What can be the most effective sustainable strategies for construction codes in “El Mirador”, Puerto Ayora – Galapagos?

Cristina Calvopiña Oña
MSc Advanced Sustainable Design
School of Arts, Culture and Environment
The University of Edinburgh
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Abstract

There has been an increased focus on sustainable construction and public awareness in recent years. How to be able to adapt new urban developments without being disrespectful to the environment is one of the most challenging strategies to achieve for planners. It has been proven that even small changes can produce big results when talking about design and architecture. Any modification to an ecosystem should not be detrimental from the outset of a design project to the completion of the urbanized area.

Historically the primary concern on the Galapagos Islands was the protection of the natural landscape. An increased population and a lack of urban planning have resulted in the balance between new developments and the protection of the natural landscape being harder to manage. Determining a sustainable direction for the growth of Puerto Ayora is essential to the future of the community and the island.

The lack of efficient construction codes for construction in Puerto Ayora, and the new development “El Mirador” has produced a disorganised growth with characteristics that are not entirely respectful with the environment. Through the analysis of the characteristics of the climate, the appropriate architecture that will work in the area and the characteristics of the existing urban developments a questionnaire was developed to confirm the improvements needed for construction in the island.

From this study the results show the necessity of improving the quality of natural ventilation and illumination related with the openings in the house and the space to the boundaries of the buildings; which will increase green areas in the properties and in urban zones. Also the improve selection of materials will reduce the impact in the ecosystem and the requirement to provide an adequate design to collect rainwater in constructions. These elements together will represent the beginning of a sustainable development, which, until today, do not have a defined line that will lead to a low impact on the environment.
Chapter 1

Introduction

The Galapagos Islands are recognized as one of the 24 provinces of Ecuador. They are located approximately 1,000 km from the mainland and are comprised of 13 major islands, 6 minor islands and 107 rocks and islets. From this, just 4 islands are currently populated. It is important to mention that in 1959 Galapagos was established as a National Park, and in 1978 was recognized by UNESCO as World Heritage and in 1985 as a Biosphere Reserve, which was later extended to also include the Marine Reserve.

The moment that the National Park was established, the Ecuadorian government defined by law: that 97% of the land will remain as a protected area and 3% will be available for urban developments. This 3% unfortunately was not planned for such rapid growth as the one the Islands had, considering that until the mid 2000’s Galapagos had a 5% annual population increase in the territory.

This percentage was the highest of the whole country and it was mainly because of the migration that the Islands received, managing to increase in 20 years from a population of 9,785 to 25,124. Both, domestic and international migration led to a variety of contrasting construction ideas. Due to the mixed population, the developed 3% does not promote today uniformed characteristics of architectural design.

One of the main impacts on the environment comes from construction, even more in a protected area like this one. The commercial, tourist and housing developments had to adapt quickly to the ecosystem. This process clearly highlighted that the islands were not ready for this fast growth and the result of this was the unplanned urban areas that we have now.

Although Santa Cruz was one of the last Islands to be colonized, the rapid annual population growth in urban and rural areas elevates it into the most inhabited island of the Galapagos Archipelago. Today the population of the island stands at 15,393. The tourism industry provides a large proportion of the islands economy and this is directly related with the construction development that is happening in the city.

“Through the years this influence affected the traditional constructions of the island homes. What once tried to be: stately, with big roofs, build with light materials on
pilots that raise them 1 m from the floor – which gave a good atmosphere inside, today reign really warm and not attractive “boxes” of concrete and cement; reflection of the absence of government and municipal assessment programs for urban development. But that is entering in political subjects.” (Idrovo, 2001, p. 246)

This political subject discussed by Hugo Idrovo implies how the technical parameters have been changing throughout the years and have not been aesthetically harmonious with the environment and the dynamic of the Islands.

The construction codes have been inefficient and unconcerned with sustainable elements that could improve the quality of the housing in this region. This is why more than half of the city was built without following any of the codes and the developments currently underway still show no intention to build in a more sustainable way.

This study will define important sustainable strategies that can be applied in the construction codes for Puerto Ayora town located on Santa Cruz Island, specifically for a small growing area, a new urban development that is taking place now, called “El Mirador”. This development incorporates 1,133 new plots in an area of 70 hectares; where at the moment there are no basic services provided such as electricity, drinking water, sewer system, finished roads or sidewalks that could facilitate the use of these spaces.

From the inception of El Mirador customised construction codes have been implemented to assure a uniformed development of this new area. Unfortunately the lack of control and strict regulations produced a different panorama of these constructions.

Now a new proposal for regulations and construction codes for the whole town of Puerto Ayora are under review, including the El Mirador area. This process is a big opportunity to consider and implement sustainable strategies that will be beneficial for construction and urban development on Puerto Ayora and of course on the Galapagos Islands collectively.

Methodology

For this dissertation the information will be sourced from relevant literature, reviewed and compared with results from questionnaires and findings from pre-existing Puerto Ayora developments and the current construction codes.

The questionnaire will be developed to help identify some basic characteristics of construction in Puerto Ayora and gauge the importance of some general ideas regarding sustainable strategies from the local community.

5 Translate by author.
The dissertation will be divided into the following chapters:

Chapter 1 will explain the motivation to undertake this study, the scope and the methodology that is going to be used in the process.

Chapter 2 refers to sustainable construction in hot climates and main characteristics that could be implemented in fragile ecosystems such as the Galapagos Islands. Discussing specifically the configuration of building, which could improve the quality of the housing and reduce the impact on the environment.

Chapter 3 will be a brief analysis of the city and the actual characteristics of construction and architecture that is taking place in Puerto Ayora; as well as an introduction to the new development and the proposals that have been taking place already for construction in “El Mirador”. There will also be a brief evaluation of the current construction codes for both the town of Puerto Ayora and “El Mirador” project.

Chapter 4 an analysis of the data collected from the questionnaires and a proposal to improve the construction codes for “El Mirador”, explaining benefits and improvements for the built environment in the long term.

Chapter 5 Conclusions.
Chapter 2

Sustainable Design and Fragile ecosystems

As discussed in the Declaration of Interdependence for a Sustainable Future:

“Buildings and the built environment play a major role in the human impact on the natural environment and on the quality of life; sustainable design integrates consideration of resource and energy efficiency, healthy buildings and materials, ecologically and socially sensitive land use, and an aesthetic sensitivity that inspires, affirms, and ennobles; sustainable design can significantly reduce adverse human impacts on the natural environment while simultaneously improving quality of life and economic well-being.”

As referenced by Yeang (1995) “When talking about the human impact the major concern in architecture is how it should be propose to reduce the effect that it generates into the ecosystems”. This approach to architecture should be as natural and low impact as possible, since as a designer it is really important to take into account that to introduce new ideas and developments to some spaces it is crucial to avoid the generation of any harmful influences in the environment, especially when the project is developed in zones with low human influences such as protected areas.

Since the Galapagos Islands were declared as protected area and world heritage a lot of studies and interventions had been done to ensure the maintenance of natural ecosystems. It was a priority not only for the country but also for many international organizations to protect the unique characteristics of this area. Unfortunately one of the issues in this process was not to consider the development of the urban growth and the necessity to generate a balance between the ecosystem and human settlements.

One of the main topics of new developments in fragile ecosystems is how the proposals can include all the basic services that are needed and at the same time to improve the quality of life of the habitants without generating or producing significant changes in the environment. It is important to understand in these processes that services to be provided will be limited and it is not possible to compare this to other developments in different urban areas. The characteristics that are adopted should represent the place, the people and their way of living.

“It is clear that in the past, designers have erroneously conceived the environment as an infinite source of all resources and an infinite sink for all discharges and waste products” (Yeang, 1995, pg. 36). Further to this Floyd et al (2012) argue that improving the design process will create architecture and urban developments that could maintain the balance between building and

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6 “Declaration of Interdependence for a Sustainable Future” World Congress of Architects, Chicago, June 1993.
ecosystems not only in the present but for future generations. This is supported by Morrish (2009), who states that it is really easy to take for granted the resources that are provided in our environment, this is why the absence of good ventilation or the increasing cost in energy bills makes us realise how crucial sustainable features are and how important it is for people to assess the goods provided by nature.

It was surprising to visualize the fast growth of urban developments in the Galapagos Islands. The population managed to settle in the areas, without any concerns about the risk of producing harm to the environment. It was easy to consider that natural resources will be provided one way or another, so there was no interest to build or create an urban development more responsive to the environment. It was difficult for authorities to provide all the services for this rapid increase of population, so residents in the islands had to manage a way to adapt on time.

It is common to see similarities from place to place when talking about architecture, but it is really important to understand that every single zone has specific characteristics that cannot be treated in different places. This is why it is crucial to realise that codes and rules in developing countries should be based on conditions specific to that country and not on foreign standards (Koch-Nielsen, 2002, pg. 18). While Koch-Nielsen refers to conditions specific to a country, the characteristics of different cities and developments should also be different according to the climate, lifestyle and the main activities of the population.

“To design according to the characteristics present in nature will lead rather to an architectural vocabulary that is shaped by rational, reasoned and proven solutions. It also produces a language that is accessible to all, and its inherent attractiveness is “natural” owing to a harmony with its environment” (Koch-Nielsen, 2002, pg. 16).

This architectural vocabulary is what allows users to recognize the reality of their environment and find a way to adapt their needs to the real characteristics and services that are naturally provided for them.

When we have a mixture of characteristics it is important to take everything into account to provide the best solutions for the comfort of the population. Just as it is important to consider customised building strategies for protected areas, it is equally important to consider customised building strategies depending on climate. With this in mind to build in hot and humid climates within a protected area creates a more complex design and development process. Greater consideration should be given to the needs of a community within these areas to sustain the balance between nature and the built environment. The importance of customised building strategies in hot humid climates will be discussed further later in the chapter.

Yeang (1995) shows that “The architect has been responsible for the assembly of materials at the site, the construction of the building, and often the maintenance and
renovation of the building after it has been completed”. Moreover it is important to understand that these traditional responsibilities are crucial in the process of construction, especially on islands, where the mobility and extraction of materials are not as easy as in big cities.

All these issues are linked with the idea of sustainability. It is recommended that when starting a process of design it is important to maintain a logical order of analysing the existing characteristics of the environment. Floyd (2012) develops this idea by identifying the following primary environmental impact areas:

a. Sustainable site development
b. Water conservation
c. Material resource conservation
d. Energy efficiency
e. Indoor environmental quality
f. Building operations and maintenance

It is from this, that the architect should be able to propose a more reliable and low impact design that would adapt easily to the environment.

a. Sustainable site development

When starting a project the first step to start is to analyse the characteristics and the benefits of the environment. How a project can be part of a specific area when including the climate, social and economic factors, defines the success of a new development. It is common to see new developments that have nothing to do with the reality of a specific area and these just produce negative reactions from part the community that may result in further environmental impacts.

The main characteristics of a space or the environment where a project will be developed should remain as natural as possible, thinking always in how to minimize the impact of construction and new expansions. As mentioned by Floyd (2012) the intent of responsible site development is to protect habitats and retain native vegetation, among others; specially in areas with fragile ecosystems where being able to adapt new ideas to the environment is more like a priority.

There are clear specifications that should be considered in areas like the Galapagos Islands, where today the process of extraction of material for construction and backfilling in plots are causing a big environmental impact. In Puerto Ayora from 2014 until 2017 only for public work it will be required an amount of approximately 2,053,238.72 m³ of extracted material⁷. This without mentioned the necessity of material for private plots and private constructions that will increase the number in a big amount. This is why is so

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⁷ Data from the Municipality of Santa Cruz
necessary to do a better planning and to avoid an exaggerate exploitation of the quarries.

“In specific climate zones such as hot humid areas it is important to be aware that the natural cover of a terrain tends to moderate extremes in temperatures and stabilize conditions” (Koch-Nielsen, 2002), totally the opposite to concrete buildings and asphalt roads that usually absorb the heat and produce uncomfortable zones to walk or stay during the warmer time of the day.

It should be a priority in new developments not only to take into account benefits in construction that could reduce impact in the environment but also provide comfortable urban zones for people, at the end this respect for the natural environment and the reduction of impact during construction will be correlated with the wellness feeling that habitants will have.

These benefits are not only comfortable houses, but the whole urban design that will include more efficient roads and parking zones, well provided areas designated for bicycles and pedestrians, walkable developments or a proper method of transportation that will simplify connections in the city or towns, public and green spaces that compliment the urban zones.

When taking into account these types of characteristics, sustainable areas are developed and with this a lot of benefits are gained. As cited by Floyd (2012), when we create sustainable sites, the landscape gives back:

- Cleaner water and air due to ground infiltration and native vegetation
- Cooler cities as a result of reduced hardscape and heat island effect
- Carbon capture through vegetation that mitigates climate change
- Resource conservation and regenerative environment due to native-vegetated landscape
- Greater energy efficiency due to the shading of buildings by trees and other vegetation
- Habitat conservation and biodiversity
- Lower cost and improved performance from storm water management
- Nature-friendly environment that produces pleasant living conditions

b. Water conservation

One of the main topics to take into account to develop a project should be the management of water and how to propose a design for new developments that allow to reduce the over consumption of it. In Galapagos, water is a complicated topic. In Santa Cruz, the most populated island there is no provision of clean water. The houses received a semi-salted island water for all the uses but drinking and cooking for which you have to obtain treated water from private companies.
In cases like this, it is important to consider what elements should be necessary to adopt in new developments where we cannot take for granted the provision of potable water. During the design phase of a new development it is necessary to consider the efficiency of water collection and distribution throughout the urban zone and the reduction of wastewater.

It is really convenient to reduce the use of water in terms of reducing the energy consumption, while more reduce the usage in the house, more reduce on the energy we need to treat and transport water (Floyd, pg. 108). A big part of these reducing mechanisms are the technologies selected to be use in houses; plumbing and distribution systems could be more efficient like eco-technologies design specifically to reduce the unnecessary consumption of water. These technologies combined with rainwater collection or grey water treatment could significantly minimise water wastage.

Puerto Ayora at the moment is not provided by potable water, and the quality of water received in the houses is just semi-salted water with a basic treatment, which is used for everything but for cooking or drinking. For cooking or drinking some companies in the city do a more exhaustive treatment and sell it by 15 litre water bottles or filling in cisterns. People usually spend large amounts of water without consideration since the water provided by the Municipality is not potable water.

In Puerto Ayora, every owner of the house pays approximately $5.24 USD monthly for the use of water in private housing and $11.24 USD for commercial properties. This is a general amount that does not consider the quantity of use in each house. This statement is justified for the authorities and for the population in response to the bad quality of water that is provided.

Most of the health problems in Galapagos are directly related to the quality of water, not only the water received in the house but also the water used for drinking. This is why processes for collection of water and reduction of consumption are really important to consider in the islands; even more now that Puerto Ayora is going through the process of implementing potable water. It is hard to know how long this process will take, but it is important to consider in advance the necessity to complement this process with systems of rainwater collection and campaigns that motivate habitants to reduce and control the consumption of water.

Besides this consideration the treatment of grey waters is a subject that concerns the population. On the islands there is no sewer system and most of the houses have to build a septic tank in their plots. These septic tanks are not always elaborated with good permeability or even worse some house owners have no septic tanks at all, letting the grey waters flow into the cracks, which results in contamination of sources of water within the community.

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8 Data from the Municipality of Santa Cruz
As part of the initial design, reflections about water should be considered, especially in cases where it would be possible to separate potable and non-potable distribution of water to the house and of course a proper treatment to grey water. Generating differences in the piping of the house and managing to use potable water only for main purposes will greatly increase the efficiency of the house.

The house itself could provide the non-potable water, potentially from rainwater collection or by grey water treatment. This treatment could be adapted in the same area of the house if there is not a centralised water treatment system established by the government. Which will reduce loses and contamination of new sources of clean water.

c. Material resource conservation

“The effectiveness of a building envelope is directly related to the choices made regarding materials and construction, that is, the thermal properties that each material has, and the properties they have when combined together to form building elements.” (Koch-Nielsen, 2002, pg. 96)

One of the most important parts of construction is the proper selection of materials that are going to be used in a project, and especially when the projects are developed in areas where production of material is really limited, and the cost of transportation is really high. In this case it is crucial to consider all the alternatives possible that will reduce the impact of production, mobilization and exploitation of materials that will improve the quality of the development and at the same time will be kinder to the environment.

As mentioned by Floyd (2012) “Vernacular buildings are built from local materials defined by the geology, ecology and climate of the region. These structures are often highly practical, culturally appropriate, energy efficient, and blend with the landscape.” Taking these ideas into account will take us back to the construction in the past, where these characteristics were developed for necessity and work much better that most of the new developments.

As time passed new materials were developed and construction in the cities became more and more ambitious to show the variety of products that the market offered. It was important to achieve reduction in costs and time of construction and local materials suddenly were losing popularity in some parts of the world, or even worse, the source was reduced at the point of the necessity to search for materials from far away.

One of the keys to achieving a sustainable development is to be aware of the quantity of material that will be needed for construction, reducing sizes of construction or even volume per square foot, which will reduce the direct impact that the new building will produce (Floyd, 2012, pg. 131). Beside this, the selection of materials that are produced in the immediate context and
that will require less mobilization, process and work, and the reuse of materials from older constructions or normal recycling processes, will improve in a significant part the sustainable aspect of a specific project.

In Galapagos the variety of materials is reduced. Almost all the material for construction has to be imported from the mainland, which increases the cost of building in a significant way. The process of mobilization and distribution of material causes in one way or another a big impact in the environment and in the natural development of the islands.

Galapagos today has a recognized recycling process that allows minimizing the impact of the disposal in the islands. If the process of recycling and building could be combined maybe a significant change could take place in construction and will reduce the environmental impact of the materials use for buildings today.

**d. Energy efficiency**

“At the present 83% of the global primary energy produced is consumed by only 25% of the world’s population, leaving only 17% at the disposal of the remaining 75% of the world’s population (who live mainly in the developing world)” (Koch-Nielsen, 2002, pg. 12).

Nowadays buildings represent 32% of the total final energy consumption in the world, and one of the big concerns about this is that it is mostly from the use of non-renewable energy, which is one of the main producers of CO2. Right now this is a big concern when talking about changes in air quality and global warming. For many years the way of construction was the main factor that determine the use of energy in the building. Vernacular architecture always proved how the adaptation to the environment could determine the natural energy systems and without a huge impact generates a zone of comfort for the spaces. The external environment can improve the energy efficiency of a home through sustainable design.

Well designed houses, with well ventilated and illuminated spaces will reduce in a significant way the use of air conditioning and artificial light, which means a reduction of energy consumption and ultimately energy production from non-renewables sources. While it is true, the energy that is required for the building could come also from renewable sources, that could be part of an initial design that allows the behaviour of the building to compliment their characteristics with eco-systems as photovoltaic, solar thermal or wind turbines that could massively reduce the use of fossil fuels.

As with all the other impact areas, it is crucial to take into account the specific characteristics of the bioclimatic environment. The correct solutions

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9 IEA, Energy efficiency
for the building and its location determine the comfort of the users and the behaviour of the building in relation to the external areas and its response to the internal performance.

“Aiming to energy efficiency means being able to reduce the dependence on non-renewable energy resources like fossil fuels and nuclear energy” (Floyd, 2012, pg. 151). In 2014 in Puerto Ayora the consumption of electricity accounted to 25,393,683 kWh, where the 95.7% was produce by fossil fuels and the other 4.3% was produce by renewables. For 2015 the use of fossil fuels decrease to an 89.5%, being able to reduce the use of diesel in a 10%. This numbers just show us how important and reachable is to achieve a sustainable direction for Galapagos; and big part of maintaining this, is to improve the behaviour and adaptability of buildings in the environment.

e. Indoor environmental quality

It is critical for a designer to provide internal spaces that could reflect comfort to the users, especially in areas where temperatures change constantly and its necessary to generate micro-climates that facilitate internal activities. As mentioned by Floyd, (2012), “Indoor environmental quality is the most direct human – related issue of green buildings, as it directly affects health, comfort, and well-being of building occupants”.

In Puerto Ayora there are two typologies of constructions. One that is an individual building separate for the boundaries of the plot, and the other one that is attached on 1, 2 or 3 sides to the neighbour. This type of building, which is the most common, usually present a lot difficulties at the moment of internal comfort, not only for the space necessary for ventilation or illumination but for the noise and lack of privacy from the neighbours.

The capacity to avoid high levels of noise that can irritate occupants of the house or the building is essential. “Improperly controlled sound transmission through floors, ceilings, and walls between dwelling units or other occupancies can lead to poor indoor environmental conditions particularly between neighbours” (Floyd, 2012, pg. 203). It is crucial to analyse the relation of the building with the surroundings and generate a proposal that could facilitate the internal activities without uncomfortable external factors.

Natural light is the best light source for the eyes, and when the spaces are not properly designed it is necessary to use excessive artificial light that is not good for health. In some cases bad use of fluorescent lighting can easily produce sore eyes and headaches.

Part of the characteristics to improve an indoor environment is also the capacity to connect the human to nature. It is essential to understand that as humans we have the necessity to feel proximity to the natural environment

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10 ELECGALAPAGOS, Electric Company in Galapagos
this can produce a sensation of comfort and wellbeing. Creating a design that allows this connection is a way to improve the quality of the internal space and the quality of life that a person could have in this environment.

f. Building operations and maintenance

When realising a design it is important to take into account not only the behaviour and the relationship that a building will have with the users, but also to make all the operational specifications of the building transparent in order to avoid confusion for users. This will facilitate the use of spaces and also will make it easy to understand what to do and how to do it if some functioning inconvenience should occur.

One of the main ideas of designing a green building is always to allow the user to be able to deal with any difficulty that is presented in the building or in any case to make it easy and approachable to find a solution or technical support that could resolve the issue. It is pretty common to find damage in buildings that could not be fixed easily when the design does not facilitate access and simple connections to all the areas of a construction.
Building Design for Hot Climates

“If God is in the details then climate is in the building section”
Peter Woods 11

The hot humid climate is found close to the Equator and extends to 15 degrees latitude, north and south. The dominant feature is lack of seasonal variations in temperature. The characteristics are high humidity and relatively high temperatures although it does not have the extremes of temperature and humidity as found in other climates (Hyde, 2000, pg. 22).

The Galapagos Islands are located in this area, but these Islands receive two main currents (Humbolt and Cromwell) that produce slight changes in the climate, generating two main seasons that define the characteristics of the weather. The garua season (June – November) when the temperatures decrease and the sea could reach a 22 degrees C, there are cold winds and continuously mist, as called in Spanish garua. The warm season (December – May) is when the sea can reach 25 degrees C; there are warm winds and sporadic heavy rains usually at night with clear and sunny days.

These variations in weather are what define the characteristics that a building or a project should consider. Even if Galapagos does not consider having only a hot – humid climate, because temperatures can vary and will not get so extreme as in other typical hot – humid territories, most of the characteristics proposed for these types of climates can be applied in this context and will be explained in this dissertation.

As a designer it is important to be able to achieve an energy-efficient project that not only reduces the impact in the built environment but also could to use natural measures to improve comfort conditions, not only inside but also outside any building. Being able to take advantage of the benefits from the climate to improve the quality of a project is part of the process of analysis that should be understood at the beginning of any development.

“In areas with hot-humid climate is important to be aware on how this climate affects human comfort, the way we occupy buildings and the activities we conduct inside those buildings” (Floyd, 2012, pg. 159). The local environment should always be considered. The characteristics that older constructions developed and proved successful could be useful to reproduce elements that already improve internal quality of the spaces and managed to adapt easily to the ecosystem.

As Givoni (1998) mentioned, there are a number of main design objectives that should be taken into consideration when developing a project in hot regions (some of them apparently conflicting from the building design aspect) and can be summarized as follows:

11 Cited by Hyde, 2000, pg. 137
- Minimizing solar heating of the buildings
- Maximizing the rate of cooling in the evenings
- Providing effective natural ventilation, even during rain
- Preventing rain penetration, even during rainstorms
- Preventing entry of insects while the windows are open for ventilation
- Providing spaces for semi outdoor activities as integral part of the “living space”

To be able to achieve these objectives it is crucial after analysis that the general characteristics of the environment produce an architectural and urban proposal that could respond to these necessities and could produce a natural connection between the ecosystem and the building environment. Following these considerations the decisions that should be taken for architectural and urban development should be distributed thus:

a. The Built environment

As mentioned in the previous section, in the development of an urban area of an architectural proposal it is fundamental to take into account the basic characteristics of the immediate environment. It is basic to understand the meteorological behaviour of the area but is also really important to analyse the characteristics of the surroundings and the buildings that constitute the proximity of the new proposal.

This analysis could be called the characteristics of the microclimate. Solar and wind orientation for the new development should be considered based on localized elements such as existing buildings, vegetation, roads and access which will determine the best proposals for the new development.

In this type of climate it is decisive to facilitate the connection of the project with the main services of the city reducing the use of motorized transportation. Supporting and providing safe and comfortable facilities for pedestrians and cyclists could achieve this goal.

Inevitably walking or cycling will be difficult in hot weather as temperatures peak at certain hours in the day. It is important to analyse the characteristics of the materials used for paths and sidewalks and the elements that complement them such as shading devices and vegetation that could improve the functionality of the area.

b. Building layout

“It’s at the building envelope that the interrelationship between the given external conditions and the required internal conditions are determined” (Koch-Nielsen, 2012, pg.66). The characteristics that are given to a building in its configuration and primary design are the factors that determine the evolution of this building. The envelope Koch-Nielsen refers to is not only the external façade of the building but also the relationship the exterior has
on the internal functionality of the building. Achieving this balance is key to good sustainable design.

As Konya (2011) mentioned it is usually better for this climate to design buildings separated and scattered with free spaces between them to utilize and maximize airflow. Open and transparent spaces will maintain the freshness in the building and will improve the quality of internal spaces.

Selecting the proper characteristics for the roof, the openings and the floors, the use of verandas or galleries or raising the building on stilts could be advantageous for the interior/exterior dynamic of the building.

**The roof**

This is one of the most important parts of the design; since the area of the roof is the one that absorbs the greatest amount of solar radiation during the day its performance is crucial for the internal comfort of the building during day and night. The characteristics in terms of materials and shape will depend on factors like economy, design and location, but in general there are some considerations that are recommended to take into account when building in hot climates. These considerations include:

- Light coloured materials that could reflect solar radiation
- Lightweight materials
- Low thermal capacity
- Parasol type to maximize ventilation
- Minimize area of roof lights
- Generate if possible air movement across surfaces (roof – ceiling)
- Generate a type of sun-breaker system

Depending on zones it is important to provide a design that will be able to protect the interior from heavy rain, in many cases to provide pitched roofs that could allow the collection of water or the implementation of energy sources such as solar panels or hot-water systems. In this case as Hyde (2011) mentioned, it is important not only to consider the inclination of the roof but also the orientation.

**The walls**

“This element besides being structural provides protection to the building from heat, rain, wind, dust and light, besides serving as an component that produce definition and partition of the spaces” (Koch-Nielsen, 2002, pg. 76). As this is part of the envelope of the building, the materials used, the colours and the orientation of the walls determine directly the internal behaviour of the rooms.

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12 Koch-Nielsen, 2002; Konya, 2011; Hyde, 2000
13 Floyd, 2012, pg. 79; Hyde, 2000, Chapter 7; Konya, 2011, pg. 64
It is recommended to use the following characteristics in the walls when building in hot humid climates:

- Lightweight construction
- Low thermal capacity
- Solid walls should be minimised
- Walls can take the form of adjustable shading devices
- If walls are facing to direct solar radiation (west and east) addition of mass or insulation can prevent the increase of internal temperatures
- Light coloured and highly reflective materials

The walls can be considered as a static element that could and should be combined with an active element such as windows or transparencies that will generate a balance between the protection from the climate and the absorption of natural elements (light and wind) that will benefit the interior of the building.

**Openings and windows**

The appropriate design of openings is critical as it is at these points that the building envelope links the internal environment directly to external conditions. As cited by Floyd (2012) the decisions taken at the moment of design, the size, the location and the treatment of the openings will ultimately affect heat gains, air movement and the quality of air and light indoors.

It is common that in this climate natural ventilation is desirable since it helps to minimise the discomfort resulting from wet skin sensation, this is why it is important to analyse the orientation of the openings, looking forward to receive the maximum airflow possible. (Givoni, 1998, pg. 89 and 93).

The main characteristics to take into account when designing openings and windows in hot climates are:

- Openings should not be positioned to face the sky, which is the main source of glare
- Openings should be large with inlets of similar size where a wide distribution of air is required
- Use of fly screens, which will reduce airflow, so if possible should be installed away from windows.
- Should have protection from rain and noise
- Shading devices could be used to exclude unwanted light such as louvers or other adjustable canopies
- If possible locate openings in opposite facades to generate cross-ventilation in the building

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Floyd, 2012, pg. 84 – 91; Konya, 2011, pg. 64; Givoni, 1998, pg. 89
It is important to know that these openings and windows not only should improve the ventilation in the building but also natural illumination, for this the selection of the material like glass, screen or any other option should be chosen according to the necessities of the space. All of this could be complemented with the use of shading devices in case needed. Just as the materials used for the rest of the house or the building, the materials used for the openings should also be able to avoid the absorption of heat to improve the quality of the interior.

**The floor**

The floor in buildings can reduce heat gains when it’s properly designed to increase its overall ventilation potential. In zones where the building needs to cool down the temperature, it’s preferable to avoid heat storage in the ground. The main characteristics to take into account in hot humid climates are:

- Preferably no contact with the ground to improve ventilation in the building
- In this case, lightweight materials are appropriate
- In case of using solid floor or directly to the ground it is advisable to have built-in ducts to reduce thermal storage and provide ventilation with natural cooling
- Use of light materials that will help to keep freshness in the internal spaces
- The use of timber decks could help to reduce temperatures around the building when this is not elevated from the ground

**Veranda, balcony and decks**

A *veranda* is an open roofed platform along the side of a house, in areas with a hot humid climate, when the outdoors is usually more pleasant that the indoors, this is a really useful element to provide, which could generate a connection of the internal and external spaces with the necessary protection from the sun and the rain. Usually the use of verandas or porches in the buildings not only provide shade to the interior and help to reduce the heat inside of the rooms but also generate a useful space for semi-outdoor activities, what we can called a servant space (Hyde, 2000, pg. 203).

The *balconies* are usually uncovered platforms, located next to a window or door in high levels of the buildings. They have the quality to allow an immediate connection with the exterior, and it is really common to confuse verandas with balconies, since the purpose of both is very similar. In most cases where the balconies are uncovered and the climate is too warm, these spaces become really uncomfortable to use, this is why due to modifications these balconies sometimes end up behaving as verandas.

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15 Floyd, 2012, pg. 82 – 83; Hyde, 2000, Chapter 8
16 Hyde, 2000, Chapter 9
Decks are larger raised platforms without the roof of the veranda. They can be usually raised from the ground and be connected to the house. Temperatures on the deck are usually ambient; in really warm zones it is preferable to combine this with landscaping elements such as pergolas and vegetation.

c. Materials

To secure the effectiveness of the envelope of the building it is really important to make a proper selection of materials and their thermal properties. The combination of different materials and their properties will determinate the final performance of the building (Floyd, 2012, pg. 96). The role of materials in hot humid zones is to minimize solar heating of the interior during daytime and to maximize the rate of cooling during the evening and night hours (Givoni, 1998, pg. 397). It is crucial to analyse always the availability and performance of the materials that could be used in these areas; moisture, temperature, ultra-violet radiation and salt-laden winds are some of the main characteristics of the environment when talking about this specific climatic zone. Being able to use proper materials that could resist all of these elements essential at the point of design.

As the properties of the materials will define a big part of the internal climate behaviour, it is important to consider three main aspects; the capacity of reflectivity, absorptivity and insulative properties. These aspects combined will determine the final performance of the material in the construction.

Reflectivity: The capacity of a material to reflect heat from its surface. This is practically the first defence of the building against the radiation, since if the material have a really low capacity of reflection a big amount of heat will be absorb and will increase the temperature in the interior.

Absorptivity and emissivity: It refers specifically to the capacity of the material to absorb as well as emit radiation. While the absorption involves heat gains the emittance involves heat losses or releases from a surface (Floyd, 2012, pg. 100).

Insulation: Is the measure of the capacity of a material to conduct heat through its mass.

According to the characteristics, the availability and the design, the following materials are recommending to be used in hot climate zones. It is important to mention that this is just a compilation of the most common materials that have been proven to work in areas with this specific climate. (Compilation from Floyd, 2012; Konya, 2011; Givoni, 1998; Hyde, 2000)
<table>
<thead>
<tr>
<th>Material</th>
<th>Positive Attributes</th>
<th>Negative Attributes</th>
</tr>
</thead>
</table>
| Cane, leaves and grass | Easy adaptation to the climate  
Waterproof and lightweight  
When used as screens allows  
natural ventilation  
Bamboo will work as a  
reinforcement in concrete | Short lifespan (except bamboo)  
Rapid deterioration due termite attacks  
Easily flammable  
Harbours insects and vermin |
| Timber             | When properly treated and dried is really durable  
Easily adaptable to the environment  
Could be used as structure or in any part of the house. | In warm – humid zones is susceptible to wet and dry rot and to attack by termites and beetles  
Wind-blown sand and grit gradually erode exposed timber |
| Metals             | Reduce construction time                                                             | Corrosion due to a combination of high temperatures, high humidity and salt-laden air  
Have to be imported to the islands |
| Glass              | Improve natural ventilation and interior comfort when used properly with adequately shaded devices | Transport, cost and wastage are really high |
| Plastics           | Used for water supply, drainage, flooring and electrical fittings                    | Rapid deterioration by ultraviolet radiation and high temperatures  
Surface damage caused by wind-blown sand  
Some types are combustible and emit dangerous gases when burning |
| Concrete blocks    | Can be produced locally                                                              | Cracking due to shrinkage caused by temperature fluctuations  
Surfaces exposed to rain have limited permeability |
| Concrete           | Can be combined with other materials in construction                                  | Rapid deterioration because of minerals, water, bad workmanship and climate  
Hot winds can dry the concrete too rapidly and high humidity can saturate it  
Requires large amounts of water |
| Stone              | Easily adaptable to the environment                                                  | It could be difficult to find good stonemasons  
High temperatures could sometimes cause cracking  
Used mainly as decoration the material is often cheap but the labour cost can be high |

Table 1. Materials characteristics. Source: Various authors
Chapter 3

Characteristics of the study area

This chapter will present a brief analysis about Santa Cruz Island and how the construction is developed today in Puerto Ayora town where the new development is taking place now. Also it will mention a more deep explanation about El Mirador, which is the new development of 1,133 plots and its characteristics. At the end there will be short review of the existing regulation codes for this area and the new proposals for construction in the town.

a. Puerto Ayora, Santa Cruz

Santa Cruz is the Island with the highest population in the Galapagos Archipelago, with 15,393 residents. The Island has some rural and urban areas that have been growing as a result of the population increase, historically the main reasons were: the fast development in tourism and the migration from the mainland.

It is clear that there was not a common architecture typology for construction on the island, but where the first settlements were taking place it was normal to see the use of lava rock, wood and sand. The characteristics of the houses were related to the facility of construction, in this case, the use of materials that were more readily available to source and transport. It was important also to generate protection from the sun especially on warm days; this is why it is easy to see in old houses small porches or open areas with roofs that allow shelter and freshness into the internal spaces.

Some of the houses were built with a small elevation from the ground; in this way it was easy to maintain a cool space, allowing the wind to circulate

Illustration 1. Santa Cruz. Source http://mural.uv.es/mangran/
around and under the house. This we can call a vernacular architecture, is a proof of how the necessities of the people where reflected in the design. A bit contradictory to construction nowadays, when it is proof that when more facilities and options we have to build, less attention and respect to the environment is shown.

An example of these old typologies of construction is “The Angermeyer Point”, a house built in the 1950’s located and adapted to function by the cliff edge. Using materials such as stone and wood that allowed the construction to make a connection with the site. The openings, the distribution of the spaces and the location permit this house to be part of the context without generating an obtrusive visual impact on the landscape.

The design also aimed to improve the internal behaviour of the rooms with good ventilation, illumination and a proper circulation that allows a simple connection between all the internal parts of the house.

“The construction of the house with “rocks” demands great efforts in manpower and time. It could be considered a slow construction technique, but it allows us to take advantage, in a more intelligent way, the accumulation of material created during the movement and cleaning of the land area in preparation to build” (Guevara, 2010, p. 105)

As Guevara mentioned, this construction used nature as part of the composition of the house, in this context every element created and built, performs a specific function, allowing the sea, the animals and the environment to behave in the same way without changing the surroundings.

This typology of construction is minimal in the island, so while walking through the town we can visualize a mix of different typologies that represents the direct connection that the population have with the continental area.

17 Translate by author.
Some of this new constructions, tried to apply some sustainable ideas in the design that allow the buildings to look more naturally adapted to the ecosystem where they are developed and also that will not cause a negative visual impact for tourism. These types of constructions proved that it is possible to find a way to adapt and not to be so invasive at the moment of implementing urban developments.

Illustration 3. Examples of construction in Puerto Ayora. Source: Author

Sadly while it is true that there are some examples in the city of constructions that were developed trying to be part of the environment and prove to work without generating a big negative impact on the town, the majority of areas in the city have a completely different idea of construction. The current construction situation in Galapagos highlights the constant comparison with the construction in the mainland and the town of Puerto Ayora has become a small representation of different parts of continental Ecuador.

It is common to visualize unfinished houses, with the hope of a future growth and improving economy. Small concrete boxes that could be build in any other place and clearly are not projecting comfortable spaces for the owners or the surroundings and even worse, have no awareness of the climate and the characteristics that are needed to improve the internal spaces.

While it is true that some buildings in the city are developed with a good sense of the space and attempt to apply good sustainable practices some other spaces give you the wrong impression of what a traditional island development should be. Walking down some streets and between these grey walls could make you feel like you are walking anywhere but in the Galapagos Islands (Illustration 4).
“La Cascada” is an urban development that followed almost the same process as El Mirador but here the plots were half the size (150 sq. meters) and even if regulations were established, as we can see in the pictures, none of them were applied. The lack of construction control, regulations for part of the Municipality and of course interest from the owners cause this view of the sector.

All of these constructions and developments in progress make you wonder how the urban development in Puerto Ayora could in any way be good for the environment, how people living in those small spaces could have internal comfort with natural ventilation and illumination. These developments pose a number of questions like: how much will they spend in the use of air conditioners or artificial light to make those spaces work and how will they be able to improve these conditions.
b. El Mirador

El Mirador is the main topic of this dissertation, as the picture shown (Illustration 6), this urban development represents almost a new Puerto Ayora, producing an expansion that will approximately duplicate the actual population. The big concern about this expansion is not only the lack of basic services or urban planning but also the fast construction process that is taking place without any apprehension about the environment.

The Municipality provided this new development in the city, with approximately 70 hectares of new land ready for urban expansion to 1,133 residents. It was a result of a political decision, where with a trade of land, the National Park approved the new growth in the area, just next to the existing development of Puerto Ayora.

For this expansion the Municipality provided the owners nothing but a piece of land (300 Sq. meters per owner) without any basic services such as electricity, water and sewer system. By 2010 the roads of the new urbanization were open (as shown in Illustration 6) and the owners had a basic idea of the location of their properties. During this phase it was concerning to realise that a big part of the project was designed for car circulation, considering that 25% of the project is designate for roads and the 39% for housing " (Guevara, 2010, pg. 49).

“Considering the magnitude of the urbanization project ”El Mirador”, the codes prepared by the Municipal Government to regulate the new development do not correspond to any criteria of shared institutional planning, this will cause

18 Translate by author
irreparable damage to the mines that the population currently uses, the urban image and the health of its inhabitants” (Guevara, 2010, pg. 71)

Comments like this highlight how some people perceived this new development, and the concerns about the political decisions that lead the city to this unplanned but fast growing development.

A lot of people from different institutions wanted to support this process so in 2011, the Prince’s Foundation for Building Community developed a workshop with the community and the Municipality, to provide some sustainable ideas that could improve the characteristics of this new development and of course, could reduce the impact in this fragile area. The result was the Report of the Code workshop for El Mirador 2011. The report outlines proposals for a sustainable expansion, with a basic idea to be implemented in construction codes, determining a consistent typology of housing, and ideas for a sustainable urban design and a proposal for solid waste treatment.

Although at the beginning the idea of using these proposals was welcomed by the Municipality and the owners of the land, all the efforts were losing interest. Suddenly the response to these proposals was elaborate housing designs in the Planning Department of the Municipality and the distribution of them completely free. These proposals had an entirely different idea of what sustainability and eco friendly housing represents.

19 Translate by author
New codes specifically for el Mirador were developed at the same time, and with this, the beginning of construction (Illustration 9). The buildings that appear in the new development show a different reality of life in Galapagos, their appearance is reminiscent of the typical construction in the highlands of the mainland. The design shows enclosed buildings with small windows and flat roofs that occupy almost half of the 300 square meters, leaving minimal green areas.
The process of construction is increasing now and there are more and more owners that have started to build their houses even if there are no basic services or facilities to do so, reaching the number of 85 constructed houses and 77 still in process. Due to the relatively low number of constructions, the lack of regulations is perhaps not fully evident. However with time and further developments these issues may become more noticeable.

Galapagos is a fragile ecosystem and construction is one of the main impacts on the environment, so every improvement that leads architecture to a sustainable future will be a huge benefit for the islands as a whole. Unfortunately this is not a main objective for the local government until now, the codes and laws that allow the construction in the islands are not demanding enough to generate an improvement in the design and development of new constructions.

The Construction Codes

With the beginning of this development, there were specific construction codes that regulated the growth of this area. There was no analysis of the characteristics of the land, about heights or about the existing nature in the plots. It was established that the urbanization would have buildings of maximum three floors, 10.5 meters in height. There would also be a compulsory space from the boundary of 3 meters in the front, and 2 meters for both sides and the back of the building as show in Table 2.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Height</th>
<th>Coefficients</th>
<th>Space Boundary</th>
<th>Principal Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsector</td>
<td>Simbol</td>
<td>Area</td>
<td>Front</td>
<td>Floors</td>
</tr>
<tr>
<td>A9</td>
<td>A-303</td>
<td>300</td>
<td>15</td>
<td>3</td>
</tr>
</tbody>
</table>

*Table 2. Construction codes for El Mirador (2009). Source: Municipality of Santa Cruz*

There was no mention of the necessity to select good design for a hot climate, good ventilation or natural lighting or to adapt the construction to the topography of the land and to maintain green areas in the lots. It has become clear that the idea of sustainable design and characteristics in the construction that are not harmful to the environment were not part of the development process.

These codes were approved in 2009 and since then have been used for the majority of the constructions in the area. All the streets were filled with a huge amount of filling material so all the levels caused by the topography could be saved. Suddenly weird shapes started to appear and some of the plots were located several meters under the level of the street (Illustration 10). No consideration was given to this matter in the original designs and now it is the responsibility of each individual owner to rectify the problem.

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20 Data from the Municipality of Santa Cruz
Although there is some concern surrounding this new development regarding the provision of basic services and all the population growth that will take place in this area, the codes do not reflect a holistic analysis of how the community will develop and which characteristics should be adopted to reduce the impact of constructing 1,133 new homes in just a few years. It could be argued, as mentioned by Floyd (2012), that if we do not understand the value of nature’s services to the quality of our lives and our ability to impact and destroy or maintain life, we are unlikely to make the necessary compromises needed to protect them.

From all this inconvenience and the visual proof that this urbanization is not growing as a sustainable development for the environment, the decision to propose new codes for the entire city including the El Mirador project was taken. An extensive analysis of the actual configuration of the city was undertaken, and new characteristics were adopted to the new proposed construction codes for Puerto Ayora. This proposal is still on going and has yet to be approved, but they reflect a better understanding of the reality on the islands, with some improvements in the subject of illumination, ventilation and the collection of rainwater.

While it is true the proposal of new construction codes has made some improvements and the codes are more in keeping with the reality of living in a protected and warm area, there are still some issues to be resolved. Are the new resolutions beneficial to the characteristics of the new El Mirador development? Will it be positive going forward to treat the growth of the city in the same way as the already developed Puerto Ayora town or it will be more conscious to treat it separately?

While usually it is beneficial to develop construction codes that treat all the areas in the city with similar characteristics, producing similarity in the look
of those cities, the reality of El Mirador from the beginning was totally different. The mixed development of the existing Puerto Ayora town affords the opportunity for the El Mirador project to develop independently with its own managed and planned style therefore establishing its own identity.

The process of implementing a whole new neighbourhood should have different and specific characteristics that could be adapted to the rest of the town but at the same time could represent this different aspect of being a new development that could be more conscious and respectful for the environment.

In 2014 a process of analysis and fieldwork took place in town, where a team from the Municipality started to update information about the configuration of the actual urban development to produce new construction codes. These construction codes included the total urban zone including El Mirador, and the characteristics defined for all Puerto Ayora where delineate by the dynamic of the population and urban connections.

The new proposal started with the actual configuration of the plots and blocks in the different neighbourhoods in Puerto Ayora. Defining from this the new heights, spaces from the boundary and type of constructions that should be constructed in the future. Taking this into account, the new characteristics for El Mirador where defined, leaving behind the specific codes that were establish for this area.

Since these codes are part of the territorial ordering proposal, all the urban areas in the Island, were defined with the same analysis to produce cohesive planning of the land. In this case for El Mirador, the regulations change a lot and the new characteristics to be adopted are just defining an adaptation not as natural and respectful to the environment as it could be.

As show in Figure 1, this is the proposal for construction in the whole town. Different elements such as heights, space to boundary and use of land, are defined by sector and neighbourhoods. For el Mirador, the proposal of codes is mentioned in Table 3 where we can see the mixture of elements that are proposed and the changes that the actual configuration will have on base to this decisions.
Figure 1. Proposal of construction codes for Puerto Ayora (2015). Source: Municipality of Santa Cruz
### Characteristics

<table>
<thead>
<tr>
<th>Subsector</th>
<th>Min. existing plot area (m²)</th>
<th>Min. area allow (m²)</th>
<th>Front (m)</th>
<th>High Floors</th>
<th>High Meters</th>
<th>COS%</th>
<th>CUS%</th>
<th>Space boundary F</th>
<th>Space boundary L1</th>
<th>Space boundary L2</th>
<th>Principal Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1_7E</td>
<td>131.27</td>
<td>300</td>
<td>17.5</td>
<td>3</td>
<td>10.5</td>
<td>43</td>
<td>375</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Residential type 1</td>
</tr>
<tr>
<td>R2_6C</td>
<td>297.27</td>
<td>300</td>
<td>17.5</td>
<td>3</td>
<td>10.5</td>
<td>59</td>
<td>415</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>Residential type 2</td>
</tr>
<tr>
<td>R3_5B</td>
<td>298.63</td>
<td>300</td>
<td>17.5</td>
<td>3</td>
<td>10.5</td>
<td>83</td>
<td>476</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Residential type 3</td>
</tr>
<tr>
<td>RM_4D</td>
<td>46.46</td>
<td>300</td>
<td>17.5</td>
<td>4</td>
<td>14</td>
<td>71</td>
<td>680</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Residential multiple use</td>
</tr>
<tr>
<td>RM_4E</td>
<td>252.02</td>
<td>300</td>
<td>17.5</td>
<td>2</td>
<td>7</td>
<td>71</td>
<td>279</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Residential multiple use</td>
</tr>
<tr>
<td>RM_4F</td>
<td>151.5</td>
<td>300</td>
<td>14.5</td>
<td>3</td>
<td>10.5</td>
<td>83</td>
<td>476</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Residential multiple use</td>
</tr>
<tr>
<td>RTA_3C</td>
<td>164.27</td>
<td>300</td>
<td>17.5</td>
<td>2</td>
<td>7</td>
<td>39</td>
<td>198</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>Touristic residential environment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>High Coefficients</th>
<th>Space boundary</th>
<th>Principal Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>COS %</td>
<td>Coefficient of land occupancy. Percentage obtains from the relation between the total constructed area and the plot area.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CUS%</td>
<td>Coefficient of land use. Percentage obtains from the relation between the building area (addition of all the floors areas) and the plot area.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RESIDENTIAL TYPE 1</td>
<td>Residential zones with limited presence of commercial activity in a neighbourhood and sector services. Where housing can occupy 100% of the allow COS and commercial activity and services maximum a 50% of the allow COS in ground floor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RESIDENTIAL TYPE 2</td>
<td>Residential zones with limited presence of commercial activity in a neighbourhood, sector and zone services. Where housing can occupy 100% of the allow COS and commercial activity and services maximum a 70% of the allow COS in ground floor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RESIDENTIAL TYPE 3</td>
<td>Residential zones with limited presence of commercial activity in a neighbourhood, sector and zone services. Where housing and commercial activities can occupy 100% of the allow COS.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RESIDENTIAL MULTIPLE USE</td>
<td>These zones allow the combination of residential areas with commercial activities as services and domestic handcraft; low impact industry and any other compatible equipment define by the Development Plan and Territorial Order?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOURISTIC RESIDENTIAL ENVIRONMENT</td>
<td>Place where human activities can be developed with low intensity tourism and low environmental impact without transforming areas that still maintain natural state.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Proposal of Regulations codes apply for El Mirador. Source: Municipality of Santa Cruz

Where:

Table 4. Explanation for table 3
As mentioned before, El Mirador was developed with specific codes where no more than 3 floors of construction were allowed. With this new proposal there is a possibility to have 4 floors of construction in the frontal area of the development, facing the main road that is the only connection between the town and the highlands and the airport.

The spaces to the boundary that were strictly required at the beginning now are changing a lot. And depending on the location some of the plots are allowed to build having only 1 area not attached to the boundary, producing massive constructions attached to each other similar to urban developments for big cities.

If it is clear that the analysis that took place in the whole town was really important and the decisions that were taken for future development are crucial, the characteristics of construction establish specifically for El Mirador could involve more sustainable characteristics to improve the quality of the growing development.
Chapter 4

This chapter will refer to the analysis of the questionnaires conducted in Puerto Ayora, with 65 residents examining the characteristics of their houses and their opinion about sustainable elements that should be used in construction for the Islands. This evaluation will help to define the most important sustainable strategies that should be considered for future constructions in the Galapagos Islands that will be shown at the end of the chapter in the results.

Analysis of the questionnaire

The questionnaire was divided into 8 general questions, some of them with specific questions that will help to understand and collect the opinion of residents in the city about actual construction and sustainable elements that should be applied in future buildings.

Even if in the questionnaire (Appendix 1) the questions are separate because of the formatting, for this analysis I combine some of the questions that are related to each other to generate a summary and conclusion of the results.

1. Did you use backfill material in your plot before starting the construction of your house

![Figure 2. Backfill material in the plot](image)

As mentioned in previous chapters, one of the big issues right now in the islands is the constitution of the plot and the use of backfill material to be able to prepare the land and adapt the building.

With the questionnaires it was proved than 55% of the people that already built their houses had to use backfill material. The plots usually have difficult topography that needs to be fixed or filled before the beginning of the construction or even worse, as in the case of El Mirador, the level of the street just keep growing without considering the level of the future houses which
will represent a big amount of backfill material that will be required for this urban growth.

This only demonstrates that at the beginning of the design this subject is not considered, which is significantly affecting the extraction of material from the quarry in the island. The process of El Mirador development has to be deeply analysed with relation to this matter since a large amount of material is being used now and still will be required to keep going with the construction that is taking place now and will continue for several years.

2. Your house is attached to your neighbour in how many sides?

![Bar chart showing attachments](image)

This is one of the main questions that define constructions in the town. Most of the houses are attached in at least one side to the neighbour. Sometimes big walls without openings are visualized in the neighbourhoods and that is the result of constructing the house in the limit of the plot. Even if there are some regulations in construction, these usually are not considered at the moment of building. This is why a lot of houses are built on the limits of the plot or adjacent to the neighbouring walls.

From this question, the respondents were asked to express about their level of comfort in relation with the proximity of the houses and constructions.
In a scale of 1 to 5, where 1 is totally uncomfortable and 5 it is totally comfortable, what is your opinion about the proximity of your neighbour house?

As we can see in the graph the results tend to reflect the lack of comfort that house owners have with the proximity of constructions. Even if more of the respondents stay in a neutral position, it is obvious that the sensation of total comfort is reduced and this could only prove the necessity of more strict parameters in the codes to decrease the construction of housing that is completely unconcerned with the wellbeing of the surroundings.

3. Do you collect rainwater from your roof?

The questionnaire shows that just the 17% of the respondents have a proper collection of rainwater system that provide the house with clean water.

As mentioned in previous chapters, the town is not provided with clean water at the moment, this is why is not understandable how there is not more interest in collection of rainwater. Unfortunately the processes of rainwater treatment are not well known by everyone and without strong campaigns that will support this process it will be difficult to increase these numbers, which at the end will benefit the population itself.
4. Natural ventilation and illumination in the house

a. Do you have natural ventilation in all the rooms of your house?

From the survey we have that the 68% have natural ventilation in the house and the rest have the necessity of use mechanical elements to provide ventilation to the interior of the house. In some cases even when the house had natural ventilation, the users mention they still need to use A/C or fans to help with the internal comfort of the spaces.

If from the beginning this question was related to the “NO” response of the previous one, several people mentioned the necessity of use mechanical elements to improve ventilation and comfort into the house. This is why this graph is headed climate comfort, since it is showing the preference of the owners to maintain a fresh internal area in their homes.

As we can see in the graph, most of the people that do not have natural ventilation chose A/C as the first option and then mobile fans. This
generates a big impact in electricity supply on the Islands; especially in the hot season when it is common to have electricity cuts for the high demand. A proper design that could take into account a functional ventilation area will effectively reduce this consumption of energy and will provide internal comfort to the house.

b. Do you have natural illumination in all the rooms of your house?

The majority of respondents affirm that their houses have natural illumination, but at the same time they consider that some spaces still need the use of artificial light to have a well-illuminated area. In this case, as shown in the next graph (Figure 9) most of the houses now prefer to use energy efficient light bulbs, which is a positive aspect to reduce electricity consumption.
5. Do you have unfinished elements in your construction?

This question is really important at the moment to analyse the construction situation on the Islands. A large amount of houses in the town look as unfinished or in process of construction, even when people are already living on them. From the questionnaire results, we obtain a number of 48% of people that still have their houses in process of construction (Figure 10).

This unfinished look of the city unfortunately is normal to most of the residents, and also for the authorities since they are still not concerned about creating strict regulation codes that demand people to finish the construction before occupying them. As indicated in the next graph (Figure 11), the main elements that are in process in the majority of constructions are: Unfinished exterior walls, which refers to lack of painting or external treatment to the walls and second or third floor incomplete, which is really common when a family is growing and the plan is to keep constructing over time and in relation to the increase of the family members.
These results are always related with economic reasons as shown in Figure 12. People could attribute this issue for a long time and leave the house in that state for several years. It is crucial for the Municipality to generate more control with these processes to finally avoid this image of an incomplete city.

![Reasons for unfinished construction](image)

**Figure 12. Reasons for unfinished construction**

6. What is the configuration of your house?

![Plot configuration](image)

**Figure 13. Plot configuration**

This graph shows how minimal is the concern of living in a protected area. From the surveys the results showed that 60% of the house owners occupy almost the entire plot for construction, leaving a minimal or not space at all for green areas or gardens.

This configuration generates inconvenience at the moment to provide internal comfort to the houses. Most of the green areas like gardens or trees provide shade and freshness to the interior, so having a continuity of buildings, without open spaces usually demands the necessity of mechanical elements as A/C to ventilate. This gives us as the results again, high consumption of electricity and increment on costs.
7. How do you think construction of housing should be in Galapagos?

This question presents a contradiction to the previous one. As shown in figure 14, the 80% of the house owners prefer residential constructions with maximum 3 floors and individual gardens. The reality shows that individual gardens are completely reduce in some areas of the town, occupying almost the whole plot for construction.

Even if percentages for land occupation in different areas of the town are defined by the existent construction codes, the minimal control of the construction process allowed people to disrespect these codes and reduce the green areas in town.

8. In a scale from 1 to 5, when 1 is less important and 5 is really important what do you think about the importance of the following elements to be use in the construction in the Galapagos Islands?
The last question of the survey was an open question where people could give an opinion of how important are the mentioned elements (Figure 15) to build in the islands. From this the results as the most important elements to be considered are:

- Have big windows that will help with natural ventilation and illumination
- Have proper space to the boundaries in the house

These two elements are crucial at the moment of build in warm climates and also in protected areas, so introducing these parameters in the construction codes should be a priority.

The third element that had a high score was the fact of having green areas or gardens in the plot. Again, this is a contradiction to question 5, as house owners believe this as an important element that should be considered in future constructions but is not currently applied in the constructions including their own. This is obviously related to the fact of having proper defined spaces to the boundaries at the moment of starting the construction, which should be defined in the codes with a deep analysis of each area.

Results

From the evaluation of the questionnaires and the analysis of the literature review there are 4 main points selected that should be included into the construction codes as a requirement for the building development in El Mirador. Even if all the points mentioned in this dissertation and in the questionnaire are crucial to define a good process of design in the islands, being able to begin with these elements could generate a significant change and improvement in house construction.

1. Big windows in houses and buildings for natural illumination and ventilation.

This element contains different parameters that define the success of sustainable design. In the Galapagos Islands, specifically, the use of big openings for ventilation and illumination represents a significant reduction of energy consumption, reduced cost of living and more importantly, improved internal comfort.

These elements are already mentioned in the new proposal of construction codes for Puerto Ayora, quoting that the minimal area design in windows for illumination should be 20% of the total area of the building and the minimal area for ventilation should be the 30% of the area of the window. Even if it is noticeable that there are good improvements in the regulations it should be important to consider a difference between the new development El Mirador and the rest of the town, since the characteristics already defined in existing constructions were based on a development where almost no regulations were respected.
2. Space to the boundaries and green areas in the plots

This parameter is today one of the most difficult to control. People are used to building in every single part of the plot. It is difficult to define the distance that a house should have to the neighbour when people are reluctant to “lose” important area for construction. This term of “losing” land with the space to the boundaries is a big issue for habitants, this is why it is necessary to prove that instead of “losing” they are actually gaining a lot of benefits for the house and themselves.

Until now in the city, just a few sectors maintain distance from neighbours and green areas in the plots, providing a better quality to the interior of the houses and buildings. For El Mirador (as showed in the previous chapter) new codes are in process of approval and with this, the spaces to the boundary are reduced significantly, giving the owners of the plot the facility to build blocks of buildings next to each other, reducing the capacity of natural ventilation and illumination.

As shown in the questionnaire analysis, most of the people are uncomfortable with the proximity of buildings and also prefer to enjoy the green areas in the plot. These reasons make more important the fact of analysing the established spaces to the boundary that are in the new proposal and generate a more real design that will not only improve the quality of the spaces and internal comfort but also will reduce consumption and generation of electricity in the islands.

3. Use of less harmful materials for the environment, such as wood

While it is true that in Galapagos it is difficult to have a variety of materials for construction, at the moment of design it should be a priority to reduce the impact of using big blocks of cement. Even if this is one of the most common practice in construction, and undoubtedly the one that facilitate and reduce time in buildings, the process could be revised and the reduction of material could improve the quality of the buildings. It should be considered the combination of concrete with other materials such as recycled plastic, wood or bamboo. Which besides being a good sustainable practice will help to reduce the waste treatment and recycling that is so important in the Islands.

An important matter about this element is how people moving forward are more resilient to accept the necessity to reduce the impact that humans are generating in this fragile area. More and more inhabitants are showing interest in new processes of construction and consider the idea of using different materials. A large part of this process should be the capacity of the authorities and organisations to provide more information and capacitation to the population, in this way the growth of the town could be developed in a different and more sustainable way.
4. Collection of rain water in the roofs

This element is one of the most contradictories issues in the Galapagos Islands. Even if it is pretty clear that this would have been a solution for most of the water problems in the islands, there was a complete lack of interest on doing this on the houses.

Luckily it is mentioned now in the new proposal of construction codes, as an optional parameter to be used in the properties. This, combine with filters and collection of water systems that could allow the proper use of the water it is essential to reduce consumption.

All these parameters, should be consider in the new development “El Mirador”, as I mentioned before, not only these are important issues for the new urban growing area; but this is a beginning that could lead to implement different and better sustainable practices for the new development.
Chapter 5

Conclusions

The aim of this dissertation was to define the most effective sustainable strategies for construction in El Mirador, Puerto Ayora. With the analysis of the main characteristics of construction for specific protected areas like the Galapagos Islands and specific weather conditions, I produced a questionnaire for inhabitants of the island.

The combination of these two elements and the analysis of actual construction in Galapagos and the process of urban growth, facilitate to define which could be the most important sustainable elements to consider in future constructions for El Mirador.

As mentioned in the results of the previous chapter, there are some elements that should be required when a process of design starts and will definitely improve the quality of constructions and adaptability to the environment of the urban zones.

Being aware of the context where urban areas are developed is one of the most important characteristics to consider at the beginning of a design process. Living in the Galapagos Islands is and should represent a different adaptability and acceptance about the limitations and at some point, sacrifices that should be made to maintain the balance between urban developments and the ecosystem.

The characteristics to be considered at the moment of construction should reflect this acceptance of adaptability and show respect to the environment and the necessity to protect a fragile area such as the Galapagos Islands. This adaptability and respect to the ecosystem should not compromise the comfort or quality of life of the community.

In terms of construction on this specific new development, El Mirador, the results of this dissertation show that a combination of adaptability and proper characteristics established during the design will define the future impact of this urban growth. The sustainable elements that are proposed in this moment of the process are crucial to determine the direction that construction of housing will take.

As the results of the questionnaires indicated, prioritizing elements like openings and spaces to the boundary are the main characteristics that could make a difference in this urban zone. Improving the quality of ventilation, green areas, illumination and the relationship with neighbouring constructions are the typology of building that not only works better for this type of climate but also for such a fragile area as the Galapagos.

It is important to understand the necessity of selecting materials that could be less harmful to the environment and reduce the use of concrete and
cement blocks combining them with optional materials that could reduce the impact to the islands, talking about mobilization, water and energy consumption and costs.

Knowing that campaigns about recycling in Galapagos are so important, the process of construction and urban developments should be included in these processes, being able to combine and generate recycling materials for housing and urban elements.

Following these elements, the collection of rainwater as a primary element in the design of housing should be a requirement for architectural proposals. At the moment, the use of rainwater implies an improvement in the quality of water use in housing, since there is not clean water provide for the community. And in the future, the reduction of consumption of water is fundamental to maintain a sustainable balance related with the process of obtaining clean water.

These elements and characteristics can only be applied and reflect an effective urban and architectural analysis if the authorities understand the necessity to provide suitable construction codes. The production of these codes should be a result of an organizational consent, where not only the authorities, but also organizations related to these subjects and even the population could be involved in the process.

The efficiency of urban development at the end is not only a result of land analysis and housing supply, but a complete understanding about social, economic and environmental issues that are involved in the process. Combining all these elements can possibly determine a sustainable development that could minimize the impact of human settlements in an environment as delicate as the Galapagos Islands.

As mentioned before, Galapagos constitute one of the most exotic ecosystems in the world, where protection and adaptation to nature needs to be a priority. Being able to acknowledge that the necessities for urban developments have to be part of this ecosystem represent a challenge, that if focussed in the right direction could successfully achieve the goal of generating the appropriate balance between the building and natural environment.
Bibliography


Corrientes marinas del Archipielago de Galapagos. [Online] Available at: http://corrientesmarinasdegalapagos9iandres.blogspot.co.uk/p/clima-de-las-corrientes-de-galapagos.html [Accesed: 9 August 2015]


Proyecto de Ordenanza (2015), *Uso y ocupacion del suelo urbano de Puerto Ayora, Bellavista y Santa Rosa de conformidad con el Plan de Ordenamiento territorial del Canton Santa Cruz y sus categorias de Ordenamiento Territorial urbanas y rurales*. Draft Municipality of Santa Cruz


Appendix

Questionnaire

Características y opinión sobre la vivienda en Puerto Ayora - Galápagos

Como parte de la investigación de tesis que estoy realizando en la Universidad de Edimburgo, estoy llevando a cabo una encuesta sobre las características básicas de la vivienda en Puerto Ayora y la opinión acerca de las nuevas construcciones. Agradezco mucho por el tiempo que se toman para responder las siguientes preguntas.

1. Fecha __________________________ 2. En qué barrio vive? __________________________

3. Al momento de construir su vivienda, utilizó material de relleno?
   - [ ] SI
   - [ ] DESCONOCE
   - [ ] NO

4. Su casa está adosada a su vecino en cuantos lados?
   - [ ] 1
   - [ ] 2
   - [ ] 3

5. Recolecta agua de lluvia por medio de la cubierta de su vivienda?
   - [ ] SI
   - [ ] NO

6. Todos los cuartos de su vivienda tienen ventilación natural?
   - [ ] SI
   - [ ] NO

7. Si su respuesta es no, que usa para ventilar los cuartos?
   - [ ] Aire Acondicionado
   - [ ] Ventiladores móviles
   - [ ] Ventiladores de techo
   - [ ] Ductos de ventilación

8. Todos los cuartos tienen iluminación natural?
   - [ ] SI
   - [ ] NO

9. Si su respuesta es no, que usa para iluminar los cuartos?
   - [ ] Focos normales
   - [ ] Focos ahorradores
   - [ ] Ductos de iluminación

10. Su casa tiene partes sin terminar o está en proceso de construcción?
    - [ ] SI
    - [ ] NO

11. Si su respuesta es sí, cuales son los elementos que hacen falta para terminar la construcción?
    - [ ] Enlucido en paredes exteriores
    - [ ] Faltan ventanas o puertas
    - [ ] Segundo o tercer piso sin paredes
    - [ ] Falta techo
    - [ ] Divisiones internas incompletas
12. **Por qué no ha terminado la construcción de su vivienda?**

- [ ] Razones económicas
- [ ] Segunda fase de la vivienda pertenece a otro miembro de la familia
- [ ] Al momento no hay abastecimiento de los materiales que necesita para seguir la construcción

13. **Su terreno:**

- [ ] Posee jardín o áreas verdes alrededor de su casa
- [ ] La construcción ocupa la mayor parte del terreno

14. **Qué tipología de vivienda considera funcionaria mejor en Galápagos?**

- [ ] Tipo residencial de máximo 3 pisos con jardines individuales
- [ ] Edificios multifamiliares de 4 o 5 pisos con áreas verdes compartidas

15. **Qué tan cómodo se siente acerca de la privacidad y el ruido con respecto a los retiros que mantiene su vivienda con el vecino**

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<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>Totalmente incómodo</td>
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16. **Calificar los siguientes enunciados de acuerdo al nivel de importancia que deberían tener en la construcción de vivienda en Galápagos según considere**

Donde 1 es menor importancia y 5 mayor importancia

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<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td>Tener áreas verdes y jardines en el terreno</td>
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<tr>
<td>Grandes ventanas que ayuden con iluminación y ventilación natural</td>
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<td>Uso de materiales reciclados o menos dañinos con el ambiente como madera</td>
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<td>Crecimiento por fases de las viviendas</td>
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<tr>
<td>Mantener retiros adecuados entre viviendas</td>
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