Human Habitat: Searching for a Response to Sustainable Development in the Eastern Plains of Colombia

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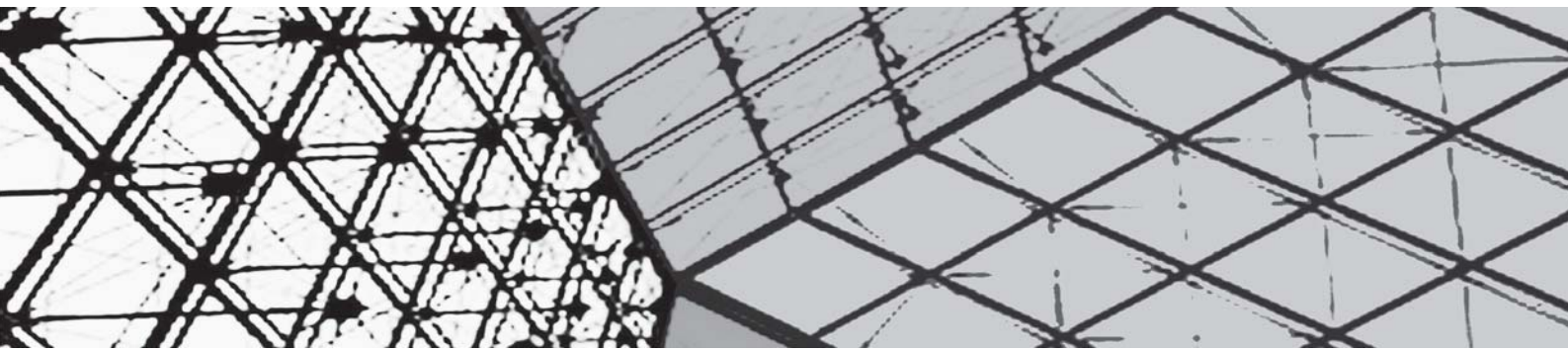

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Abstract

This study presents the "Human Habitat Concept," an alternative resettlement proposal for internal displaced people. The research focuses on planning and architectural issues related to sustainable development, as outlined on the Brundtland Report: *"Meeting the needs of the present generation without compromising the ability of future generations to meet their needs."* (Brundtland, 1987). A sustainable settlement is defined, here, as one economically self-sufficient; socially self-determining; and environmentally self-supporting.

The research is a theoretical/practical one based on a case study in the Eastern Plains of Colombia, and its objective is to create a planning and design replicable platform for sustainable development in developing countries; which can be adapted to different socio-economical and environmental scenarios. As a result, calculations are proposed to show how the annual output of a settlement changes by accumulating, restoring and balancing key components of the community. In particular, the study shows how the fusion between city and countryside, and urban zoning contribute to the aims.

The final result is a framework to help urban and architectural decision-makers to choose the most environmentally friendly and socio-economically responsible solutions, based on nature's design/functioning; in which a sustainable architecture is one that is: economically affordable; socially fulfilling; and environmentally integrated.

Keywords

Sustainable
Development
Alternative
Bioregionalism
Orchard-town
Bionic-architecture

1. Introduction

1.1 Precedents

Massive human displacement (Figure 1) is a main problem in developing countries around the world. The immediate causes are: extreme socio-economic differences and the presence of armed conflicts; often derived from the transfer of the Industrial Revolution model to the third world countries; in a misunderstanding of the socio-economic, urban, ecological, planning and cultural implications.

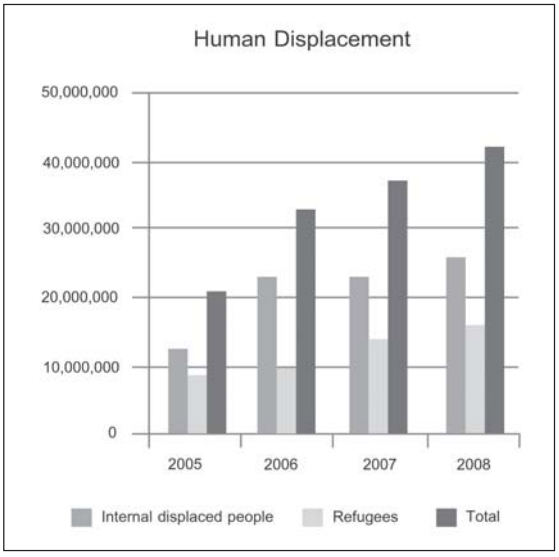


Figure 1. United Nations High Commissioner for Refugees, Global Trend reports.

The lack of basic infrastructure and services in the rural areas makes irresistible the city; this generates massive abandonment of productive agrarian areas with ravaging impact on the economy, while creating inhuman overcrowded urban rings of misery.

At present, one billion people live in absolute poverty (United Nations Committee on Economic, Social and Cultural Rights, 1995); 37 million people in the world are refugees (Guterres, 2007) or displaced, representing an acute humanitarian crises. While the internal phenomenon is the reflex of the gap between rich and poor people, the increasing flux of immigrants from poor countries to industrialised countries is the symptom of a global unbalance. Therefore, Human Resettlement in poor countries is the most important international social and ecological challenge in the dawn of the 21st century; and a unique sustainable development opportunity in a long-term basis, which could positively modify the international migration fluxes and the present global climate changes patterns.

1.2 Challenge: Sustainable Rural Development through Orchard Towns?

The departing premise of Human Resettlement is that sustainable development is a mean to improve the human life; so that people are able to fulfil their expectations and potentials, in symbiosis with nature, while preserving biodiversity and ecosystems in order to perpetuate these ideals. The main issue is to understand and define: the meaning, scope, dynamics and mechanisms of sustainable development to be applied to the Human Habitat project. Key challenges were coped: establish that sustainable development is not an utopia; that it is possible in developing countries; that it is an equalizing option that will cover the gap between rich and poor, people and countries; that new human resettlements are a suitable solution to sustainable development in developing countries; and that Human Habitat is an appropriate concept, and a feasible and replicable model in accordance with sustainable development as defined for developing countries.

1.3 Case Study: Colombian Eastern Savannahs

Colombia (Figure 2) has a population of 45 million people and the highest number of IDP (Internal displaced people), 3 millions, in the western hemisphere and a diaspora of 4 million people mainly towards developed countries. The background is a socio-economic conflict, aggravated by the deforestation of 50,000 hectares of the Amazon

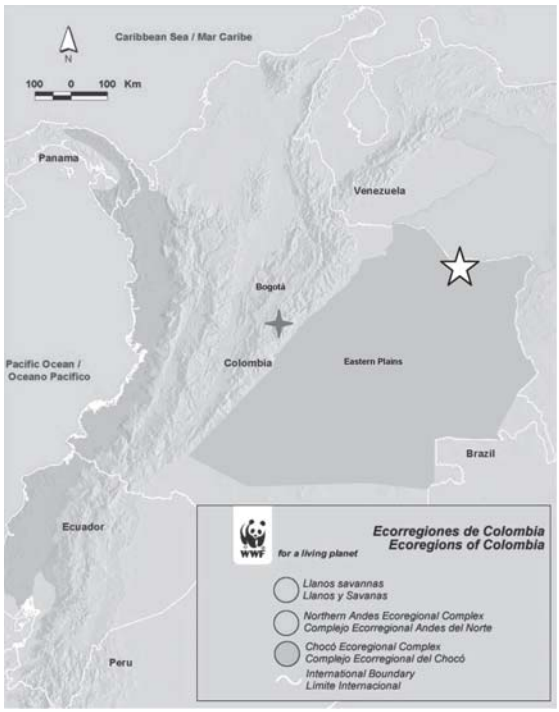


Figure 2. Location of the proposed settlement in the Eastern Plains of Colombia.

rainforest and 100,000 hectares of Andean forest for coca plantation purposes (United States Department of International Information Programs, 2001); becoming an ecological disaster with worldwide consequences.

Bogotá, the capital of Colombia, is a pathetic example of the consequences of the IDP in an urban context. The city's population increased from 300,000 inhabitants in 1940 to 7 millions in 2000 at a growth rate of 36% a year. This growth has created a situation of urban unsustainability in a city that did not have the dynamics and the capacities to absorb the influx of immigrants. Consequently, 227,000 homeless IDP live in the capital at present, and 22% of Bogotá's population (almost 2 million people) (World Bank, 2009) live in informal settlements, virtually slums. (Echanove, 2004) Besides, the unemployment in the capital is close to 15% but almost 50% of the population has an informal employment. Ironically, the main IDP flux to the capital, 20%, comes from the least dense area in Colombia, the Eastern Plains region, which contains only 2% of the country's population (Departamento Administrativo Nacional de Estadistica, 2009). This region is a transitory area between the Andean mountains and the Amazon rainforest.

2. Research

2.1 Status

Planning and architecture related to sustainable development have been largely approached from a technological and industrial point of view in developed countries. In developing countries, this issue is approached from a social and productive perspective, but at a traditional level; the results are often inefficient and poor. In both approaches, sustainable development tends to be fragmentary and the solutions isolated, focused on punctual disconnected issues. The Human Habitat research project aims to combine the two approaches: the high tech with the traditional; providing solutions that could be efficient and affordable, and adaptable to diverse social and environmental contexts.

Human Habitat is conceptually innovative and relatively advanced to the international and national status regarding sustainable development and new settlements; due to its holistic approach from a bioregional planning and bionic architectural perspective. In Human Habitat, the architectural research involves local materials, solar, biogas and wind energy, water recycling and composting; while the planning research involves organic layout, productive gardens, pedestrian town, human scale buildings and orientation.

2.2 Method

The method is based on Nature's life methodology, and it outlines the principles for sustainability and Bio-mimicry. The study demonstrates how these principles can be implemented

in a small settlement in a developing country. Sustainable buildings in the Human Habitat project are designed following basic Nature's life principles (Benyus, 2007): 1) Runs on sunlight. 2) Uses only the energy it needs. 3) Fits form to function. 4) Recycles everything. 5) Rewards cooperation. 6) Banks on diversity. 7) Demands local expertise 8) Curbs excesses from within. 9) Filters water, cleans air, builds soil. 10) Taps the power of limits.

Considering that the project is based on sustainable development principles, the method was framed under the following international acts as the sources regarding the social, environment, economic, planning and construction guidelines: 1) The Rio Declaration as global principles on sustainable environment (United Nations, 1992a); 2) The Agenda 21 as global parameters for sustainable environment (United Nations, 1992b); 3) The UN Millennium Declaration and its Goals (MDG) as global commitment to social sustainability (United Nations Development Program, 2000); 4) UN-Habitat as global parameters for urban sustainability (United Nations Committee on Economic, Social and Cultural Rights, 1996); and 5) The Kyoto Protocol as a tool to a proactive approach (United Nations Framework Convention on Climate Change, 1997).

The research evolved from a universal to a particular vision. The departing point was sustainable development as a general notion; then it was introduced the specific elements related to Colombia, including the IDP problematic; which is the fundamental scenario to the Human Habitat proposition. At this stage an assumption was verified, that sustainable development is the result of a synergic dynamics and symbiosis between environment, economics and society, presupposing that each one of them must be sustainable by its own. The final step was the statement of Human Habitat as a particular concept: an archetype of bionic, self-sufficient and sustainable settlement for developing countries. Comprehensive bio-mimicry architecture involving the landscape, urban tissue and building, was the design focal point; while the bio-regional planning, including the territory, the environment and the urbis, was the link between the core areas of the sustainable development concept and the notion of habitat.

2.3 Approach

The approach to the research has been from a Bionics (Luxton, 2001) or Bio-mimicry (Blicq, 2008) stand, which means studying nature's best ideas and imitating their design and processes to solve human problems. In this context the city is assimilated to the forest, a living and evolving organisation ruled by the ecological succession, which key elements are: efficiency, symbiosis and synergy. Meanwhile, architecture is assimilated to single plants, individuals with its own function form organisation and environment.

3. Sustainable Development

3.1 Definition

The universally accepted definition of sustainable development was formulated by the former Norwegian Prime Minister Gro Harlem Brundtland, in her "Our Common Future" report as: *"Meeting the needs of the present generation without compromising the ability of future generations to meet their needs"* (Brundtland, 1987). Sustainable development, however, is not a statistic statement, but the network of economic, social and environmental interrelations of a society (Figure 3). In an attempt to clarify and quantify this concept, the following equations have been developed. These equations correspond to the integral elements of sustainable development: society, nature and economy. The common denominator for the three elements is man, which becomes the measurement unit to define their sustainability. The sum of the three sustainable elements results in sustainable

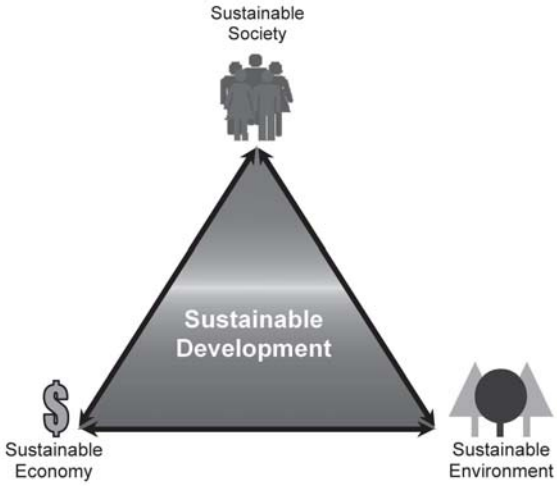


Figure 3. Network of sustainability.

development. The developed equations are in text and in graphic format; for the graphic format some pictograms have been created with its own meaning (Figure 4). Each pictogram can be used separately or in combinations to visualise aspects of environ-mental, social and economical sustain-ability. The purpose of the pictograms in equation format is to show that they give a coherent frame-work to sustainability.

3.2 Sustainable Environment Equation

The Carrying Capacity of the environment divided by the Individual Human Footprint by the Number of Inhabitants, all multiply by time at infinite, which is equal or more than One. As shown in Equation 1.

$$Es_{\infty} = \frac{El}{hf \; x \; pop} \; t_{\infty} \geq 1$$

by Es_{∞} = Environment sustained infinitely

El = Earth's limited load resistance (13.360 million hectares in 2008)

hf = human footprint (2,7 hectares/capita in 2008)

pop = population (6.475 million people in 2008)

t_{∞} = infinite time

Environment sustained infinitely =

$$\frac{\textit{(Earch's limited load resistance)}}{\textit{(human footprint) (population)}} \; \textit{(infinite time) = 1 or more}$$

(1) Basic environmental sustainability equation

	environment		Σ	summation		-1	contrary		energy
$\rightarrow$	sustained			time		$	economic		power
$\oplus$	Earth		∞	infinite		$\int$	integrated		e	final
ε	limited		$\neq$	diverse		$\in$	member			work
	load			ecosystem		$\sqsubset$	part hood		i	imaginary
Ω	resistance			soceity			economy			
	people/human			development		Π	production			
	footprint		μ	friction		η	efficiency			

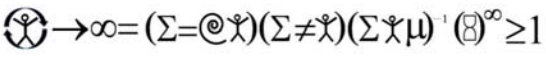
Figure 4. Pictograms and meaning used for graphic representation of environmental, social and economic sustainability.

3.3 Sustainable Society Equation

Equal Opportunities by social diversity by social cohesion multiply by time at infinite, which is equal or more than One. As shown in Equation 2.

$$Ss_{\infty} = (Eo)\,(D)\,(Sf)^{-1}\,t_{\infty} \geq 1$$

by Ss_{∞} = Society sustained infinitely
Eo = Equal opportunities
D = Diversity
Sf = Social friction
t_{∞} = infinite time



Society sustained infinitely = (Equal opportunities) (Diversity) (Social friction)$^{-1}$ (infinite time) = 1 or more

(2) Basic social sustainability equation

3.4 Sustainable Economy Equation

Productivity by Energy by Purchasing Power by time at infinite, which is equal or more than One. As shown in Equation 3.

$$Se_{\infty} = (Pe)\,(Ee)\,(Pp)\;\; t_{\infty} \geq 1$$

by Se_{∞} = Economy sustained infinitely
Pe = Production efficiency
Ee = Energy efficiency
Pp = Purchasing power
t_{∞} = infinite time

Economy sustained infinitely = (Production efficiency) (Energy efficiency) (Purchasing power) (infinite time) = 1 or more

(3) Basic economic sustainability equation

3.5 Sustainable Development Equation

The sum of sustainable environmental, plus sustainable society, plus sustainable economy, which is equal or more than One. As shown in Equation 4.

Development sustained infinitely = (Environment sustained infinitely) + (Society sustained infinitely) + (Economy sustained infinitely) = 1 or more

(4) Basic development sustainability equation

3.6 Sustainability Scenarios

In the four last decades, the human sustainability scenario has had a dramatic change which includes: a tripling of the population; almost the tripling of the ecological footprint; and stable biocapacity, which gives a ratio between footprint and capacity that went from 54% in 1961 to 131% in 2005 (Figure 5).

The following imaginary scenarios are represented graphically, in order to better understand, the variables intervening in sustainability and consequences of their changing values.

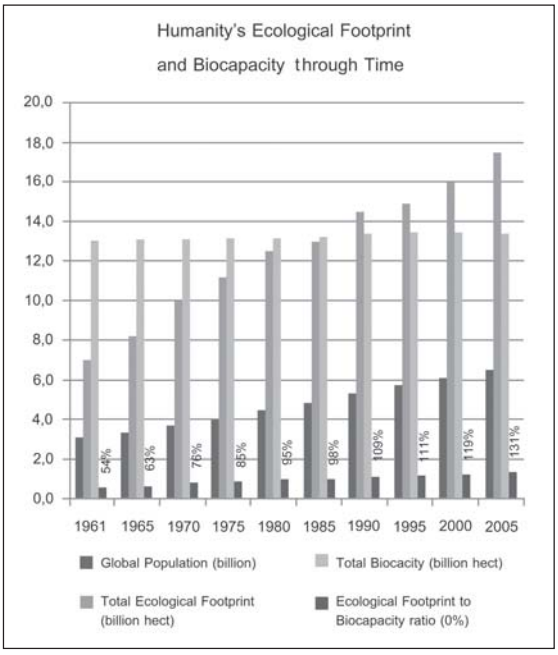


Figure 5. Data Updated, based on National Footprint Accounts 2008 edition: October 26, 2008. Global Footprint Network.

Simple Constant (Figure 6)

The first scenario has constant population and constant annual environmental output per person over a period of 10 years. The graphic has time on the x-axis while the other variables are horizontal lines, which frames the idea of sustainability within the concept of durability.

Simple Accumulate (Figure 7)

The second scenario has the same variables and values as the first one; but it is considered the accumulated environmental output during that period, which results in an environmental deficit. This implies that having constant population and constant annual output in a period of time is not enough to produce sustainability.

Accumulative Restoring (Figure 8)

The third scenario has the same variables and values as the second one; but it is introduced an environmental mitigation (restoring), equal to the environmental deficit, which results in an environmental balance. The restoring is implemented by using and regenerating renewable sources, recycling waste and extending the lifecycle of material.

Simple Increasing (population) (Figure 9)

The fourth scenario has an increasing population at an annual rate of 1,5%, constant annual environmental output per person over a period of 10 years, and an increasing environmental output in that period of time; resulting in an increasing accumulated environmental output or deficit.

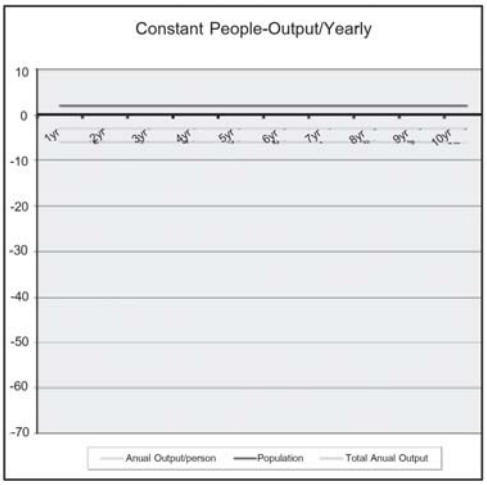


Figure 6. Simple constant.

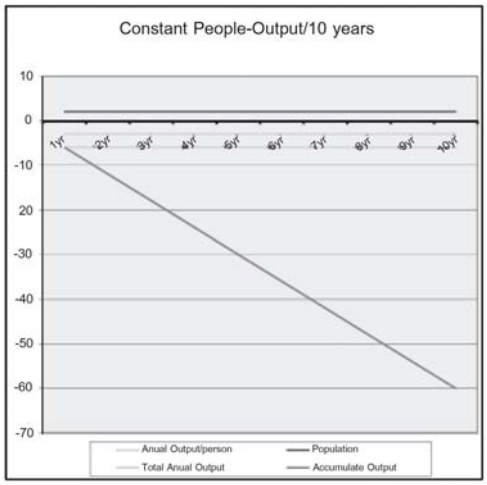


Figure 7. Simple accumulate.

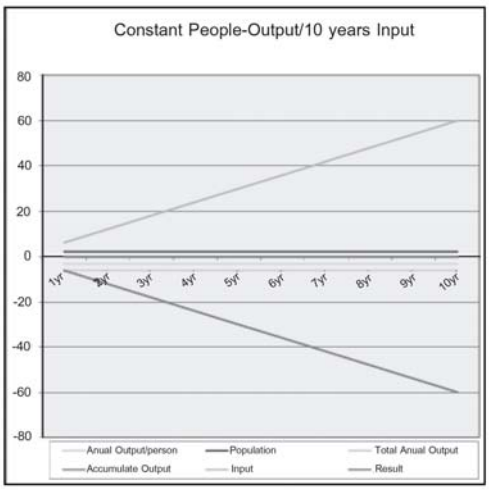


Figure 8. Accumulative restoring.

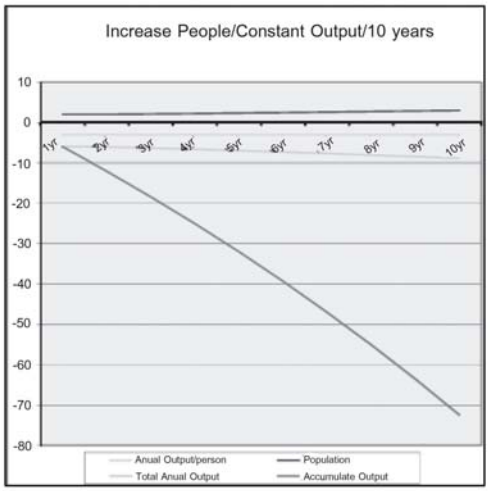


Figure 9. Simple increasing (population).

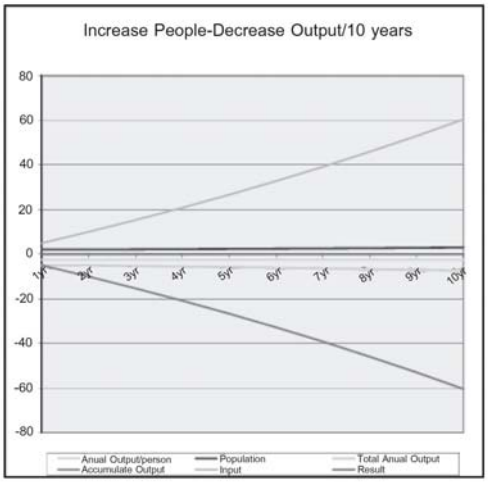


Figure 10. Simple increasing restoring.

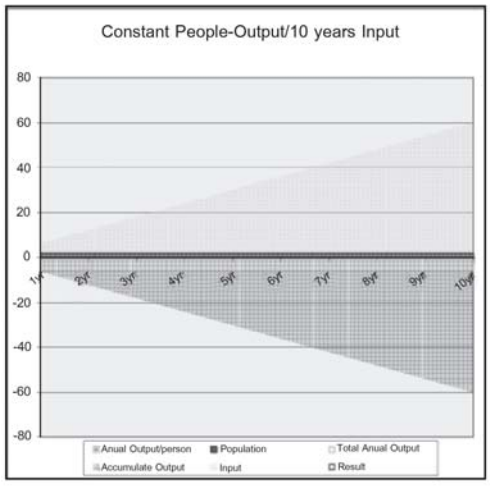


Figure 11. Balance.

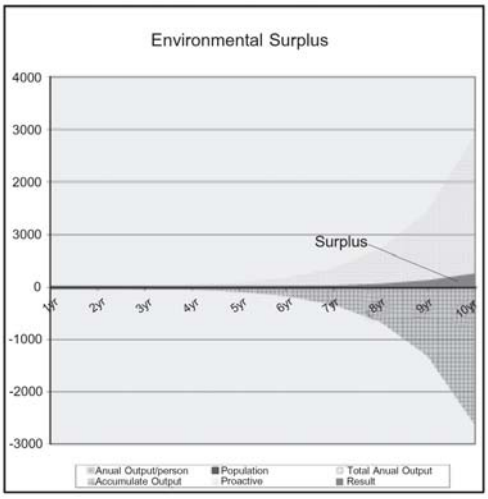


Figure 12. Surplus.

Simple Increasing Restoring (Figure 10)

The fifth scenario has the same variables and values as the fourth one; but in order to compensate the increase in the population, a decrease in the annual environmental output is included; and a restoring variable equal to the deficit is introduced. The result is environmental balance.

Balance (Figure 11)

The sixth scenario is the first step to sustainability; it has constant population and constant annual environmental output per person over a period of 10 years; an accumulated environmental output (deficit) and an equal accumulated environmental input (mitigation), leading to an environmental balance.

The seventh scenario is the ideal of sustainability; it has an increasing population at 1,5% annually, constant annual environmental output per person over a period of 10 years; an accumulated environmental output (deficit) and a higher accumulated environmental input (proactive), which includes the mitigation plus planting O_2 producers and a learning process. This will lead to an environmental surplus.

3.7 Parameters

The ecological position of this research is founded on the recognition that when resources are consumed faster than they are produced or renewed, the resources are depleted and eventually used up. Striking evidences such as the Footprint theory (Wackernagel, 1995), (the footprint measures how much land and water area a human population requires to produce the resource it consumes and to absorb its wastes, using prevailing technology), corroborates that at the present time each person around the globe is spending 2,7 hectares of natural resources to cover his needs, while the estimated capacity of the planet is 2,1 hectares per person; meaning that in order to sustain the needs of the present average lifestyle is needed 1.31 earths. From this -31% of global environment deficit, carbon footprint is 50% of humanity's overall Ecological Footprint (Global Footprint Network, 2008).

The cornerstone of the sustainable development equation is the carrying capacity of natural resources. The reason is that natural resources are the only variable which is limited; therefore, the one determining the others. Consequently, there are only two alternatives to achieve sustainable development: one is improving the productivity of natural resources, increasing their carrying capacity; the other one is restraining the other key variables: population and consumption. In the current global situation, the solution must be the combination of these measures, which coincides with Malthus' theory of population exposed in "The Principle of Population" (Malthus, 1789). At the present time the restoring scenario is beginning to be implemented through mitigating actions, but the consumption and population are still growing and the environmental deficit with them, while the sustainability goal remains very distant.

4. The Idea

Since the research is based on sustainable development principles (Figure 13), its focus is socio-economic and environmental. The planning aspect has a Bioregionalism (Berg, 1978) approach: a regional integration through a spider web of inter-related urban poles providing infrastructure for the region; accompanied by alternative approaches on land use, transport, infrastructure, construction and services, based on Biomimetics (Guild Biomimicry, 2009), to promote integral sustainability.

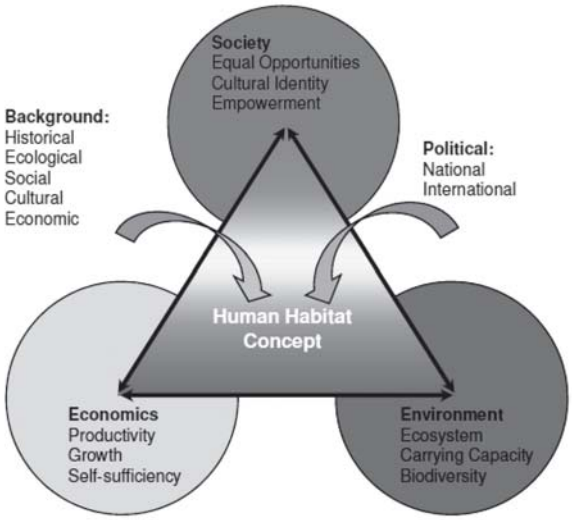


Figure 13. Sustainable development dynamics involving social, environmental and economical interrelations.

Economically and environmentally, the settlements are integrated to the countryside, linked to rural activities but introducing urban ones such as processing and transforming raw agrarian material into finished products. This encourages associative and symbiotic productive systems and innovative ownership concepts to provide land and productive means to the small producers. This approach results in bionic planning and architecture, directed to design environmentally friendly and economically self-sufficient settlements anchored to proactive and precautionary principles.

Social and political issues are key in sustainable development in developing countries. A sustainable community is based on its self-sufficiency of human resources, founded on a participatory and equal opportunities society. The result is a socially balanced, democratic and politically self-determined community. This approach involves alternative planning and architectural proposals, more equalitarian, prioritising the communitarian over the private including activities, services and spaces.

5. The Settlement

A sustainable settlement should be built and defined as a sustainable basic urban unit, economically self-sufficient; socially self-determining and environmentally self-supporting. In other words, the productivity and growth must be higher than the demand; the empowerment and equal opportunities must include all the population; and production must be within the carrying capacity of the supporting ecosystems, respecting biodiversity.

5.1 The Region

The region is the background for the sustainability of one or more settlements; it's an environmental, social and economic unit defined by natural, cultural and productive factors, which determine the typology, vocation, function, scale and potential of the settlements. The region is formed by several territories, which are the surrounding area of a settlement on which its sustainability depends. Socially, a territory is a political unit defined by the human capability and governance of the community; environmentally, the territory is the habitat where all the activities of a community are developed, and it is determined by the carrying capacity (The Global Development Research Center, 2008) of the ecosystem and the environmental footprint of the community; and economically, it is an efficient entity derived from the relation between the community and the environment, determined by the soil vocation and the productive chain. In the Colombian case study, the region is the Eastern Plains; the largest environmental unit in the country with the lowest density and fewer infrastructure. This region is located in a neo-tropical savannah ecosystem, covered by native grasses, bushes, trees and palms, and the main activity is cattle. The lack of new technology to improve the savannah's productivity forces the farmers to practice techniques that cause enormous environmental damage.

5.2 The Fusion between City and Countryside

The industrial city introduced an excessive concentration of power, richness, production and population in the urban centres; while plunging the countryside into an extensive abandonment. Several attempts to restore the disrupted balance through new urban schemes were proposed; the utopian (Owen, 1991) and the garden cities (Howard, 1902) are examples, but they produced solutions for the suburbs of the big cities. Human Habitat (Figure 14) develops a scheme for the countryside, in which function and form are integrated to the region, within a defined territory for the settlement. The settlement emerges from the landscape in a mixed tissue of greenery and urban fabric; while the countryside, physically and functionally, intertwines with the built environment, creating an organic sequence of productive orchards interlinking the urban activities. An Orchard Town appears, surrounded by a productive agrarian territory, and functioning as social promoter; environmental proactivator; and economical transformer.

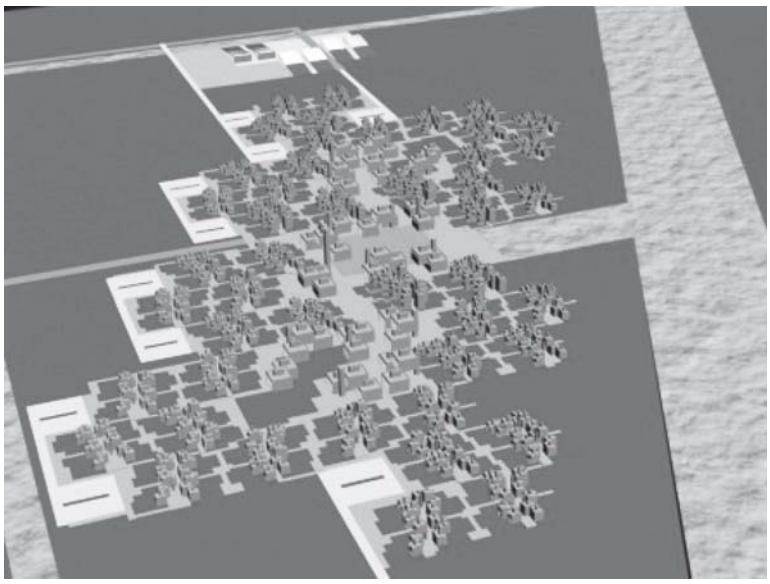


Figure 14. Human Habitat Orchard Town scheme proposed for Colombia.

5.3 The Vocation of Nature

The Human Habitat concept, Orchard Town, (Figure 15) has a holistic approach to nature. Nature is proposed as a cultural, environmental and economical factor. Culturally, it has specific values, symbolisms, forms and imaginaries that must be considered in order to develop a strong sense of ownership and identity; being the bio-climatic function and the spatial delimitation key elements. Environmentally, it has an ecological function as an eco-systematic stabiliser and defender, while consolidating biodiversity. Finally, economically, nature is the great provider of resources for human activities and survival; its renewability and recyclability are fundamental to increase its carrying capacity. The vocation of nature, in this project, is summarised in the Orchard which combines the three essential factors.

5.4 The Human Scale

The main scale focus of industrial cities is to satisfy the needs of the machines; horizontally and vertically, they respond to the demands of mechanic transportation: the car and the elevator. The human scale of the urban centres disappeared through endless and out scaled grids; while the verticality of the buildings overwhelms the human size.

In the Human Habitat project, the human size is the measurement for the town, horizontally and vertically. The main effect is the pedestrianisation of the settlement in its two planes, limiting the extension of the town and the height of the buildings; allowing breaking the axiality of the vehicular grid, introducing a smaller and organic pattern that integrates with the Orchard Town concept (Figure 16). The absence of mechanical transportation within the town implies less pollution and energy consumption, while the human scale gives less density and population, and therefore, a sense of identity, belonging and solidarity.

5.5 The Function

The settlement's main function is symbiotic, which means the support for mutual beneficial interactions between diverse coexisting organisms (Ahmadjian & Paracer, 2000). This is the natural principle that rules the forest, in which all the individuals are interconnected and work together in synergic processes. The town is conceived as a

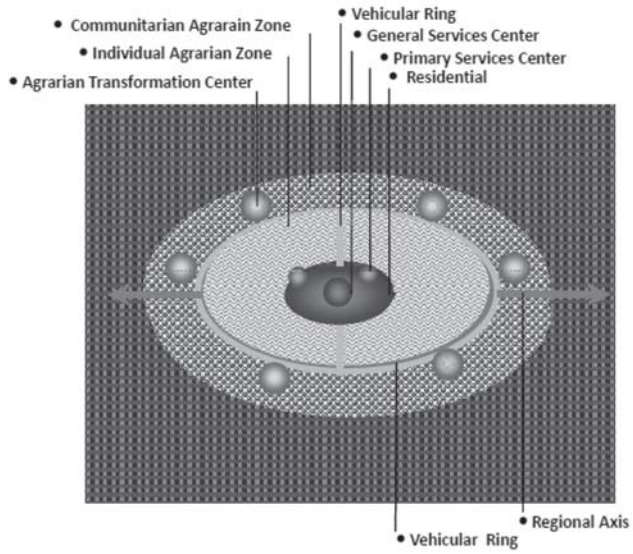


Figure 15. Orchard Town Zonification scheme.

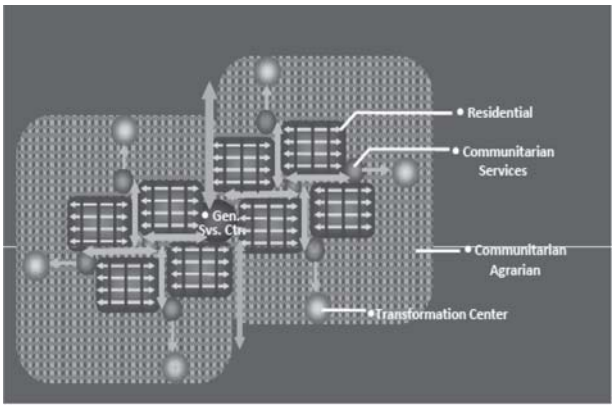


Figure 16. Orchard Town Functional scheme.

network of superconductors linking all the activities of the settlement, in an interchanging feeding process to catalyse and optimise the operations. The settlement's structure aims to reduce the energy consumption, the loose of energy and the production of waste; while using the waste in other activities. The town is proposed as a socio-economic and environmental transformer based on efficiency and interchange.

6. The Architecture

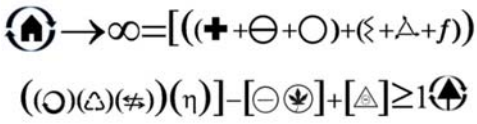
A sustainable architecture is one that is: economically affordable; socially fulfilling; and environmentally integrated. In other words, the cost of the construction and the operation must correspond to the economic capacity of the user; the architecture must satisfy the physical and cultural needs of the user through flexibility and adaptability; and the construction must follow the principles of lifecycle, renewability, recyclability, alternativity and efficiency.

6.1 The Landscape

The landscape is the immediate natural surroundings of the architecture, the space where it lies. This environment is formed by two parts: the biotic or living one, and the abiotic or nonliving one, which includes physical factors such as space, views, temperature, light, soil, wind and precipitation. The landscape has cultural, ecological and economic values, and the combination of those determines the variables used to design a building. From a sustainable approach, the location, density, orientation, materials and typology of the architecture are direct resultants of the landscape.

6.2 The Building

In the Human Habitat concept, the architecture is perceived as a living entity; a dynamic and active building, in contrast with a static and passive traditional one. The building is assimilated, bionically, to a tree; a living object with natural interacting processes such as respiration, nutrition, energy and waste. Functionally, the building is proposed as a Cocoon: a protective refuge with life in its own and in a permanent state of evolution. Environmentally, the building is defined as an equation involving its lifecycle and processes, in which the optimal result is an environmental surplus. As shown in Equation 5.



Sustainable Building =
[((Material+Water+Air) + (Energy + Waste + Operation/ Maintenance)) ((Recycling) (Renewable) (Alternative) (Efficiency))] - [(Natural Resources)] + [(Proactivity)]
= Environmental surplus

(5) Sustainable building equation

6.3 Energy

Energy is the primary mean of progress and today is the most critical issue for sustainable architecture; which includes all the processes: from the extraction of resources, elaboration of materials, transportation, construction, operation and maintenance. Energy has been perceived as an external input to the building, depending for its production on non-renewable sources, which are exhaustible and a cause of the global warming crisis. Therefore, alternative, renewable and recyclable sources of energy are key elements to achieve a self-sufficient energy building. Bionically, a living building in its own dynamics should produce the energy it needs.

The Human Habitat project combines three alternative, renewable and recyclable sources of energy, working synergically to complement and substitute each other. These sources are: solar energy, wind energy and biogas; which will be plugged to a central energy transformer and accumulator. Two solar energy solutions are con-

sidered: solar panels with photovoltaic cells to produce electricity from sun irradiation; and thermal collectors to heat water with sun energy. The wind energy solution is a vertical turbine installed on the top of the building. To provide a better air flux, a metallic duct is built to evacuate the warm air from the interior spaces. The idea is to combine the "chimney effect," involving the Venturi effect, and the "solar chimney effect'' to increase the difference between the internal and the external air pressure, creating small turbulences to help the turbine's rotation. The biogas solution involves a recycling process, using the normal digestive and waste production activities of a building. Regular activities within a building are sources of biogas: organic waste from cooking, and human excrements. Composting processes are used to collect methane gas for cooking and produce fertilizers for agricultural purposes. This solution generates a renewable source of energy, reducing sewage and solid waste problems.

6.4 Water

Fresh water is a steadily decreasing renewable resource. Rain is the cheapest and cleanest primary source of fresh water; and the main source proposed in the Human Habitat project. Its collection, storage, conduction, purification, separation, treatment and recycling are key processes to make more efficient and safe its use. Water consumption must be minimised while recycling maximised. Bionically, the water system of a building is the circulatory system for living beings; with two simultaneous flows, one of desoxynated blood, used water, going to a cleaning area, the lungs; and the other of oxygenated blood, clean water, going to every single cell. The water system starts by harvesting rainwater from the roof, filtering it of debris, and storing it for none drinkable domestic use. A non chemical purifying unit, gravitational filter, located in the kitchen, provides drinkable water to the house. The waste water is divided into biological water, used in the production of biogas and fertilizers; and grey water used for irrigation, cleaning and toilets, after being cleaned and recycled.

6.5 Waste

The production of waste is a natural process in all living beings, related to the unwanted substances derived from the nutrition and digestive processes, which are expelled from the organism and used by other organisms in their own nutrition processes. In a building, waste is the unwanted material remained after all the inputs for its functioning are used. Bionically, the waste process in a building is the digestive system; with ingestion, digestion, separation and egestion. The production of waste must be minimised and the waste transformed and used in other processes. Like in living beings, the building has liquid and solid waste. The liquid one is separated into grey and biologic, transformed and reused. The solid waste is separated into organic, plastic, glass, metals and paper. In the Human Habitat concept, separation in the source is mandatory. The organic waste moves to a composting container, where processed and transformed into fertilizers and biogas. The remaining solid waste is separated, compacted and treated collectively, making more efficient the recycling.

6.6 Air

The health and well-being of the occupants of a building depend on the quality of the air. (Christensen, 1994). The quality is defined by two aspects: cleanliness and temperature. Cleanliness refers to the correct exchange of CO_2 and O_2, in practice done through ventilation; and the temperature refers to how hot or cold the air is, controlled by the exchange of hot and cold air, which allows a comfortable temperature. Bionically, the air management in a building is the respiration in living beings, which is a gas exchange process.

The Human Habitat project proposes a respiratory system, inhaling O_2 and exhaling CO_2, and stabilizing the temperature. The O_2 and CO_2 exchange is executed through the physics law that determines that CO_2, a warmer gas, moves up in the air, while O_2 stays down; to produce the exchange without mechanical means, air entrances are located at the lowest part of the building allowing the access of O_2, while air exits are located at the highest part allowing the extraction of CO_2. To increase the amount of O_2 coming in, green plants are planted close to the air entrances. In the case of tropical areas, such as the one of this pilot project, a "solar chimney" increases the extraction of hot air and CO_2, improving the gas exchange wanted.

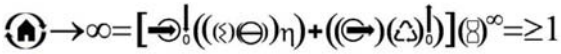
6.7 Materials

Bionically, the materials are the structural and epidermal systems of the buildings. The materials must protect the building from the environmental conditions and use local natural resources. The protection includes weather conditions, solar radiation and natural events; while the use of resources is dictated by renewability, lifecycle and biodiversity. In the case of the Human Habitat project, the hot climate, high solar irradiation and abundant rainfall are the main variables to consider. The control of indoor temperatures depends on the orientation and small openings in the facades, avoiding the direct exposure to the sun, and using vegetation for shade. The hot temperatures of the region constrain the use of thermal isolating material and the "chimney effect;" while the excess of rain imposes the use of water collector roofs, and landscape levelling and canals to prevent flooding, system inspired in the Aztecs "chinampa," (Arco & Abrams, 2006), which reinforces the Orchard concept. Finally, the region is scarce of trees but rich in excellent clays, encouraging the use of brick as material; which is a good thermal isolator and a local cultural element.

6.8 Operation

The operation and maintenance of the building is focused on two elements: energy and water; and the issues are: efficiency and transformation. The idea is to create a living self-sufficient building, in which the inputs are minimised, the use optimised, and the output transformed and recycling maximised. As shown in Equation 6.

The sustainable building operation could be defined as:



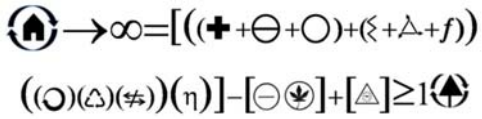
Building operation sustained infinitely =
(Minimum input) (Energy) (Efficiency) (Water) (Efficiency)
+ (output) (Maximum recycling) (infinite time) = 1 or more

(6) Sustainable building operation equation

Bionically, the building's operation and maintenance is proposed as the combination of several examples in nature, having the following characteristics: 1) Interacting; an effective and permanent captor of energy, as the sunflower. 2) Absorbing; being able to clean its own used water and recycle it, as the water hyacinth. 3) Exchanging; being able to exchange CO_2 and O_2, naturally, efficiently and without mechanical means, as the blue-green algae. 4) Flowing; self-thermo regulated, as the termite mounds. 5) Transforming; incorporating a natural decay process to its functions, as the Californian earthworm. 6) Integrating; use efficiently and ecologically local materials and mimicries with the surroundings, as the anthill. 7) Evolving; dynamic, adaptable and flexible; as the butterfly's metamorphose.

7. Conclusions

The Human Habitat project intends to develop a self-sufficient building capable to produce its own energy, recycle its own waste and minimise the use of fresh water, within an affordable cost. As shown in Equation 7. The proposal is to create an interacting, absorbing, exchanging, flowing, transforming, integrating and evolving building, which footprint will be as close to 0 as possible (Figure 17).



Sustainable Building =
[((Material+Water+Air) + (Energy + Waste + Operation/ Maintenance)) ((Recycling) (Renewable) (Alternative) (Efficiency))] - [(Natural Resources)] + [(Proactivity)]
= Environmental surplus

(7) Sustainable building equation

The settlement will be composed of clusters of self-sufficient buildings, interconnected and organically distributed. The use of the open areas as productive orchards will increase the self-sufficiency of the settlement and will work as O_2 producer, which will be reinforced by the pedestrian character of the settlement.

Creating a spider web of small sustainable communities, within a region, will generate regional sustainability, which is the basic unit of national sustainability. The environmental sustainability must be accompanied by a social sustainability and an economic sustainability in order to achieve a sustainable development. The main objective effect through the spider web is to bring the infrastructure and services of the city to the countryside, and by doing so; stop the migration to the cities and then subsequently reverse it.

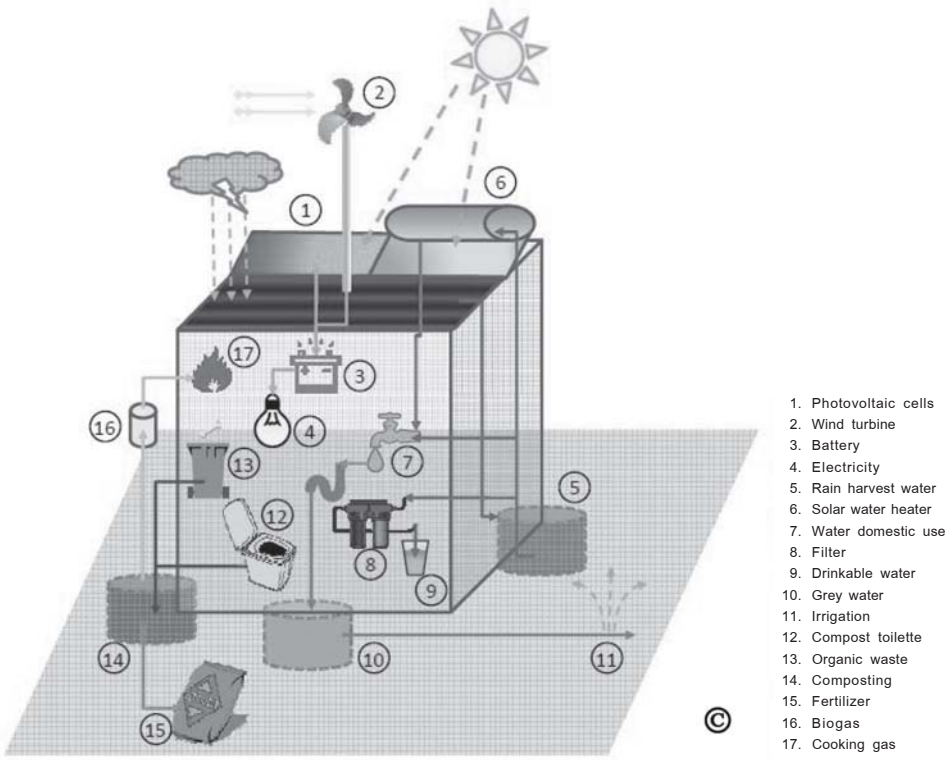


Figure 17. Scheme of the bionic house dynamics proposed.

By developing a whole community based on these principles and involving the orchard town concept, the goal is to reach, at least, an environmental balance, aiming to an environmental surplus, which is one of the keys to sustainable development.

The final results of the research are the equations, which allow calculating different aspects of sustainability under diverse perspectives. Another result is the framework that permits to formulate the Human Habitat concept in different socio-economical and environmental contexts. These results are useful to adapt and replicate the Colombian case model to other developing countries and resettlement conditions.

It was the scope of the study to demonstrate the benefits and inconveniences of applying sustainability and bio-mimicry principles to new settlements in developing countries.

8. Acknowledgement

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