Guidelines for energy optimization through landscape architecture in hot humid regions

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ABSTRACT

The first part of the paper gives criticisms of convetional practice in landscape architecture in hot humids climates, in terms or efficient utilization of energy. Basic criticisms are: overdependence on imports, oversize of open spaces, oversize of exposed potable water, inappropriate irrigation systems, inappropiate use of plants, and mismanagement of natural resources.

The second part of the paper gives recommendations for energy efficient landscape architecture in hot humids regions. The basic recommendations are: environmental conservation, site selection for climatic control, site planning and design for climatic control and water conservation, and production through landscape design.

1. INTRODUCTION

1.1 Natural Landscape

Human actions such as housing construction and any other endeavor taking place in the natural setting will have repercussions upon its components. In the same way, these will have environmental impact. Thus the natural landscape's distinctive existing features should be taken into consideration, in order to make a diagnosis according to the predominant natural resources, and to propose sustainable development in the affected zone.

The natural components of the physical setting are all those elements which existed prior to the city. These include bodies of water, soil, topographical contours, vegetation, etc.: these will be modified in varying degrees by the development criteria urbanists and architects use (Sthjetnan, 1984).

1.2 Urban Landscape

These are all the elements created in any way by human activity: urban development, building, or any other such enterprise; also components which alter or impact the natural physical environment. Because of this, it is the professional's task to carry out controlled and rational use of resources, toward preserving and improving the natural as well as the urban environment.

The artificial components of the physical environment of a city are those which have been constructed by man, such as infrastructure for services; streets, plazas, buildings, etc (Sthjetnan, 1984).

Another area that relates directly with landscape design is that of Environmental Impact Studies and Evaluations. These represent, from the point of view of many knowledgeable in the field, the final end of all environmental studies. Through these it is possible to improve the urban setting considerably, and to rescue the environment or natural landscape.

Among the physical environment's components it is necessary to better analyze several which are considered as most likely to influence the ecological design of Urban Landscapes. Those which stand out within the Natural Physical Environment are: climate, vegetation, and the land's relief or topography. Open spaces also represent the urban landscape, and are analyzed from a Landscape Architecture perspective as corresponding to the Artificial Physical Environment, but also to the natural landscape in its widest sense, inspiring sustainable development of natural resources.

The focus that shall be given to landscape analysis in order to achieve suitable urban design will aim toward sustainable development in large metropoli, wherein residents of new and existing subdivisions are those who pay for and maintain the ecological equilibrium of the city's physical environment. Only in this way will there be ownership of the soil and properties resting upon it; thus there will be interest in maintaining and preserving them in good condition, assuring the environment's future existence in optimal conditions for life and for advantageous use of the limited territorial reserves still at our disposal.

2. NATURAL PHYSICAL ENVIRONMENT: CLIMATE

In general it may be said that for appropriate landscape design it is first necessary to analyze the climatic conditions of the region or locale where humans are residing. For this it is well to understand the descriptions most used in environmental analysis of climatic concepts.

2.1 Climatic Conditions

Throughout humanity's history, geographic and climatic differences have, all over the world, determined customs, traditions, clothing, food, and aspects of human conduct, as well as housing. The human body's anatomy reacts in various ways to a range of environmental phenomena. Therefore, for purposes of future evaluation, man's ambient comfort will only have value if it is established within the immediate setting. Within conventional parameters of physical health, the human body functions normally just below 37° C (98.6° F) and this temperature is only sustained within very limited conditions which, if exceeded, will cause danger and risk to metabolic function. Other equally important elements are nutrition, and the different activities in which humans engage (Szokolay, 1977).

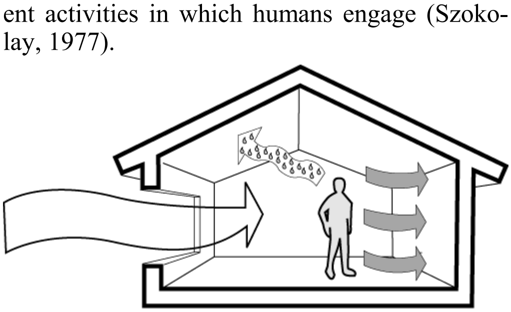

Figure 1: Thermal energy exchange between the human body and the surrounding elements.

The following factors are required for the gradual cooling of the human body: energy loss via convection and heat dispersal on the skin's surface, water loss through perspiration and vaporization by the lungs, respiration, etc. Aspects of greatest relevance within environmental design are temperature changes as perceived by the skin, which become a response in the form of dilation and contraction of its blood vessels.

Through a varied series of conditions it is possible to regulate the proportion of heat loss from the vasomotor system. Perspiration is another process which corresponds to demands by the human organism, when cooling intensity through the act of respiration or radiation and convection on the skin layer are not sufficient to counteract the heat affecting the body.

The phenomenon described above is known as evaporative cooling, and begins the moment that water produced by the skin's pores evaporates: environmental conditions to which the organism is subjected will either help or harm its system. Human health and energy depend to a large degree upon direct environmental effects. It is a demonstrable fact that on some days humans are stimulated and invigorated in their activities by atmospheric conditions, but on others they become physically and mentally depleted.

The physical environment is made up of a complex interrelation of various elements, and a system for attempting to describe them might begin with: light, sound, weather, space and animate elements. These act directly upon the human body, which tries to absorb or counteract their effects. Physical and psychological reactions arise from the struggle to achieve a balance, seeking to employ the minimum amount of energy while adapting to the environment. Conditions which achieve equilibrium create a "comfort zone" where humans are left with energy for physical and mental work.

Human shelter is one of the principal instruments for achieving optimal comfort requirements, as it modifies the environment to create viable conditions for habitability. It must filter, absorb or repel ambient elements according to their beneficial or adverse contributions to human comfort. Criteria for achieving a habitat with balanced environmental conditions must lead to satisfaction of physiological needs. The basic climatic elements by which the environment intercedes in human comfort may be ranked as follows: air temperature, radiation, air movement and moisture. All act upon the human being, in a complex and interrelated manner.

2.2 Climatic Data

Climatic elements regulate the natural system. Temperature, humidity, winds and precipitation together determine how nature is regulated, such that a variation in any one of these will produce immediate repercussions on other natural aspects, such as soil or vegetation, to mention several.

2.3 Requirements for Climate Control

The graphic represents existing variations of thermal oscillation, by which it is possible to distinguish those seasons requiring additional climate control. Several authors have previously introduced this prediction method: Steven Szokolay considers only the temperature variable. The present proposal consists in also utilizing relative humidity, in order to transcribe all results into the solar graphic for the first semester, corresponding to the sun's path from January to June, by which are obtained, in geometric form, the different exposures which require either maximization of, or protection from, solar output. The previous analysis is realized month by month within Olgyay's climatic chart, so that thermal oscillations that present during the course of the 24 hours of a day, and throughout the entire year, are also detailed. This schema shows climatic behavior through different seasons; as well as graphically representing zones from the most critical to the most comfortable, or those with the least heating requirements. The foregoing will determine general bases for development of environmental control measures in the architecture, by determining constructive elements, graphically analyzed by the method developed herein.

Through this analysis it is possible to graphically show climatic data and thus establish the bioclimatic situation for the study's specific site. Results by season are utilized in developing design strategies to counteract possible sensations of discomfort. Said control strategies should be channeled to increase or decrease either the temperature or relative humidity level, through other means of respectively heating, cooling, ventilating or humidifying.

Zone of mild heating requirements. Here induction of direct or indirect solar energy is necessary. Sun may be drawn into interior spaces, thus taking advantage of the calorific capacity of the different building materials used, in order to obtain appropriate passive heat, though only for short periods during the cooler months.

Comfort Zone. This zone requires protection from the sun; real ambient comfort only occurs in shade.

Protection and Dehumidifying Zone. Principally, it is necessary to guide heat toward the interior of a built space, by using solar control devices. But we must also offer ventilation for dispersing the heat which accumulates in the interior, by means of conductive qualities in the materials we use.

2.4 Solar graphic with climate control requirements

For this type of analysis a solar graphic with stereographic projection is used; this is an easily-managed design tool which permits us to understand geometric characteristics of the sun's apparent movement at any point on the earth's surface, by season and time of day.

Along with gathering the data described above, it is practicable toshow the first six months corresponding to the sun's apparent transit, and to then transcribe climate control requirements for that part of the year. These strategies provide geometric data with ease of

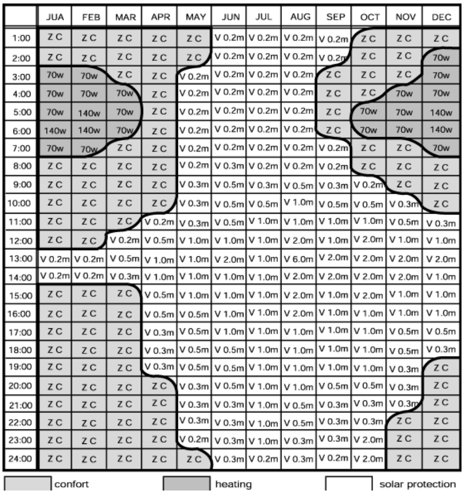

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Figure 2: Climatic annual requirements.

use in architectural design. This type of projection may be read by degrees and seconds, such that the horizontal represents solar height and the vertical the solar azimuth.

2.5 Determination of seasonal weather

In a warm and humid setting, environmental conditions occur over four seasons: the warmest two of these encompass the months of March through September, and the cooler months, when it is easier to achieve climatic comfort, extend from October to February.

Average atmospheric conditions for the hot-dry season, or the months of March, April and May, in San Patricio Bay, Jalisco: during the day, there is considerable sun, with ambient conditions ranging from warm to very hot. At night the sky is clear and conditions are warm to warm-subhumid.

During San Patricio Bay’s hot and humid season, which corresponds with the months of rainy season, atmospheric conditions are as follows:

Daytime is quite cloudy, with abundant precipitation most afternoons. The air is hot because of the high solar radiation during this part of the year, and so humid as to cause a feeling of suffocation.

At night, conditions continue to be very hot and humid. Dissipation of heat toward higher atmospheric layers is impossible due to the constant presence of cloud cover.

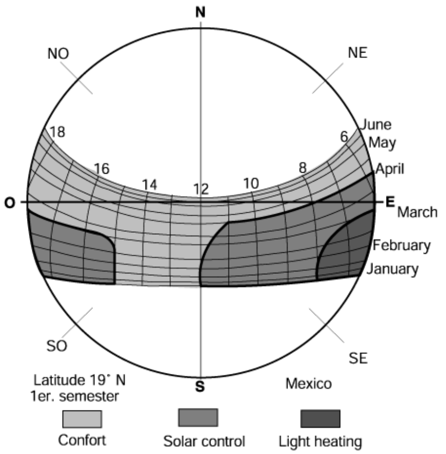


Figure 3: Solar chart with requirements of the 1st semester.

3. NATURAL PHYSICAL ENVIRONMENT: ELEVATION

Air flow over the Landscape’s Relief or Topography. On any sort of sloping land, day-night breeze variations move in the same direction. However, energy exchange is greater in those settings with greater inclination. Effects from these phenomena will depend upon the specific exposure of the sloping land.

In sectionally analyzing different topographical conditions, we may plainly see the behavior of air currents: during the day, air moves landward from the water.

During the night air moves inversely, from land to sea. This is a permanent sea breezes-land breezes phenomenon (Mc Clenon, 1987).

Air flow behavior, along with following breeze conditions, will vary according to land features. A higher percentage of slope or outcropping will maximize turbulence caused by relief formations, and wind velocity will rise. On the other hand, where the surface has lower relief, there is no turbulence and velocity is minimal.

Representation of San Patricio Bay, Jalisco from different directions and under different ambient conditions is shown in Figure 5.

It has earlier been mentioned that on very sloping land, we will see increased energy ex-

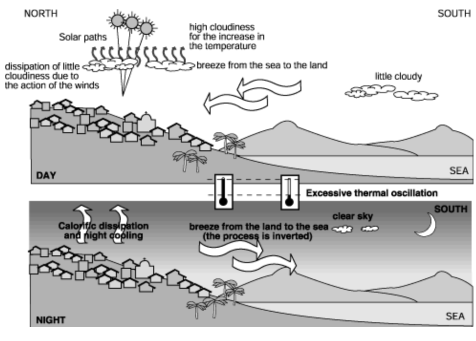


Figure 4: Dry and warm season (March-April-May).

Figure 5: Relative elevation in the landscape.

changes. However, we may also observe that conditions specific to the site or locale will be modified according to the relative altitude of the immediate surroundings.

The existence of various exposures within the bay are due to its irregular shape. Environmental features at each of these differ according to their relation to the sea and the amount of solar radiation they receive. For practical purposes four of the landscape's most representative exposures are described.

Zone 1 (east). There is moderate elevation compared to the rest of the Bay. It acts as an protective area against winds moving toward central zones, because of the small bay which shapes it. This site is considered moderately recommendable as a new building location; however, such protective aids as vegetation and artificial elements should be used, as they will control oceanic phenomena as well as morning sun, throughout the year.

Zone 2 (south). For the greater part of the year there is solar radiation: it is recommended that vegetation be used for solar protection. Still, this exposure on the slope permits some flexibility in locating buildings on the site, as it represents a large area within the bay. It is also advisable to turn the longer axis of the any structure in a SSE direction.

Zone 3 (west). Over the course of the year this exposure is the most critical, as it receives the late afternoon sun. Apertures are not recommended for facades which face in this direction. To lessen the effects of overheating it would be well to use perennial plants, which produce shady areas around the buildings and surrounding terrain, and yield a less-troublesome microclimate all year long.

Zone 4 (north). Because temperatures are lower as the year proceeds, except in the summer with its hot climatic conditions, it is recommended that protection be included to balance these. Through constructed elements around the building, and perennial vegetation, overheating from the north may be avoided.

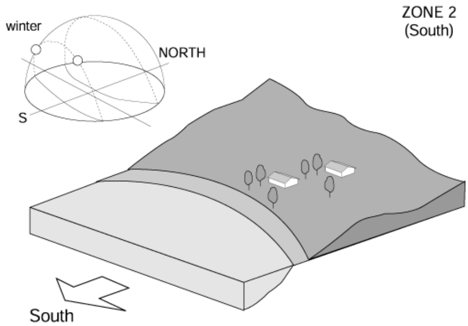


Figure 6: Zone 2: SOUTH.

4. NATURAL PHYSICAL SETTING: VEGETATION

4.1 Plant Density

Plant density analysis makes sense if air currents around and through the area are also taken into consideration. According to wind-tunnel studies at the University of Wisconsin, plant behavior differs according to air flow (Mc Clenon, 1987).

An irregular tree windbreak is more effective in deflecting air currents from above, as plant species are mixed and different sizes along the barrier produce a rough surface along the top, which more effectively controls and channels air flows away from the direction which brings the wind.

4.2 Plant density behavior

An irregular line of trees is more effective for reducing whirlwinds or turbulence than one comprised of regular planting structures.

Windbreaks of trees where each section is made up of different heights of the same species, are less effective for blocking and deflecting wind 1 than those which arrange trees of the

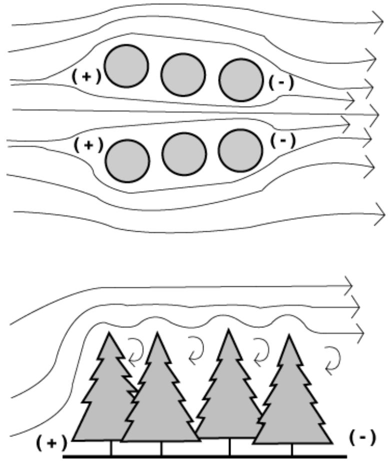


Figure 7: Behavior patterns for a tree windbreak.

same size vertically. This is due to the greater density offered against air flows that the more symmetrical planting offers 2.

4.3 Plant typology

According to plant typology, the qualities of vegetation may be applied either to blocking or allowing the sun's rays. On the one hand, trees with deciduous leaves permit sunlight to enter during certain times of the year. On the other, vegetation with perennial foliage prevents the passage of solar energy, because such foliage reflects light and absorbs heat. Aeolian control may also be achieved with vegetation, depending on whether it is deciduous or perennial, and whether the aim is to deflect, filter, or permit passage of air flow (Mc Clenon, 1987).

4.4 Proposals at an urban level

Proposals for use of vegetation at an urban landscape level in the setting proceed as follows: Erosion control, atmospheric purification, integration of built structures, creation of connective spaces, plant barriers, solar transit, and plants and trees according to exposure.

4.5 Integration of buildings

Plantings are recommended for achieving architectural integration: above all, if the buildings' volumes are large. With the appropriate species of trees and bushes, a homogenous atmosphere is attained within the aggregate habitat. By creating tree-lined avenues, central areas of lower-growing plants and flowers, areas appear where rest and recreational activities may take place. Plant harmonies and contrasts are also created with the use of different foliage colors, lending a pleasant aesthetic to the whole.

4.6 Creation of connective spaces

In designing a center for habitation, the use of plants to create connective spaces between different buildings is suggested. Said spaces may be designed through the use of different tree varieties, which will produce cool, shaded settings which are also fragrant, if the proper species are chosen.

4.7 Plant barriers

The usefulness of vegetation, along with its various aesthetic benefits in the urban landscape, is that trees and other plants represent a natural protective element against solar radiation as well as wind control.

In the case of warm and humid microclimates, where the greater part of the year requires protection from excessive solar radiation and at the same time the passage of air, vegetation may be used like a parasol; as in the case of palm trees, whose perennial leaves are able to block solar radiation, but whose tall trunks will easily allow unimpeded ventilation.

4.8 Solar transit and vegetation

As we know, plant species differ from region to region and thus an appropriate selection of trees and shrubs should be utilized. If plant species from other ecosystems, even those where climatic conditions are similar, are introduced, there is a risk of epidemic plant disease. The goal here is the correct installation of plant species at the building's various exposures, permitting control of ambient comfort conditions for inhabitants, with protection from wind and/or

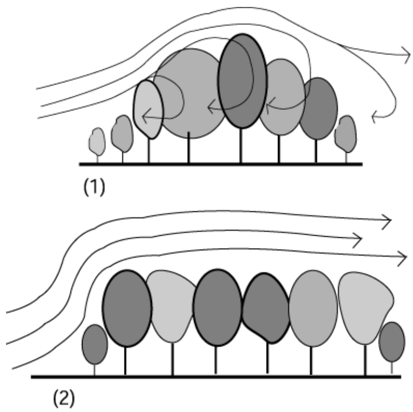


Figure 8: Ventilation behaviour.

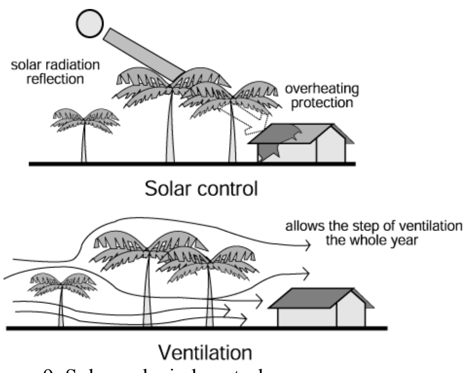


Figure 9: Solar and wind control.

sun (Olgyay, 1992).

For isolated buildings, the proportion of vegetation necessary for each exposure should be considered with heat, light and acoustic controls in mind.

4.9 Tree planting, according to exposure

Proposed use of different plant typologies should follow these directional requirements: SE and ESE – deciduous plants to allow the passage of the sun's rays. West SW and NW – dense perennial plants to create deep shade. North, South, NE and SE – a shaded area with ventilation, by using palm trees as well as a combination of other species which do not obstruct air flow.

4.10 Proposals at an architectural level

Among the principal aspects linked to improving a building and its adjunct activities, there is the aspect of privacy control.

For residential construction it is important to provide a degree of privacy for the inhabitants' sense of wellbeing. The use of plantings to create screens or curtains of trees is recommended. Generally hedges are comprised of dense shrubbery, kept in shape with periodic pruning. These elements have the advantage of permitting the flow of air, unlike constructed walls which are completely opaque to the passage of wind.

5. NATURAL PHYSICAL ENVIRONMENT - ARTIFICIAL

5.1 Landscape Antecedents and Concept

Due to the compelling importance of analyzing the landscape with an eye to appropriate architectural development in the natural setting, reference points for concepts used by landscape experts has been established.

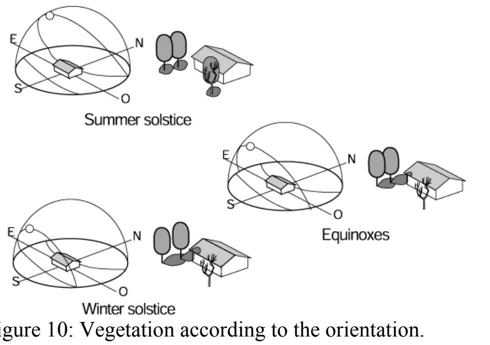


Figure 10: Vegetation according to the orientation.

Briefly, landscape is the natural area which surrounds the activities of humans and other living beings. It is often studied by such natural scientists as ecologists, geographers, biologists and others; however, it has recently taken on importance in the area of Humanistic Sciences, engaging professionals from architecture, urbanism, and planning in general.

Landscape Architecture was first mentioned as a field midway through the 19th century, when not only urban designers but architects became aware of their role in developing projects which would be appropriate to their particular environments.

The difference between the two concepts rests prinicipally in the fact that in speaking of Landscape, we refer to an overall setting; whereas in Landscape Architecture, once planning has ensured that landscape's natural elements are respected, the optimal goal is to maintain ecological banace and avoid environmental impacts. All this is done through ordinances, planning and soil management in a manner that promotes sustainable development (Laurie, 1983).

5.2 Landscape Elements

Basic visual elements. When someone observes their surroundings, perception may go beyond visual receptiveness; direct reference is made herein to those visual elements which human beings are capable of processing. It may be said that "Landscape is understood as a set of territorial units with distinct properties and characteristics, which may be analyzed and defined through the following visual elements" (Escribano, 1989).

According to the classification established by María Escribano in her publications, the principal visual elements are: shape, texture, line and

Figure 11: Visual elements of the landscape.

contrast, and finally color, to complement all the others.

5.3 Landscape Components

Along with the visual elements that form the landscape, it will be shown that the landscape is shaped by different natural and artificial elements. Various authors call these practical effects “Landscape Components” and group them into four major areas:

5.3.1 Land

This component is easily observed: relief, textures and different materials in the terrain, as well as how it has evolved to conform with the ground surface of its surroundings.

On the tropical Pacific coasts, the shape of the beaches presents some peculiarities. For several hundred kilometers the topography is very irregular: within a short span, a zone of wide beach may suddenly give way to the mountain range which stretches the length of North and Central America.

5.3.2 Water

This component is distinctive, in that its presence in the atmosphere is essential for any form of life. It also contributes aesthetic elements which greatly enhance the landscape.

Referring to a landscape embedded in the coastal region, it is also possible to find many rivers and lakes which connect to the ocean. The uniqueness of a landscape marked by the existence of such bodies of water is considered to be very important.

5.3.3 Plants

Another vital component for the landscape, because they provide a great variety of color and texture within the natural or artificial setting. In the tropical coastal zone of the Pacific there exist a great variety of plants, ranging from various palm species to tree varieties with dense and exuberant foliage, the majority of them with perennial leaves. This shapes the plant habitat of said setting.

Finally, Structures, or artificial elements are inevitable elements in the landscape: a manifestation of man’s intervention in his surroundings, represented by constructions of all kinds – residential, tourist centers or offices.

What is truly important for this analysis is to consider building forms, materials, and systems which will determine future application to a specific natural landscape, in order to achieve global integration of architecture. The above will depend upon conservation or deterioration of the visual and ambient value of the natural landscape.

5.4 Visual comfort in the Landscape

The way in which inhabitants communicate with their surroundings is, or may be, quite different; especially if intervisibility, or mutual sightlines with the exterior, are taken into consideration. The following aspects give a clearer idea of how these relationships with the outside surroundings function.

In a recreational environment, where the natural landscape itself provides residents and visitors with relaxation, visual comfort plays a prominent role. If the size and position of windows are studied from a landscape architecture point of view, given that they are the element which most connect to the exterior, they will come to determine visual comfort. It is necessary to take into consideration three fundamental aspects (Serra, 1985).

The first is Visual Aperture, the relation which exists between the inhabitant and that which he or she observes when looking toward the exterior.

Visual Dominion, which consists in the specific area the inhabitant is able to observe at any given time, if he or she so wishes.

And finally Visual Privacy, since to have the previous elements there must be windows or openings which are more or less expansive, but it is important that there be a pssibility of isolating oneself from them when greater privacy is required. This is achieved by means of blinds, curtains or – what may be more interesting – with strategically-placed outside plantings which permit the inhabitant a view of the landscape, but prevents passers-by from being able to see into the interior (Serra, 1985).

Visual aperture, dominion and privacy repre-

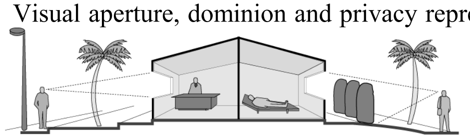


Figure 12: Visual privacy.

sent necessary elements for finding visual comfort in the landscape.

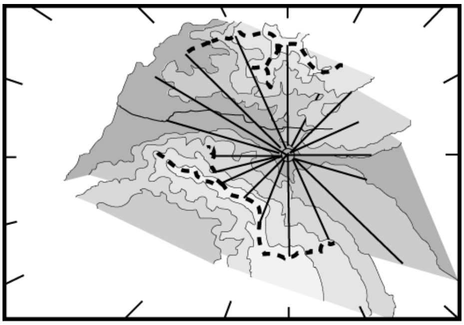
Once landscape components are established, and a study made of different ways of visualizing the surroundings, it is well to make an assessment of the setting which will permit appropriate interaction, without altering the landscape.

5.5 Visual perception of the landscape

Normally the landscape study, for correct visual interpretation, will contain definitions of considerable subjectivity, making it necessary to establish logical means of follow-up in conceptualizing it. Two visualization factors have been defined as most relevant for correct siting in the landscape, according to views and impressions which the natural environment may offer. As applicable to said study, these factors are known as visual edge and intervisibility (Escribano, 1989).

5.5.1 Visual Edge

"It is the zone from which the four directions are visible or, conversely, that which is visible from one or several directions. In territory with irregular relief, its limits coincide with the watershed. Methods for determining the visual edge from a given point are founded in tracing visual input from the point (straight lines), and their intersection with the elevation that the surrounding topography offers. Emission of visuals is carried out upon the terrain or a relief map. These visuals go forth radially from the point to determine their edge. It requires at least 16 views to obtain trustworthy results." (Bolos, 1992).



Emission of visual from a point, represented on a topographic map. They are not seen from the above mentioned point, on having remained hidden by the relief, the discontinuous zones of the expressed beams those that these do not reach.

Figure 13: Visual edge.

Figure 14: Landscape capacity.

Determination of visual edge becomes very important for later evaluation of visual impacts.

5.5.2 Intervisibility

Qualifying the land according the the degree of shared visibility between all its units. This allows us to appreciate the existence of wide panoramas on the visual horizon, from each point in the setting. Such appreciation is proportionate to the zone's relative elevation and the high contrast between elevations in the surroundings.

5.6 Landscaping Capacity

With respect to Landscaping Capacity, in the image of the landscape may be observed an analysis of the elements which comprise a hot-humid climate located on the coast, as regards visual quality. Here are also found a series of tourist sites which have transformed and altered the natural landscape. It may generally be said that landscaping capacity has been saturated, as it can be perceived as having been altered by buildings placed within the landscape.

1. The intrinsic visual quality is moderately altered because of construction, but some values of its natural aspects, such as vegetation and the topography of surrounding mountains, are preserved.
2. The quality of the immediate surroundings (for a radius of 700 meters or approximately 2300 feet) has been notably modified, by buildings as well as of roads constructed for vehicles, and sidewalks for pedestrians.
3. The visual quality of the scenic background is the best-preserved section of the landscape, because there are no elements to interfere with the agreeable backdrop of the mountains or the "horizon line".

5.7 Visual assessment

Assessment of visual fragility with an eye toward preserving or improving the landscape, consists in combining the action of visibility factors, natural landscape characteristics and man's access to the specific setting being assessed (Escribano, 1989).

The landscape analyzed belongs to the coastal area, where visual fragility may be evaluated. To attain this objective three zones are ranked according to their level of visual perception: the group of buildings located upon the relief surface (to the left), the zone where buildings are situated on the flat part of the terrain (to the right) and lastly the scenic backdrop constituted by mountains and the soft textures of greenery (upper part, in the background).

1. The visual absorption capacity is very low due to the degree of incline, another way of saying that its visual fragility is high, so that human action, ie., construction, is flagrant and little integrated into the natural surroundings.
2. In this zone the group of buildings are better integrated because the surroundings are able to absorb them, for two main reasons: the land's low degree of inclination and the use of vegetation and sloping roofs, which aid markedly in visual absorption of built elements.
3. Any type of action realized in this zone should be carefully studied, since there is a risk of losing visual quality, if another silhouette is incorporated outside the natural line of the scenic background.

5.8 Landscape intervention proposal

Within the affected landscape feasible building plots are determined though analysis of the landscape's contours (Faye, 1974). In this way

Figure 15: Visual assessment of the landscape.

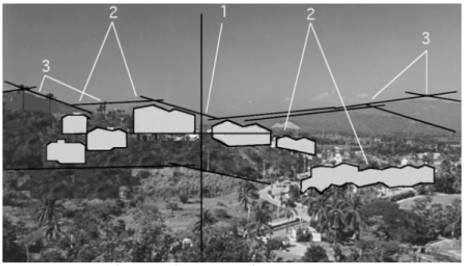


Figure 16: Landscape intervention.

forms are studied for their gracefulness, and for better integration with surroundings.

Firstly, the most interesting viewpoints are established, along with elements entering the landscape by means of the respective structures.

Next, possible intervention zones are determined, and lastly the manner of distributing the buildings' nuclei within the affected surroundings.

Determining the landscape's lines of force (based on the land's natural formation).

CONCLUSIONS

This building proposal stresses adaptation to the landscape, simply respecting the terrain and following existing force lines (either horizontal or sloping, as the case may be). It may also be observed that proposing a series of inclined roofs parallel to the horizon composed of the mountains' various planes, maintains the built environment as an integral part of the affected landscape.

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