energy Efficiency. The MIHOUSE prototype was also selected as the second favorite house chosen by the public.

The comments provided by the juries in regard to the MIHOUSE project were:

- In relation to its first place in the Sustainability contest:

  "It is a house adapted to the network and the climatic conditions of Cali. Despite the low height inside the house, the climatic comfort achieved through passive strategies is excellent. The wood enclosure fulfills aesthetic, bioclimatic and lighting control functions in an outstanding way. It highlights the use of materials, which are easy to assemble and build, form a good set and are of good cultural acceptance. The urban project is outstanding in its spatial, urban and landscape conception."

- In relation to its second place in the Architecture contest:

  "The proposal is very complete, synthetic and feasible, with a high quality of execution. Its aesthetic is fine and balanced. It is a project that could be executed immediately and that solves very well the aspirational needs of the population. Its urban proposal is also very attractive and congruent with the architectural proposal. Its spaces of semi-public and public transition, generate life in community and capacity to make a city.

- In relation to its second place in the Urban Design and Affordability contest:

  "The proposal reflects innovation in social management. It presents a system of public space equitable to all homes and on a human scale. Seeks to create community, families and neighborhood in their communal spaces. There is an innovative proposal on the construction system, waste management and infrastructure management as well as a social proposal among the various institutional actors, citizens and non-governmental organizations."

- In relation to its second place in the Engineering and Construction contest:

  "The coherence and correspondence between the different systems stands out, from the architecture to the engineering solutions, and therefore its constructed result. However, the structural solution is not very flexible and difficult to recycle."

- In relation to its second place in the Innovation contest:

  "The evaluation estimated the incorporation of creative solutions (around architecture, engineering and construction, energy efficiency, urban design and affordability), to improve the living situation of habitability by increasing its value and / or improving its performance and efficiency. The jury recognized the enormous effort made by the participating teams, who have had to face different difficulties for the conceptualization, development, construction and tuning of their housing proposals, facing the challenge posed by the competition and the limitations that the same represent. Understanding the dissimilar characteristics of the prototypes, the jury clarified that it does not seek to reward a "unique" and "universal" solution that allows satisfying all needs and contexts; so it has decided to focus on the fundamental ideas that lead teams to make decisions on their proposals, the consequences teams expected of them and their impact on contemporary context. For the jury, innovation does not necessarily mean novelty, but the search for the necessary and appropriate within the economic, social and environmental reality."

Given these results, the MIHOUSE team and the institutions that supported it (USB and UAO), felt immensely proud and inspired to continue in the research for developing new sustainable housing solutions that could depart from the experience acquired with the MIHOUSE project. The legacy of this project was very significant because it fostered the awareness of taking care of the environment and of the responsibility in the consumption of the natural resources among the team members uncharged of thinking the MIHOUSE proposal. These vision was also transmitted to sponsoring companies and to the society, mostly through the team´s testimonials, actions, and through MIHOUSE ´s social networks, which supported the progress of the proposal (since its conception as idea, its design, structural and budget calculations, and in a near future during the dynamics of students and the community in the MIHOUSE Sustainable Housing Laboratory at USB).

It is possible to conclude that the MIHOUSE project is successful and enriches the social capital of the city. This is because since its conception and through its own developing phases, the project helped to educate by spreading a citizen culture where all the individuals are conscious of themselves, of their contribution to a community, of their compromise with taking care of the private and collective environment, and of the values that constitute sustainability.

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The MIHOUSE project presented by USB and UAO won the following awards: first place in Sustainability and second place in Architecture, Urban Design and Affordability, Engineering, Innovation and Energy Efficiency. The MIHOUSE prototype was also selected as the second favorite house chosen by the public and now a day's serves as a sustainable laboratory for students and researchers at USB campus. The success of the team and project was the product of a constant and interdisciplinary effort from all decathletes; a clear understanding of the contest rules; an arduous commitment to produce the best sustainable housing prototype for tropical contexts; an enormous effort from all research groups working in innovative solutions applicable to the constructed housing prototype; and an important engagement with sponsoring companies that worked with the MIHOUSE team in creating a better future.

Due to the success of the MIHOUSE project and the tremendous opportunity to participate once again in an international contest as the SDLAC, both universities decided to create a new group called TUHOUSE to participate in the new SDLAC2019. The selection of 16 new teams will be held at the same time this book goes under revision. Therefore, the aim of this book is to provide a pathway to new Solar Decathlon participants and a tool to inspire the new generation towards the design and construction of real sustainable housing solutions for low-income families in tropical contexts.

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