INTRUSION OF BUILDINGS IN NATURAL ENVIRONMENTS:

IDENTIFYING THE NEW ENVIRONMENTAL CHANGE REGIME

by

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ABSTRACT

This thesis examines the degenerative processes of planning procedures and buildings intruding in natural environments as the result of a dysfunctional social value of nature. Such intrusions are assumed to embody a notion of detachment of artificial processes from those of nature, leading to unexpected changes in the natural environment. Unlike urban environments, previously undeveloped locations present no artificial thresholds in the ecological relationship between buildings and nature. The likely isolation of these "social" artefacts intervening in previously undeveloped natural environments is examined in order to stress the functional interaction between natural and artificially contrasting systems as developing a new environmental change regime. Such direct connections highlight the need for accurate design considerations regarding the local conditions of ecological functioning, especially if such conditions are to be maintained. Therefore, a central question of this thesis is not whether buildings should or should not be placed in non-urban locations, but how. Revisiting core concepts from scientific fields, and especially, understanding how theories about the natural environment are constructed comprise a driving strategy in specifying the potential role of planning and design within these processes of land modification. A common ground of analysis and understanding for both scientific disciplines and design processes not (traditionally) involved in environmental evaluations is thus encouraged. The core intent of this thesis is to offer an integrated vision of an ongoing and yet dysfunctional relationship between buildings and natural environments. If the final artificial intervention's layout and its consequent environmental performance considers the landscape structure and functioning as an integral part of the building system, then the building becomes unique to that particular place. By embracing a profound understanding of this functional dependency on the larger natural system, a "sustainable synthesis of nature and culture" (Forman 2001) may hopefully be accomplished.

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A further debt is owed to the numerous other faculties and students from UBC that offered me great feedback and support when I most needed it. Among them, special thanks to Dr. Ray Cole who always kept his door wide-open and ready to offer sharp advice and words of encouragement.

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DEDICATION

This work is dedicated to my friend and wife, Paula Ferrer, for her love, patience and tireless support; and to my family in Chile who despite the distance, were on my side at all times and circumstances.

CHAPTER 1

Statement of the Problem

1.1 INTRODUCTION

This thesis reviews and analyzes the process of ecological modification resulting from constructing buildings in previously undeveloped natural environments.

Such ecological modification is assumed to occur not only from the spreading of urban settlements, but also from dispersed human-made structures[1] contributing to the fragmentation of the natural environment in which these buildings are located.

Buildings interfering with remote areas are considered to be the contribution of a foreign *artificial system*, whether positive, neutral or negative, to a previously stable ecosystem or *natural system*. Due to this contribution modifications to the intervened ecosystem may be inferred. As these modifications increase in intensity and magnitude, complex landscapes are created with many functional ecological bottlenecks. Furthermore, these landscapes have decreased legibility, integrity and aesthetic appreciation (Gulinck and Wagendorp 2002). While considering modifications the building industry causes in the natural environment, especially at global scales[2] (Zeiher 1996), this thesis focuses on the direct relationship between buildings and their immediate natural contexts and assumes that local scales of interaction have a key role in modifying processes on-site and throughout the landscape.

Embracing ecological awareness in building design processes is proposed as a means of providing constant feedback regarding land use planning process throughout the stages of ecological

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[1] This research considers as human-made structures any type of built intervention that could be possibly located in natural environments. Regarded as such, these may be anything from single buildings and infrastructure features (bridges, roads, mining facilities, etc), to more complex groups of structures such as urban developments and cities. For the sake of clarity, human-made structures will be referred to, from now on as "buildings".

[2] Since the oil crisis surfaced in the 70's, advances have been made to try to understand the environmental constraints embodied in the building process, stressing the natural environment. New issues regarding the availability, management, and use of energy supplies raised new interests in renewable resources on and off-site and now, a considerable amount of information –especially in environmental design– is available (Zeiher 1996).

impact evaluation. This may not only improve the ecological suitability of a building's configuration, but may also diminish the uncertainties of overall ecological impacts resulting from the development process as a whole.

Unlike urban environments, previously undeveloped locations present no artificial thresholds[3] in the ecological relationship between buildings and nature. Such direct connections highlight the need for accurate design considerations regarding the local conditions of ecological functioning, especially if such conditions are to be maintained.

Purposes of the Investigation

- **Ecological Synthesis in Architectural Design**

The fields of ecology and design have developed in isolation and with a certain degree of antagonism (Viljoen and Tardiveau 1998). Increasing development pressures on undeveloped natural environments often forces designers (architects, urban planners, landscape architects, etc.) to deal with a context that is not adequately understood within their professions.

While new understandings of environmental change and issues alike are developing among academic and non-academic circles, the lack of ecological awareness in decision-making and design endeavours are increasingly compromising local ecosystems. Thus applied science fields such as Landscape Ecology, although limited in the participation of building design processes, have achieved remarkable progress towards understanding and integrating ecological and human processes.

Merging the latest scientific understandings in ecological functioning with the most recent environmental approaches in building design practices may deliver a more integrated planning process and ecologically conscious design practice whenever a natural environment is modified. This thesis proposes a progressive synthesis of concepts from both ecology and design, with the aim of creating integrated ecological assessment procedures.

[3] Urban environments embody a certain complexity that may blur effective interactions between single buildings and a local site's ecology.

• Engaging Architects in Environmental Planning

Engaging architects in ecological assessments before the design stage may not be an easy task. The lack of scientific background within traditional building design educational programs and the delayed emphasis of design phases within the sequence of environmental planning may explain why architects are not well versed in ecological assessment processes.

The relative isolation of buildings in pristine settings does not necessarily imply that buildings are isolated facts in nature: placing a single structure responds to an earlier planning process that includes goals, decisions, and requirements. Isolation is often considered an added value for the project. Typically once the agenda of development and its environmental planning have been fixed, little room remains for designers to improve their building strategies concerning possible ecological constraints.

Even though a building's ecological impacts may be far from certain, ecological "weakness" is assumed, both in the planning process and the building design. This is due to a lack of references for and from the design process within environmental planning endeavours. Consequently it appears that architects in general do not have a clear understanding of available and prospective assessment tools that can be used to measure likely ecological modifications imposed by the building.

Providing architects with straightforward information regarding possible ecological conflicts in building design may not only improve the actual configuration of the designed structure but may also allow architects to contribute at earlier stages of the planning process. The overall ecological impact of the artificial system may accordingly be decreased through the incorporation of key design considerations. Synthesis and conceptual integration of ecological processes may provide a usable framework for environmental planning driven by interdisciplinary teams.

• Developing an Integrated Tool of Ecological Assessment for the Intrusion of Buildings in Nature

A successful assessment tool needs to be flexible enough for it to be applicable to different ecosystems across different building configurations. Time and spatial scales, which are a part of processes of ecological modifications, can be woven within processes of building design, performance, and disposal. By developing and defining this tool this thesis intends to encourage architect participation within the decision-making processes, and promote collaborative efforts toward ecological assessments, which may lead in turn to a less disruptive planning process. Furthermore, comprehension of the ecological dynamics of modification may be introduced into the academic curriculum and add value to architectural students' education in environmental issues. In fact, the "understanding of the basic principles of ecology and the architect's responsibilities with respect to environmental and resource conservation in architecture and urban design" (Board 1998) has been included among the areas of performance criteria required for professional accreditation by the Canadian Architectural Certification Board for professional degree programmes in architecture in Canada.

This thesis considers each of these core purposes as interrelated keystones in the development of human habitats within natural environments. Each step towards developing these so-called "natural settings" initiates a sequence of cause and effect throughout the process of disruption. They should not be analysed as isolated cases, but as equally important elements within the phenomenon of environmental change.

1.2 BACKGROUND OF THE PROBLEM: THE SOCIAL VALUE OF NATURE

"In shaping the places where we live, we shape the patterns of our own behaviour."

John T. Lyle (Lyle 1994)

Since the dawn of time humans have been and continue to be a modifying force in nature. Diminishing our ecological footprint[4] in non-urban environments as an expression of this force is a fundamental concern in this thesis.

Whether we like it or not each of us embraces a set of values that determine our choices and judgements. Although planning procedures upon the natural environment are often considered "value-free", such a set of values should be recognized as playing an important role in shaping our daily environmental behaviour and thereby its physical results on the land. To ignore this leads us to lose sight of the problems entailed in environmental modification (Wines 2000). Even the utopian ideal of a self-sufficient city would fail when judged by this social value of nature, which subjugates nature to the dynamics of population expansion and resource extraction.

A central question of this thesis is not whether buildings should or should not be placed in non-urban locations –since they will continually be placed there– but how.

The problem of intervention in nature is not purely an ecological issue but a social one as well. According to various authors (Hodges 1990; Toynbee 1974; White 1973) the social value of nature plays an important role in the current environmental crisis. The performance and significance of a building –as a "social artefact"– exceeds the physical facts of the structure and cannot be understood outside the values maintained by the sponsoring society (Hodges 1990). This becomes especially

[4] 'Ecological Footprint' is the term used to describe the total ecosystem resources or productive land area required to sustain a given organism, population, region or county. It is an accounting tool, which uses land area as its measurement unit. Types of consumption are translated into equivalent areas of land required to maintain the average citizen at his/her current lifestyle. It allows the impact of human societies to be compared to the earth's ability to support them. (Extracted from Leeds ECO, 1997)

critical in the context of western culture, where attitudes toward the land are typically economically oriented: "… how can we get more from the land; how much can we make out of it" (Hodges 1986).

By losing sight of the urgency of survival in nature[5], our attitude towards nature becomes 'rational', and therefore serves social values rather than physical needs. Those physical needs are left to be taking care of by technology. As a result, our current and future survival relies on economic development and technological achievements, rather than on close interactions with the functioning of nature. Thus in the traditional building process the overall quality of buildings depends upon the development of new technologies and equipment, decreasing the importance of the professionals involved in the process: "how they interact, and how the building delivery process can be improved" (Reed and Gordon 2000, p.330).

The latest achievements in technological sophistication have led us to conceive some sort of "obvious" linkage between our technical achievements and nature's capacity to support human development. Regardless of arguments to the contrary, nature's carrying capacity is already showing signs of failure due to unsustainable practices and development dependences on cheap, non-renewable resources (Catton 1980; Hodges 1990). In other words, in fulfilling our development demands we have built a rational abstraction –or "civilized concept"– of the natural world's capacities. Buildings are materializations of this rational abstraction, reflecting our behaviours, habits, desires, and expectations. In contemporary thinking, "rationality and economic gain are synonymous" (Lyle 1994). Certainly, this understanding has shaped our attitudes towards nature, and is counter to any ecological coherence (Crowther 1992). Ironically, current environmental crises, which are consequences of our economic gains and technological success, have reminded us of our fundamental origins in and links to nature.

The notion of nature yields contrasting opinions: some believe that the earth should and will naturally reflect our own path of growth, decay, and death. Others adhere to the idea of a self-healing planet capable of coping with the most dysfunctional of human practices. The first philosophy of nature recalls a profound sense of being in the natural world, therefore embracing the concept of reciprocal

[5] See: **CHAPTER I: Development of the Value of Nature of History**, p 7.

stewardship for the sake of mutual support and survival, while the second philosophy proposes a self-regulatory performance of the natural environment, considering the overwhelming powers of nature regardless of any actions taken by the human race. Either way, both ideas imply a meaningful role for the human race in nature. However, when considering the disrupting allocation and performance of our buildings in the natural environment, it is easy to conclude that the second philosophy of nature has been adopted as the rational understanding of the natural world.

This widely held approach to the natural world has precipitated profound changes affecting and shaping the natural world throughout history, and may explain how we have reached such social detachment from nature while being entirely dependent upon it. Such a dichotomy may be explained in part by discussion of environmental degradation that has taken place within ancient cultures and which continues through to current civilizations.

Development of the Social Value of Nature

In early nomadic times our ancestors relied exclusively on the natural environment to survive. Being aware of environmental conditions and incorporating thousands of years of trial and error in their behaviour and in construction of their dwellings was the key to survival for our species (See figure 1). It is believed, however, that around the beginning of the Holocene period, 10,000 years ago, a major change occurred and sedentary behaviour became common worldwide (Goudie 1994): migrating and hunting were replaced by gathering and keeping. Our species abandoned the nomadic lifestyle and established shelters

Figure 1: Dwellings of the Kau people in Sudan, Africa. (Extracted from Riefenstahl 1976).
Note the relationship between shelters and rocks, and the behavioural adaptation to this particular structural solution of the walls.

and community structures. It may be said that a new threshold between humans and the natural environment was created: our own psychological detachment from nature. Nevertheless, some sort of integration between human needs and nature's functioning prevailed until farming practices evolved and came to replace this former notion of integration and reciprocal stewardship between nature and human.

Following the example of the Kau people, we might solve our intrusions in nature by creating a harmonious development that recognizes humans as an integral part of the environment (Lyle 1994; Wadland 1995). Historical evidence suggests that some modifications to the land may well have played an important role in the extinction of key cultures in human evolution. In fact, authors like Martin (1967), believe in a tight relationship between human evolution and such environmental modifications, starting as early as in the Stone Age and the Late Pleistocene, 1.8 million to 11,000 years ago.

• **The Case of Easter Island**

Easter Island represents a tragic tale of rise and fall of a great island civilization. Extensive deforestation between 1200 and 800 BC caused an irreversible loss of native flora and fauna, creating a massive ecological disaster. This is widely considered to be the reason for the rapid decline and the total disappearance of the megalithic civilization responsible for the famous statues (See figure 2) still standing on the island (Flenley et al. 1991). The rapid collapse of this civilization defied any rational explanation, condemning to obscurity their lives and thoughts. Researchers are still now struggling to find evidence that would explain, among other things, how the large statues were raised or the decline of vegetation and endemic species on the island.

Figure 2

• **The Case of Ancient Greece**

Ancient Greece is one of the most admired and influential cultures of the past, and it still influences modern western culture. However, according to Wines (2000, p53), the superiority of mind over matter led the Greek culture to treat the landscape as a functional surface to be exploited (Wines 2000, p.53). Further, along with the high levels of sophistication reached in its plenitude, a dominant process of soil degradation and accelerated erosion followed the constant thinning of vegetation cover caused by human action and its associated activities (See figure 3). The superiority of mind over matter the Greek culture to treat the landscape as a functional surface to be exploited (Wines 2000, p.53).

In the semi-arid environment of the Mediterranean, these processes led to irreversible desertification. This sequence is explained by Yassoglou and Kosmas (1997) as:

- ► Destruction of the forest around 4000 years BC
- ► Soil degradation due to soil erosion in the cultivated and grazed sloping lands
- ► Severe drop in land productivity leading to abandonment of agriculture (around 500 to 40 BC)
- ► Grazing on the abandoned lands further degrades the land
- ► Severe erosion and irreversible desertification (present)

• A Sustainable Example from the Past

Unlike the references mentioned above, Ancient Egypt culture circa 5,500 BC may be a good reference of sustainable practices achieved by an ancient culture. The anthropogenic association in Egyptian religious life seems to have worked well for this ancient society since it provided the bridge between a multitheistic mythology rooted in nature and a monotheistic structure essentially placing the monarchy above nature. This theocratic system honoured every major environmental force, while investing the Pharaoh with all of the transcendental power needed to rule the kingdom as an unchallenged divinity. “This theology was organized to function simultaneously as

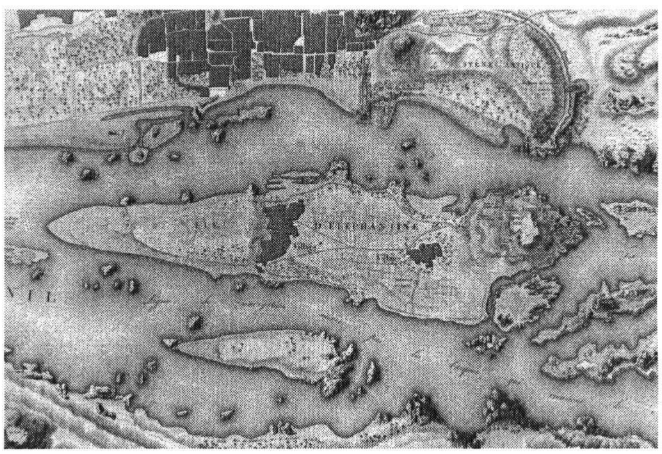


Figure 4: Nile Valley civilization (Wines 2000, extracted from Description de l'Egypte, 1809)

an acknowledgement of nature's demand for respect and as a vindication for the profligate indulgences of the ruling class" (Wines 2000, p.50). Once these natural conditions and the seasonal cycles of the Nile River were recognized on an annual basis as the "fertility cycles" of the Nile River, agricultural practices adopted these cycles accordingly. This system flourished and supported the development of successive dynasties from the Pharaonic era, through the Roman Empire, and lasted over 7,000 years, until the 20th century. Less than a hundred years ago these fertile cycles were reinterpreted as annual floods. In the 1950's, a new dam was constructed to control floods and water cycles. This intervention in nature finally regulated water levels; however, it also retained the silt that previously enriched the agricultural soils in the past. Consequently, the natural fertility of the soil decreased, and is now replaced by artificial fertilizers.

After millennia of human development and societal evolution, we have gradually embraced a psychological distance and antagonism toward our natural context, ironically depicted by Northrop Frye, as "the conquest of nature by an intelligence that does not love it" (Northrop Frye cited in Wadland 1982).

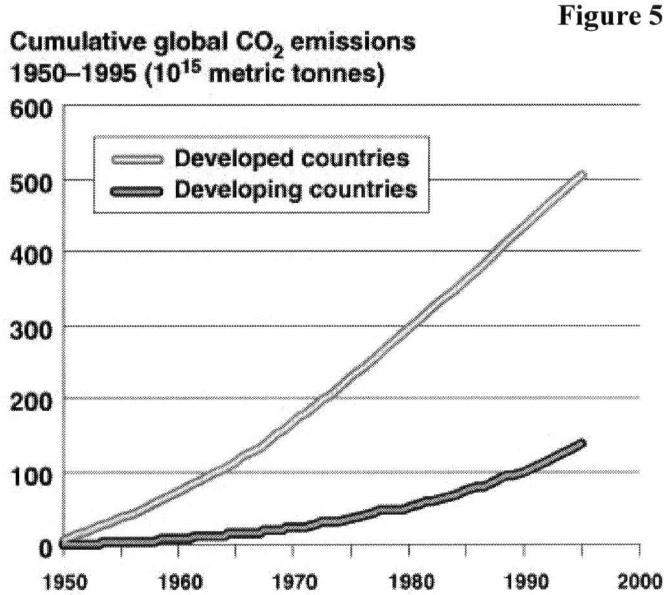
This notion of cultural detachment is especially explicit in architectural thinking, where nature continues to be seen as the "external supplier of energy and material resources for the building's physical form and substance, as well for maintenance of its operations" (Yeang 1999). These immediately perceived economic benefits are virtually always achieved at the expense of lower long-term sustained revenues. In fact, in virtually every field there is considerable literature on the aggregate economic effects, ecological costs, and impacts on future generations, which shows that for every gain obtained from discounting the future there are losses, which far outweigh those wins (Norgaard and Howarth 1991).

The New Biophilia of Western Societies

In spite of our progressive cultural detachment from the natural environment, and the dysfunctional dependence on it by our built environments, the idea of nature is awakening new public awareness, especially among western societies.

Quantitative researches indicates that 70-90% of the population in Europe and the USA have developed a strong sense of nature-friendliness, recognizing the right of nature to exist even if it is not useful to humans purposes in any way (Vandenborn et al. 2000). Interestingly, those "eco-sensitive" populations reside in those countries with higher energy consumption and greenhouse gasses emissions (See figure 5).

Figure 5



Sources: G. Marland et al., 1999. Global, Regional, and National CO2 Emissions. Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Tennessee. Extracted from (Columbia 2001)

These cultural forces are shaping a new socio-economic model, which in turn is creating new markets and associated products and services — offering nature not only as a place of joy and spiritual fulfillment, but also as an attractive business (tourism, eco-tourism). Public participation in these new markets, although not directly involved in the political and scientific debate of environmental crisis, represents the new social *biophilia*, and is the central force shaping these markets. This new idea of nature is becoming the basis for current and further demands in products and services such as leisure facilities, more diversified tourism infrastructure and destinations, and new urban developments rather close to natural settings, among others. As a consequence, unprecedented intrusions in natural environments have become more frequent and also ecologically harmful since these markets are primarily ruled by economic benefit rather than environmental awareness.

1.3 THE PROBLEM DEFINITION: BUILDING ON UNDISTURBED LANDS

The current debate on the relationship between human beings and nature[6] has evolved as an "ecocentric-anthropocentric division" (Humphrey 2000). As broad and blurred as it is, the concept of nature has been an explicit focal point for human culture. "Representations of nature decorated ancient Roman homes, preoccupied the wealthy in eighteen-century England, and span the range from high art to kitsch in North America today… whether represented in poetry, painting, or environmental art, it is a fact that nature is a popular concern" (Nassauer 1997). In general terms, McHarg (1969) defined nature as "the arena of life" presenting the notion of an interacting assemblage of functions and changes affecting living thing and their nonliving environment. Therefore, nature is not conceived herein as the "background image" of natural landscapes giving context to our urban environments, but as the web of ongoing natural processes and structures that support all life, including human life. Defined as such, humanity and nature are both part of an unbroken matrix, whereas natural environments –as the focus of this investigation– are simply specific landscapes mainly dominated by natural processes with no apparent human intervention.

Nature preservation –as the ecocentric vision– is commonly presented as a key strategy for maintaining ecological integrity, and is usually seen as opposed to human development. Moreover, an effort to maintain such levels of ecological integrity are still considered to be possibly harmful to development endeavours –the anthropocentric vision. Both, anthropocentric and ecocentric visions imply static notions of ecological processes and socio-economic models that define fairly inflexible notions of human development and nature preservation. However, mutually excluding one vision

[6] Webster's Dictionary defines nature as: "The physical world, including living things, the universe; the forces or powers that animate and regulate it, natural phenomena; the order, disposition, and behaviour of all entities composing the physical world."

creates a particular connotation of nature (Humphrey 2000) and a very narrow vision of a rather complex relationship: the ongoing cohabitation of artificial and natural systems.

Degenerative Patterns of a Dysfunctional Socio-Economic Model

It is assumed that human-made structures (including buildings and the city as a complex whole) as artificial systems impose changes on the natural environment. Yet, such systems are usually considered to be major achievements of our intricate technological development.

On the other hand, they can also be seen as schemes of extreme simplification of the ever-changing complexity in nature. Nature's endless complexity is indeed nothing but the evolution of inimitable places adapted to local conditions; however, "human ingenuity has replaced them with a system of relatively simple forms and processes" (Lyle 1994). Human simplification of nature is repeated with consistent regularity despite any singularity of local environments and its features. The environmental risk associated with such simplification increases if the ongoing curve of population growth and the different patterns of urbanization[7] are taken into consideration.

According to the World Resource Institute (World Resource Institute [WRI] 1988), current land sources[8] cover 61 percent of the world's land area. Consumption has become increasingly concentrated in large cities, demanding ever-increasing volumes of materials from those sources. Presently, cities cover less than 2 percent of the 61 percent, but they include over 42 percent of the population (Lyle 1994). That 2 percent can be certainly expected to grow in the years ahead, with the intensification of simpler and more sophisticated technologies to improve. As a result, the natural landscape will continue to be dramatically changed and human activity has now an omnipresent influence on the earth's ecosystems, reorganizing the global landscape in order to assist and support the various networks of urban production. Through these artificial networks, energy moves from source to sink, diminishing the first and accumulating toxicity in the second. Unlike nature's recycling processes, this sequence of one-way energy flow imposes a serious stress on the environment: enormous amounts of raw materials are

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[7] See: **New Spatial Urbanizing Patterns**, p.15

[8] This category includes agricultural and grazing lands, oil fields, mines, productive forest, watersheds, and a variety of other lands from which materials are taken to supply consumption centres.

extracted for inputs into the entropy process (See figure 6), and disposed in larger quantities in natural sinks (air, land, and water). Simplification processes and energy concentrations increase waste as a result of progressive mixing of materials, air and water, increasing the pressure on natural sinks[9].

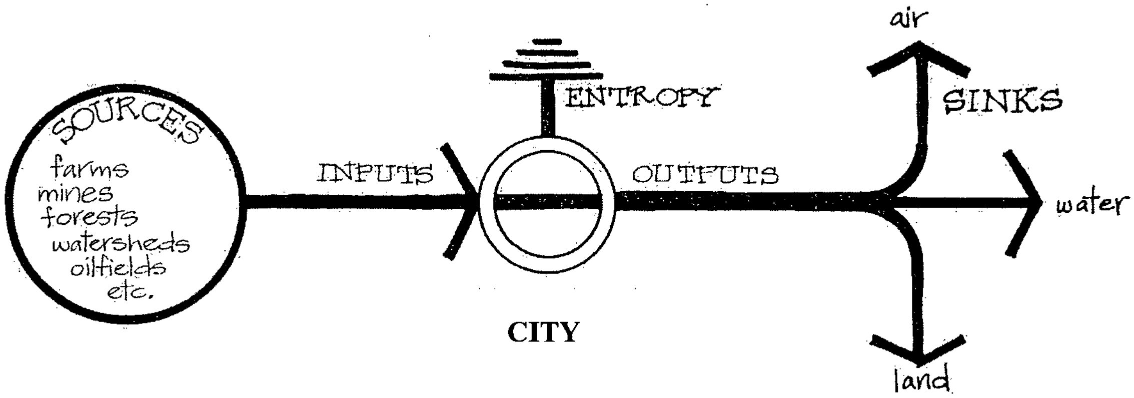


Figure 6: Modified from Lyle, 1994

Predictably, the increasing exploitation of non-renewable natural resources is progressively harming the carrying capacity[10] of those natural sinks. If the concept of carrying capacity is meant to be a main root for sustainable development (See figure 7), then the continuous depletion of that capacity certainly promotes a declining curve or degenerative pattern of development for our present economic model. Eventually, the one-way production systems will deplete the source and overload the sink beyond its abilities to function, thereby destroying the landscape that supports the process.

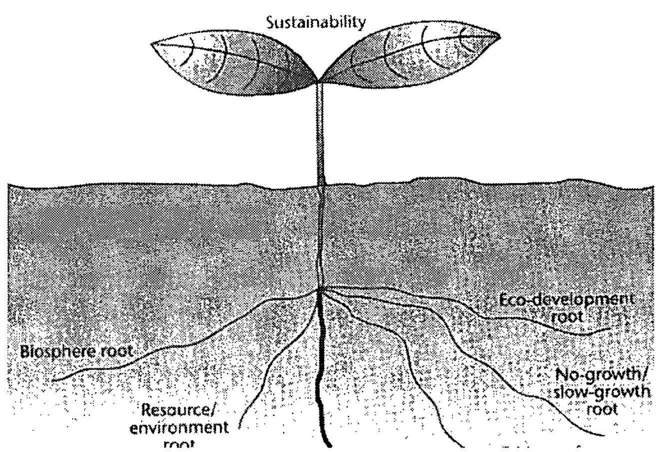


Figure 7: Modern view of sustainability (Adaptation of Bell and Morse 1999)

[9] A pound of burned fuel carbon releases 3.3 lb of carbon dioxide to the atmosphere (Lyle 1994).
[10] This measurement indicates the capacity of an ecosystem "...to sustain a certain density of individuals because each individual utilizes resources in that system. Too many individuals results in an overuse of the resource and eventual collapse of the population" (Bell and Morse 1999), or more specifically, "...how much use the land can accommodate without degradation." (Marsh 1998, therefore defining the development capacity of the landscape)

• New Spatial Urbanizing Patterns

Complex processes of urbanization also occur beyond a city's physical layout, with the expansion of its boundaries well into the rural-urban fringe and across "natural habitats" between cities, as a consequence of population deconcentration from urban cores. These areas, with the most fertile soils and equable climates, are often the areas of greatest biological diversity. (Janetos 1997)

Indubitably, this economic scheme has, so far, enriched western societies by increasing income levels and resolving wealth inequalities. As exposed by Yorukoglu (2002), "population density and income inequality are closely linked, establishing a tight connection between migration vectors and population distribution with economic cycles." (See figure 8 and 9)

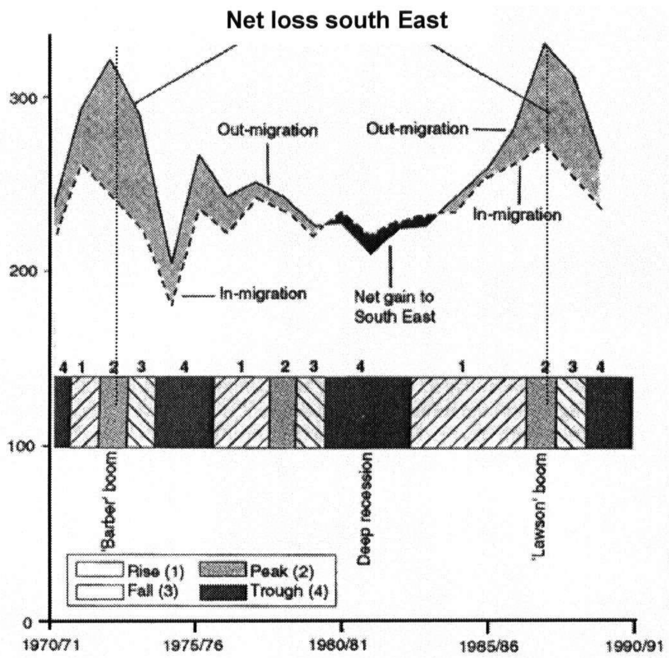


Figure 8: Link between inter-regional in-and-out migration and business cycle for South East England. Notice the link between economic booms and out-migrations. Extracted from (Fielding 1998, original source: NHSCR)

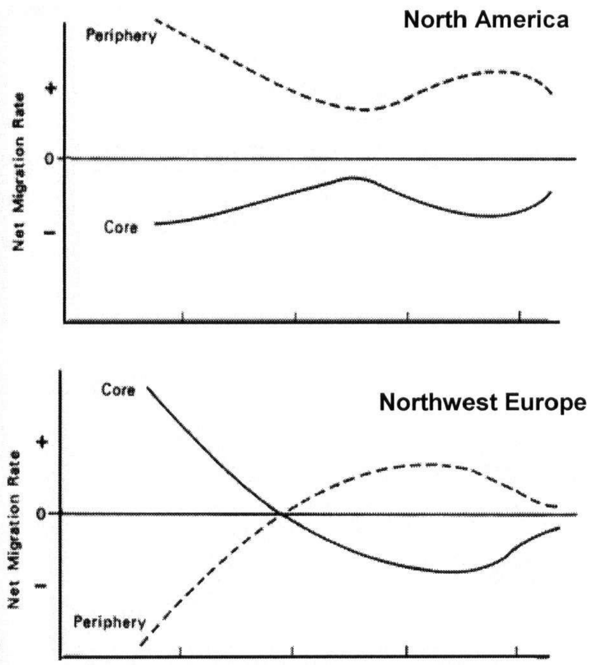


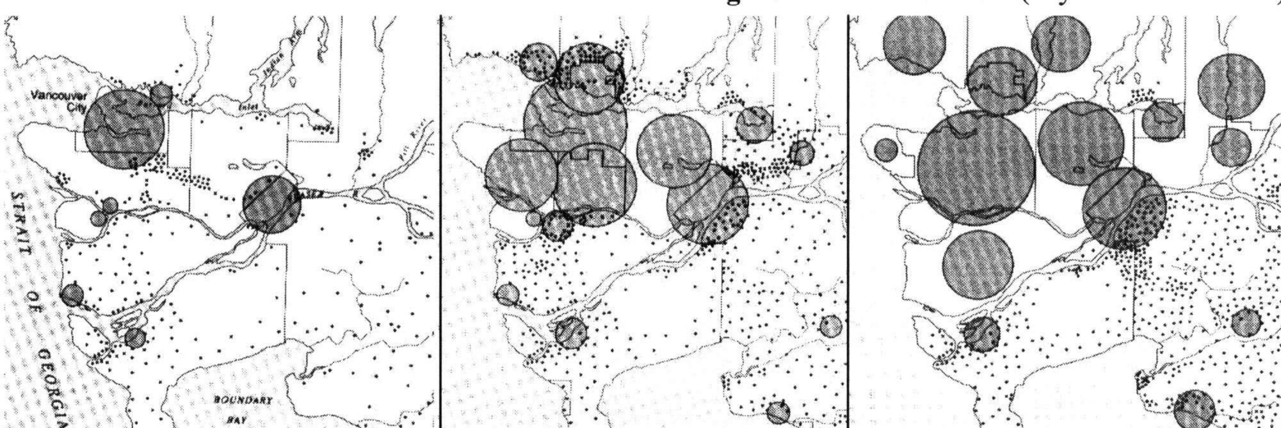
Figure 9: Extracted from (Champion *Counterurbanisation* 1989). This figure shows net migration rates at a city's core and periphery throughout time.

As density increases, productive differences between locations become more pronounced, which is apparent from the steeper land-value profiles in denser cities. During times of economic booms, transportation and communication technologies improve drastically, transforming American and European cities from geographically narrow, high-density centres, to wider, lower density metropolitan areas, initiating the so-called process of urban sprawl.

- **Urban Sprawl**

Science has started to categorize urban sprawl and other urbanizing patterns as the main culprits responsible for environmental changes to the landscape, due to land conversions: new settlements are expanding along with industry, transportation infrastructure and communication routes. Together this becomes a major factor in landscape modification, and it is estimated that these uses now occupy about 6% of the world's land area, and among them, urban settlements are currently the most significant factor of change (Rozanov, Targulian, and Orlov 1990). Figure 10, for instance, shows the increase of population density over forty years in Vancouver. A clear gravitation towards the urban core is indicated, along with urban sprawl towards the Fraser Valley.

Figure 10: Extracted from (Wynn and Oke 1992)



1901 | 1921 | 1941

As a consequence, the former vibrant downtown of the typical North American city has become a clean and retrofitted backyard that no longer relates to citizen's daily life. The outskirts of the modern city is being fragmented by suburban clusters relying on better transit infrastructures and car technologies (Ioffe et al. 2002). Agricultural land that once displaced natural ecosystems is now being

Figure 11: Displacement of agricultural land by settlements (Rozum 2002)

displaced by settlements (Meyer 1996) (See figure 11). The spatial dispersal of north American cities is currently ongoing and apparently no longer confined to the suburbs, as suburbanites show signs of relocating to communities more and more distant from the city core, often times outside the metropolitan realm (Ioffe et al. 2002).

Evolving cultural compositions in capitalist economies and developing social values regarding nature is profiling a new resident in the exurban[11] zone of the countryside, restructuring long held beliefs about what quality of life is about.

- **Counterurbanisation**

In 1975, a researcher in the Economic Development Division of the United States Department of Agriculture first drew attention to another type of population turn-around in which "…rural populations were increasing more rapidly than urban population." (Walker 2000, p.107-8) (See figure 12).

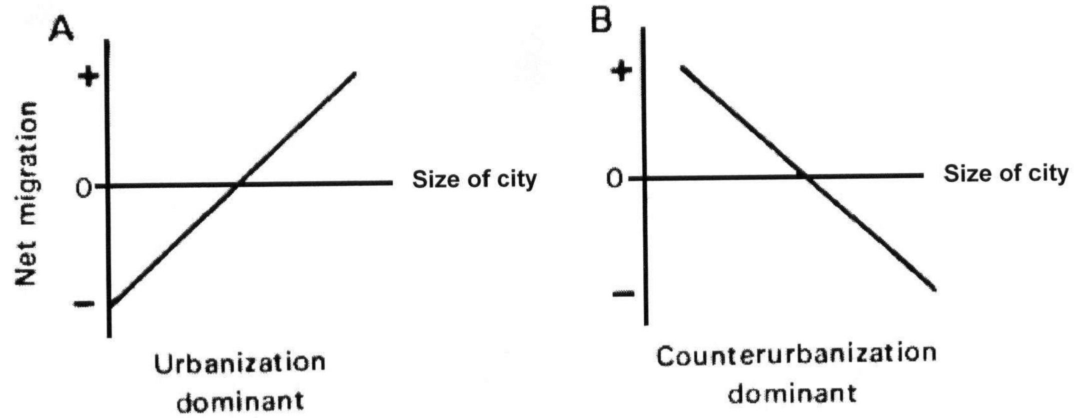


Figure 12: Modified from (Champion *Counterurbanisation* 1989)

[11] Increased out-migration from urban and suburban areas, more land consumption per capita, and edge city formation around the periphery of central cities have led to more complicated patterns of settlement in which the distinction between suburban and rural has become increasingly blurred. A new type of development that is neither fully suburban nor fully rural has emerged, sometimes referred to as the "exurbs." Exurbia or the "exurbs" are a type of spatial pattern of settlement that differs from their suburban counterparts. Exurbs are located at greater distances from urban centres than suburban developments and are comprised of a different mix of land uses and population (Ohio State University, 2000).

This new large relocation process, identified as *counterurbanisation,* introduces a new and expansive urban dynamic into the surrounding natural environments. Initially defined by Berry (1976) as "...a process of population deconcentration, implying a movement from a state of more concentration to a state of less concentration." The causes and complex implications still remain unclear. In fact, Berry's definition presents a limitation since it does not explain "how concentration and deconcentration are to be recognised and, as such, is no more than a starting point." (Champion 1998, p.25) As used by Berry, counterurbanisation refers to all types of population deconcentration, while considering these processes to be part of a larger single one, in which residential preferences constitute the primary motivating force. Meanwhile economic and technological improvements act as a permissive context "influencing the speed with which these new patterns can unfold." (Champion Introduction: The counterurbanisation experience 1989, p.32) But in fact, it is not a simple process of deconcentration: "the dispersion of population growth beyond metropolitan areas was not so much a movement to smaller towns as a movement to the open countryside, suggesting a new shift towards rural life-styles" (Long and DeAre 1982). Among the explanations stated by T. Champion (1998) for this population movement are:

- ► Emergence of social problems in large cities
- ► Concentration of rural populations into local urban centres
- ► Reduction in the stock of potential out-migrants living in rural areas (especially after the former migration from the countryside to the city)
- ► Growth of employment in particular localized industries such as mining, defence, and tourism
- ► Improvements in transport and communication technologies
- ► Improvement of education, health and other infrastructures in rural areas
- ► Change in residential preferences of working-age people and entrepreneurs

• Environmental Constraints of an Evenly Scattered Urban System

The disruption of nature is primarily due to urban phenomena such as urban sprawl, counterurbanisation, the primary concentric spreading rings of development, suburban clusters at the edge of the urban fabric, subsequent urban growth along exurban transportation corridors, and the final spread of satellite towns in addition to urban infilling (Forman 1999).

Considering fast-track urbanization, which took place during the last century, it is perhaps too early to forecast counterurbanisation processes and phenomena alike as long-term trends. In fact, being defined as a negative association between net migration and settlement size (see figure 11, page 17), counterurbanisation is believed to "contain the seeds of its own destruction in a way that was not true for urbanization. Whereas the latter can be considered a cumulative process in that the largest places grow fastest and thereby increase their attractive power, counterurbanisation is self-defeating because the fate of the smallest places that, by definition, are the most attractive is that they should grow most rapidly and thus decline in their attractiveness." (Champion *Counterurbanisation* 1989, p.241)

In other words, counterurbanisation patterns can be expected to decline as settlements of smaller size saturate the countryside, becoming parts of a more disperse distribution of the traditional pattern of population concentration. Regardless of whether they are collapsing or not, these "exurban waves or frontiers beyond the area actually converted to settlement" (Meyer 1996) are creating new communities and imposing a wide array of materials and mechanisms that are "thermally and hydrologically extreme to the land and in structural forms that are geomorphically atypical in most landscapes." (Marsh 1998) The lack of specific information regarding associated impacts due to these ecological modifications increases uncertainty levels for processes of environmental planning.

Physical Outcomes of a Degenerative Model

Emerging and uncertain urban growth patterns towards environments different to the city are imposing unpredictable changes on the landscape at the edges of cities and across the natural areas between them.

As noted by Johnston (1980), the location of potential urban developments responds to three key factors: space, time, and attributes. That is, the intrinsic structure of the site, the various socio-economic values applied to it, the relationships to the context, and how these factors are affected or influenced in time will finally determine the specific location of further development. Consequently, an accurate forecast of ecological change due to any built intrusion should consider not only the affected ecological features, but also the pursued value of development[12], plus the spatial relationship between the actual site's attributes and its surrounding attributes (Lagro 2001). Keeping this in mind, the interface between urban and natural environments becomes of particular interest when it comes to defining potential spatial scales relating to the problems discussed in this investigation.

- **The Isolated Intrusion: Stresses on the Natural Gap**

The spatial context for the problem of human-made structures intruding upon natural environments may be defined in part by the gravitation of nearby urban centres, as built interventions may occur randomly across natural locations. The spatial context of the problem is also defined by what we may call unsuitable places for "isolated intrusions" of human-made structures and their artificial systems. Built interventions on natural environments pursue exactly that, naturalness. Thereby, cities are considered non-suitable for such interventions.

Other non-suitable locations for development endeavours are those landscapes less likely to be directly pursued by urban development because of extreme natural conditions such as mountain peaks, water bodies, explicit avalanche runs, rocky riparian zones, etc. Finally, there are those specific policy-protected ecosystems, which would include parks and other protected areas of ecological significance. This category would include those establishing and promoting human activities linked to particular settings (i.e., forestry activities in dedicated land, agricultural land reserves, etc). Yet, these types of non-suitable landscapes do also embody an intrinsic "naturalness", which makes them eventually

[12] The pursued value is what may distort, eventually, the intrinsic ecological value of a site due to land speculation. (Note of the Author)

susceptible to being targeted by land speculators. Policies may change to create better land economic exchange values, threatening exactly what makes them unique: their natural heritage[13].

These different settings may constrain urban development. They usually enclose large tracts of land lacking in accurate definitions, either in terms of land use suitability or ecological characterizations. These lands will be referred to, henceforth, as *the natural gap*.

Current and potential green corridors, agricultural land, wetlands and other sensitive wildlife habitats, watershed and other drinking water supplies, estuaries, forestland, and urban recreational areas (Buchanan and Acevedo 2002) are considered integral components of this so called natural gap. Due to their proximity to urban systems these ecologically active lands are assumed to be highly susceptible to colonization by artificial means. If analyzed as major ecological boundaries or *ecotones*[14] (Clements 1905; Odum 1971), the environmental sensibility of these natural gaps become critical. (See figure 13)

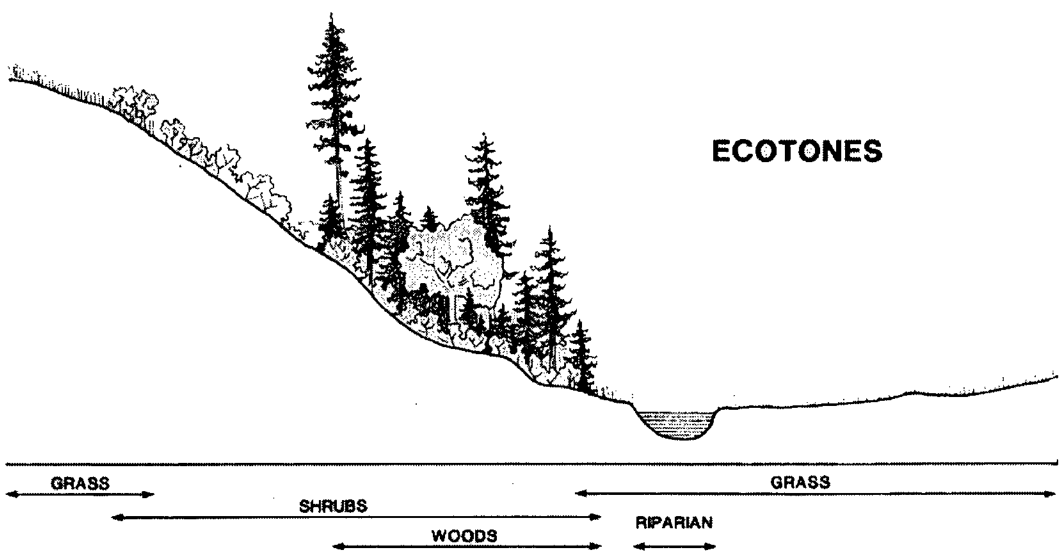


Figure 13: (Bailey 1996)

[13] For instance, while some watersheds are explicitly reserved to provide drinking water to urban centres, they might well be considered as highly critical in terms of both ecological and urban contexts. Changes in land-use policy throughout time plus increased pressures by urban development markets may eventually promote further modification to such policies on behalf of economic interests. As a result of changes in the resource's socio-economic value, the watershed becomes no longer a mandatory ecological feature for proper urban functioning, but a possible source of available land for urban development.

[14] An ecotone was defined in 1971 by E. P. Odum as: "a transition between two or more diverse communities", and earlier, in 1905, by Clements as: "The junction between two communities where the processes of exchange or competition between neighbouring formations might be readily observed."

The relevance of an ecotone is rooted in its capability to allow biotic and abiotic components to move across heterogeneous landscapes, controlling important functions of the interacting ecosystems. Ecotones can also act like filters or controllers satisfying the life cycle needs of different organisms and are generally characterized by high biological diversity. Hence the proximity of urban centres and pristine locations may not have to be considered entirely harmful to natural ecosystems. If built environments are considered as another type of ecosystem taking place within a larger landscape, then proper management of particular ecotones between urban and natural ecosystems may well promote biodiversity. Thus, human interventions in nature are not any more a reason to assume less biodiversity — but, if well planned, can in fact promote biodiversity.

Because of the intense ecological activity taking place within and through such boundaries, ecotones are considered to be sensitive indicators of environmental change as well (Holland and Risser 1991). Thereby the notion of ecotones or ecosystem boundaries is considered to be a key reference in this research. Potential interactions between the most concentrated human ecosystem (the city) and more pristine ecosystems (the natural environment) are assumed to trigger unexpected processes of environmental change. The *natural gap,* previously defined, becomes the tract of land containing the ecotone between natural and artificial systems and therefore the selected spatial scale of analysis for the problem of this thesis.

• Ecotone Displacement as a Consequence of Environmental Change

The likely stress exerted by artificial structures on natural environments, within and across the natural gap not only depletes the intrinsic ecological properties of this ecotone, but may also be shifting its setting towards more pristine and undisturbed landscapes.

While natural gaps are gradually displaced and urbanized, those areas beyond become closer and are increasingly seen as desirable places to explore, whether for new development trends, tourism diversification, resources exploration or simple leisure. Unfortunately, rare features of the landscape such as rock formations, watercourses, endangered wildlife presence, spectacular views, or other sporadic situations –at least to the human eye– become evident points of attraction, and while a sporadic visitor may feel attracted to the place, commercial interests may see these pristine sceneries through the lens of revenue (Hummel 1989). Hence, progressive landscape fragmentation is promoted across the natural gap, threatening a critical ecosystem, the uniqueness of which is assumed essential to the overall ecological stability of the ecotone. Even without direct intrusions into those more sensitive ecosystems or protected areas, human-induced stresses at the natural gap are also being increasingly recognized as potential factors contributing to a reduced distribution and abundance of ecological biodiversity at broader spatial scales (Buechner 1998). These events of environmental change certainly include a complexity of processes and raise some important issues:

a) Are current-planning practices adequately forecasting the actual participation of these factors and their resulting environmental outcome?

b) Are environmental planning practices addressing the complex link between human-induced environmental changes and ecological functioning?

c) If yes, are these practices understandable by technical and non-technical participants of the planning process, as well as the public in general?

An integrative vision of the planning process must incorporate the appropriate tools to address these complexities, and these tools should be simple enough so they can be utilized by all the actors involved and readily communicate results to the public.

Problems, Distortions, and Opportunities in Current Environmental Planning Practices

Buildings intervening in natural environments are the result of a meticulous decision-making process, which has determined the building's physical attributes, performance, location in the landscape, and therefore, the structure's ecological role within a given landscape unit.

The social value of nature, degenerative patterns of urbanization, isolation of artificial systems in natural environments, and current environmental planning practices, are all primary components of the problem. Site inventory techniques, ecological concepts integration, and accurate biophysical characterizations have made it possible to understand how landscapes are affected by artificial means.

However, traditional stages in land planning procedures and late design proposals present an extended and linear operational sequence (See figure 14).

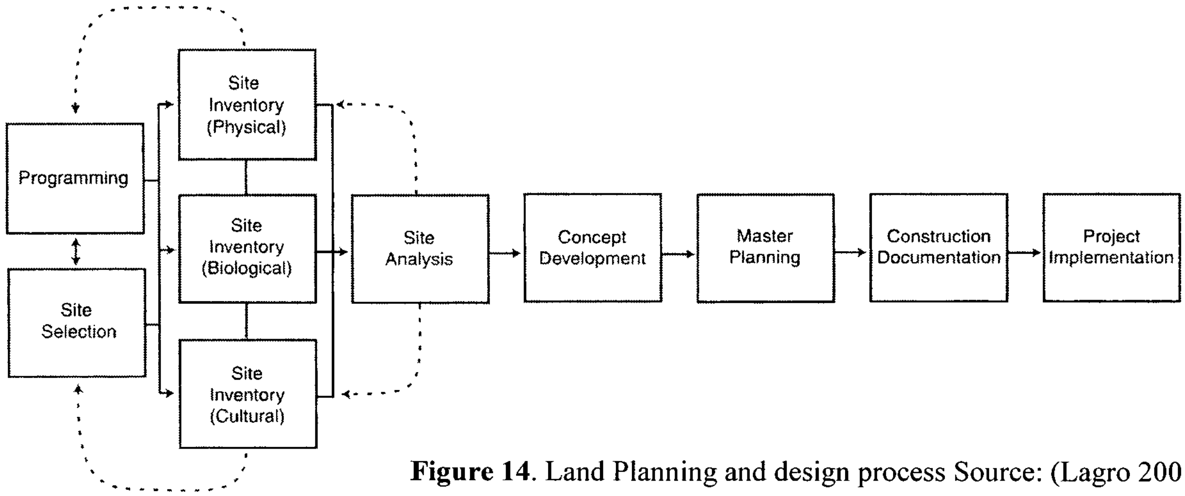


Figure 14. Land Planning and design process Source: (Lagro 2001)

According to Lagro's analysis, phases requiring disciplines less related to scientific fields are displayed in a step-by-step sequence, whereas prior scientific analyses are presented in a more looping integration. Only after key primary decisions on site selection and programming and technical analysis have been made, the planning process moves into the arena of design (Marsh 1998). Thus the involvement of consultants in implementing ecologically oriented decisions in design occurs in the latter stages of the planning process (See figure 15).

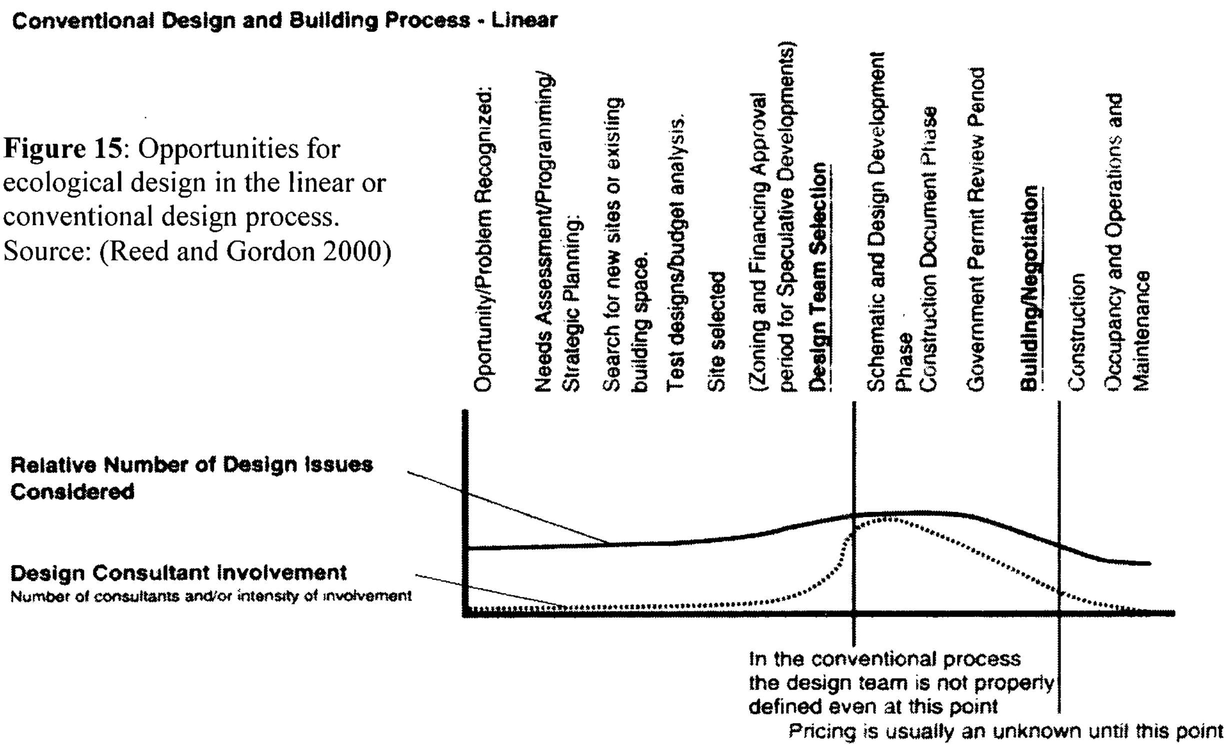


Figure 15: Opportunities for ecological design in the linear or conventional design process. Source: (Reed and Gordon 2000)

As a result of the master planning, the design process and the project implementation rely on a fixed environmental scenario delivered by the first stages of landscape examination, dismissing the opportunity of ecological conflicts resolution through design. Approached in this way, the three major forces driving the planning process (See figure 16), which are supposed to support each other in an integrated and not necessarily linear way, end up relying heavily on the technical sphere of analysis because design has been transferred to the latter stages of the planning process. Paradoxically, having design involvement later in the planning process compromises environmental conservation goals (expected in environmental planning) and diminishes key design considerations regarding the ecological suitability of the planned structures. Consequently, the environmental planning process may be imposing an inherent ecological weakness in both the building and the overall process of disruption.

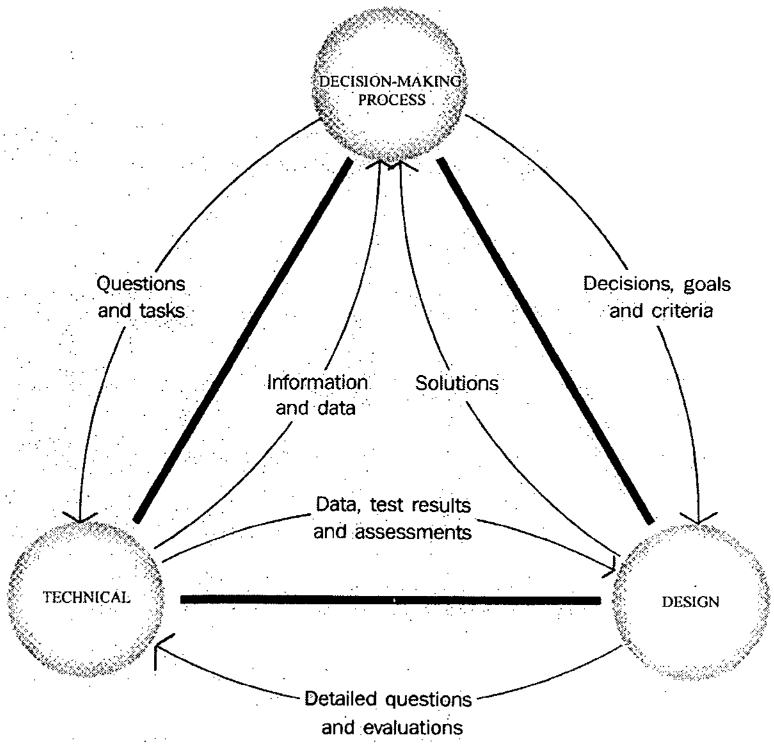


Figure 16. Source: (Marsh 1998)

- **Global vs. Local: The Missing point in Environmental Design**

Regardless of the relative position of design considerations within environmental planning processes, designers do regularly make decisions that involve explicit and implicit trade-offs between alternative uses of environmental resources (Jensen and Bourgeron 2001).

Examples of design practices incorporating environmental concerns in a methodological way can be found as early in the 1900's with William Atkinson's book "*The Orientation of Buildings*" published in 1912. He lectured about the need of recognizing solar orientation and sunlight for hygienic reasons (Atkinson 1912; cited in Watson 1998, p.213). Buildings started to be seen as technological assemblages of parts and pieces (again, the additive approach) delivering structures, systems, and forms. The inclusion of more energy-intensive systems developed a whole new vision for design disciplines, recognizing that energy intensity bears a close relationship to air pollution and environmental degradation. On-site resources and constraints became mandatory requirements for the accomplishment of some degree of energy efficiency. Climate-responsive architecture and urban planning with optimal site-specific use of natural conditions were all answers leading to less energy-intensive materials, more efficient energy uses, and improved comfort (Crowther 1992, p.1-23).

Ninety years after Atkinson's proposals, the amount of available information concerning environmental constraints has caused building design to evolve rapidly from an original approach of using on-site natural resources for the building's energy requirements (also called "ecological design")[15] to a more current approach known as "sustainable design" which no longer sees the building as a merely efficient user of environmental conditions, but rather assumes some responsibility for the environment or context. Sustaining ecological processes became a core objective in contemporary design.

By embracing the ecological process, a new time scale is raised: "all design endeavours in relation to the earth's ecological systems of course refer to the future." (Yeang 1999, p. 33) This thesis relies on reviews of available literature to assume that no emblematic study has been completed, in relation to developing an accurate tool to evaluate the ecological implication of the building. Certainly, this investigation does not pretend to do so, but proposes to open new ways of thinking for engaging architectural design in ecological assessment efforts.

[15] The on-site conditions regarded in ecological design shapes the building interior as "an efficient and healthful interior solar and climatic space planning." Whereas the outer form is acquired from its interface with the radiation of the sun and the daily and seasonal microclimates" (Crowther 1992)

• Ecological Impact Assessments (EcIA) and Architectural Design

"Ecological impact assessments are all about identifying and quantifying the impacts of defined actions on specific ecosystems components or parameters and evaluating their consequences" (Treweek 1999, p.128).

Rather than pure scientific analyses, building sites and location choices usually respond to social and cultural values. Responding to these values is part of the designer's daily practice. This thesis intends to shift those driving values in design from a merely cultural standpoint towards a more holistic understanding of our buildings in nature. To do so, building and ecological information per se is critical, but how we use it, is perhaps more important.

• Current Building Assessment Tools

"A need for a tool in the early design stage, which can use basic information, is very important and is a target of many researchers nowadays" (Sa'deh and Luscuere 2001). Although human-made structures in general, and buildings in particular, have been increasingly incorporated within environmental assessment analyses, general inputs and outputs of the structure – that is, energy and water diversions, and outgoing waste loads– remain the key concerns in building environmental performance (Jameson 1976, p.3-1). However, methodologies for environmental building assessments are still considered a new topic, even though they have gained a considerable attention in the last fifteen years (Radermacher 1994; cited by Sa'deh and Luscuere 2001). Although many assessment tools, like computer-model based, checklist and rating systems, exist today (See figure 17), they vary greatly

Tool	Country	Tool	Country	Notes
Eco-Quantum	The Netherlands	LEED	USA	* is a Product-to-Product Comparisons and
Bees 1.0 *	USA	H.E.N.K**	The Netherlands	not applied to the whole building.
BREEAM	U.K	Athena	Canada	
ENVEST	U.K	BEE 1.0	Finland	** is an energy evaluation tool
EcoPro	Germany	GreenCalc.	The Netherlands	
Eco-Design-Tool	The Netherlands	EQUER	France	*** is a computerized LCA method
Green Building	USA	EcoEffect	Sweden	
CB Tool	Interaction	SimaPro***	The Netherlands	
LCA-based tool	Norway			

Figure 17. Source: (Sa'deh and Luscuere 2001)

depending on the evaluation's reference that may be either the building under evaluation, in which case evaluation uncertainty is introduced by likely modifications to the building throughout time, or other built references offering similar levels of environmental conditions under comparative analysis, in which case usage and building configuration may vary from case to case. As a consequence, most of these tools may have problems in terms of assessment uncertainties due to partial references regarded in the analysis, incomplete design proposals, or simply because of the need for specialists to operate such tools. More problematic, these tools are mostly meant to be use in latter stages of the design process due to highly detailed input data requirements. Thus a critical amount of work has already been inputted into the building's design, and key design decisions undertaken, thereby defining these tools more as mere rating systems rather than as proactive analytical procedures regarding the building and its ecological context.

• The Role of Architects in Environmental Design

The growing complexity of available information has thus shifted the problem of environmental considerations in design, from the local scale of on-site constraints, traditionally associated with vernacular design and later with Ecological Design, to a more global scale according to the current picture of global environmental conflicts.

Building energy inputs and outputs[16] which compromise the global environment are engaging designers in more sustainable design practices (Yeang 1999). However, the growing concentration of buildings in increasingly larger cities has centred the attention on urban environments and their role in the global environmental crisis. Yet, the urban colonization[17] of the natural environment beyond urban boundaries continues to happen. The environmental crisis is both local and global, and the sensitivity to on-site conditions and local ecosystems has been overridden by the overwhelming environmental modification imposed by highly homogenized urban environments. As a consequence of this, the

[16] Building inputs and outputs:

- 40% of raw materials are used in building construction, globally each year
- 36-45% of a nation's energy is used in buildings
- 20% of landfills' trash is construction waste
- 100% of energy used in buildings is lost to the environment

[17] Through suburbanisation and counterurbanisation processes.

architect may have lost the ability to perceive and assess ecosystem processes that, although sometimes barely visible, continue to exist.

From a scientific perspective, it is clear that designers in general and architects in particular need to learn a lot more about the function local ecosystems play in the larger environmental scenario. Their role as participating designers in the environmental planning is especially decisive when it comes to intervening in natural systems consisting of low carrying capacities and fragile ecological structures. Designer's knowledge concerning possible outcomes of a building's intrusion within sensitive ecological structures may be valuable to indicate how, if the development goes ahead, the likely environmental modification may be anticipated and hopefully mitigated.

The U.S. Environmental Protection Agency (EPA) released a document defining integrated environmental assessments, and provided a broader classification of building environmental constraints. This document differentiates "between impacts on our resources (*what is removed*), impacts on the surrounding environment (*what is added*) and on people (during construction and later operation)" (EPA *Integrated assessment* 1998). In fact, building activities may add, remove, or redistribute physical, chemical or biotic components or energy resulting, directly or indirectly, in a net loss or gain of valued ecosystem components or functions (Treweek 1999, p.135). Are designers aware of such dynamics? If the answer is yes, is this the proper base for designers' criteria? Actually, the 'removed-added' approach may be helpful if the context is fixed. However, we have already witnessed that it is not. Instead, designers should analyze the intrinsic dynamics of the landscape, and coherently incorporate them into actual building forms evidencing the changing nature of evolutionary processes. If those processes are embraced as built-in features, then the building becomes exclusive to that location and specific to that landscape dynamic.

Likewise, a holistic approach to design should not only depict the odds of ecological deterioration, but also inform the design process about more suitable structures. That is the case of regenerative technologies, as explained by John Lyle (1994), where the form and operation of the building should be intrinsically linked to the context, demanding specific attributes of form, function, and location. This is the link that needs to be discovered by designers. In other words, environmental design should integrate with rather than add the building to natural processes, in order to maintain the consistency of both systems. This means coherently enhancing structural and functional features of the building, so they can properly serve human needs that motivated its conception, while guaranteeing adequate levels of ecological integrity, which ultimately supports the processes vital for both the building and the landscape. Such building design strategies should be promptly analyzed and integrated with the designers' analysis of the broader processes of environmental planning. Thus proactive analysis and integration are central to this thesis.

1.4 TOWARD INTEGRATED ENVIRONMENTAL PLANNING PROCESSES (IEPP)

As a planning activity, Environmental Planning Processes (EPP) are specifically concerned with the use and abuse of landscape resources. Its environmental focus pursues the matching of environmental preservation goals with the use of resources by human development goals. As explained by Marsh (1998, p.3) the term is "a title applied to planning and management activities in which environmental rather than social, cultural, or political factors, for example, are the central consideration."[18]

This thesis aims to improve current Environmental Planning Processes with a method of ecological assessment that considers potential interactions between natural and artificial systems as integrating components of a single dynamic function of environmental change. Integrating natural and artificial system processes, requires cross-disciplinary efforts, and may result in simpler approaches to more complex planning activities which are key to sustainable planning and design (Reed and Gordon 2000). Instruments such as Environmental Impact Assessments may be used as proactive tools, forecasting likely environmental constraints at the level of project conceptualisation, rather than delivering highly detailed projects susceptible to countless amendments established by the environmental agency responsible of further authorizations to the project.

[18] Arguably, human interventions in the landscape are inevitably a result of all of these factors, as every human intervention in the landscape somehow responds to a fundamental notion of nature embedded in the culture (Lyle 1994).

An Environmental Impact Assessment (EIA) is now accepted as the proper tool to identify unavoidable adverse impacts of proposed actions, any irreversible and irretrievable commitments of resources as a result of the proposed action, and the relationship between short-term uses of the environment and long-term productivity (Marsh 1998). Beanlands and Duinker defined it (1983) as the process or set of activities designed to contributed pertinent environmental information to project or programme decision-making. In doing so, it attempts to predict or measure the environmental effects of specific human activities or do both, and to investigate and propose a means of ameliorating those effects. As a core component in current planning practices, EIAs have become prevalent mainly because they address the relationship between biophysical, social, and economic factors explicitly (Treweek 1999, p.5). As a consequence of the increasing activity and complexity of environmental planning, environmental factors are now presented as legitimate considerations in urban and regional planning, being clearly promoted in the USA by the National Environmental Policy Act of 1969 [NEPA] (Marsh 1998, p.14). Trends between ecological and built features are addressed by advocating optional design strategies in the type of artificial systems and their connecting structures. There are no straightforward answers to complex environmental constraints, just as there is not a single type of ecosystem. As a proposed statement of integrated environmental planning, the process from complexity to simplicity becomes the goal, and synthetic integration the tool.

Irreconcilable systems?

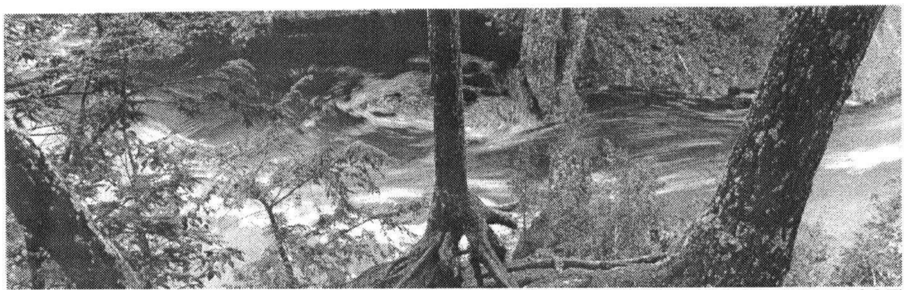


Figure 18: Source: (Nassauer 1997)

CHAPTER2
Hypothesis

"In many ways, the environmental crisis is a design crisis"

(Ryn and Cowan 1996)

2.1 DESIGN AND SCIENCE: A POSSIBLE AND NECESSARY DIALOGUE

Training and education are traditionally different in design and scientific disciplines. Analysis frameworks and outcomes from both disciplines differ substantially even when they are applied to the same subject – in this case the natural environment. Johnson, Silbernagel et al. (2001) stated, "...designers intend specific solutions for individual places; scientists seek general principles across multiple cases."

In architecture the design process of a building embraces different and often conflicting goals regarding the object itself as a physical fact, the object's performance as a functional fact, and the context where it is situated as a fact of location constraints. On the other hand, environmental scientists perform several tests using scientific methods to develop analysis models as accurately as possible, which are geared towards an understanding of the natural processes within already existing places. Such apparent differences have transformed these disciplines into narrowly defined roles within the disrupting process with well-defined boundaries of expertise, methodologies, and results especially when it comes to human development in more natural environments. However this has little to do with how nature works.

An integrative approach, on the other hand, requires a sound coordination in understanding, planning, designing, and managing such interventions in nature. Moreover, it requires the ability to identify the actual connection, rather than the boundaries among disciplines, and "...to organize the disparate fragments of information from different disciplines into coherent wholes...it is inherently interdisciplinary" (Lyle 1994, p.28).

As suggested by Viljoen and Tardiveau (1998), there is much in common between current environmental science and design theories.

Finding Common Grounds Between both Disciplines

In spite of the increasing complexity of environmental problems, both design and scientific disciplines have developed in relative isolation and with some level of antagonism, whereas synchronization between them should indeed strengthen them, either when working separately, or when coordinated. Evolution in both fields of expertise has started to show a growing common ground not only in their subjects but also in the way these disciplines act upon current environmental challenges. "Disciplines like ecology, including landscape and regional ecology, although based on science, obtain some ecological understandings from studies in social science and the humanities" (Forman 1999, p. 15).

Science builds new hypothesis based on tested theories, whereas design builds new physical arrangements based on design precedents (Johnson et al. 2001). Moreover, recent evolutions in scientific thinking are opening opportunities for design disciplines to be engaged in integrative analysis regarding environmental subjects where intuitive and rational processes in design may help to expand the understanding of complex landscape dynamics, particularly now that ecologists have started to recognize humans as a keystone species in most, if not all, ecosystems (Johnson and Hill 2001).

Traditionally, ecologists focus on specific species and sophisticated ecosystem interactions. As a mixed discipline landscape architecture focuses on how human beings perceive and interact with the landscape as a whole. Building design deals mainly with the particular features and configuration of the building, whether situated in urban, rural or natural environments. This basic sorting of disciplines locates building design somewhat close to the complexities of science.

A broader approach in design may improve designers' understanding of landscape functioning (certainly invisible to untrained eyes), either concerning how it may affect human activities and development, or more importantly, how human activities may affect landscape functioning, which ultimately supports human development. Some similarities between the two disciplines can be inferred by reviewing Jameson's notes (1976). He explains the maintenance of life on earth depends on the *flow of energy* and the *cycling of materials.* Ecosystem stability, biological diversity, and complex interrelationships within the natural system are all concepts that depend on and are controlled by these two factors. This intricate functioning is similar to how we conceive buildings or other human-made structures. Along the same lines of thought buildings may be assumed to be open and dynamic systems, as well.

• Opportunities for Design in the midst of New Ecological Paradigms

Ecology is considered to be in the midst of a new paradigm (Pickett, Parker, and Fiedler 1992), which brings the opportunity of merging and articulating design and scientific disciplines. The recent shift in ecological thinking is mainly based on two changes in primary approaches, as explained by Pulliam and Johnson (2001) below:

Equilibrium approach		***Disequilibrium approach***
Populations and ecosystems in balance with local resources and conditions	→	History matters! Populations and ecosystems continuously influenced by disturbances
Closed systems		***Open systems***
Populations and ecosystems relatively closed and independent of their surrounding	→	Populations and ecosystems strongly influenced by the "flux" of materials and individuals across system borders

In other words ecosystems are neither static nor closed systems that can be conceptually isolated and explained within the context of a single space and time. Rather they are beginning to be understood as highly interconnected at different scales of space and time and thus strongly influenced by disturbing events occurring within and beyond the ecosystem's physical extension.

Based on these new paradigms, this thesis aims to establish new understandings in the role buildings play in the landscape and how design may address such interconnections. As open systems, buildings can actively interact with the ecological functioning of the surrounding environment, becoming susceptible to complex events originating in the natural context (as stated by ecological design thinking).

That said, modifications in the landscape might depend on both the final configuration and performance of the building, and previous ecological functions of the landscape itself. The final interaction then, should reflect changes both in the landscape and the building. This acknowledged connection and mutual influence reinforces the idea of an integrated analysis fostering good design and healthy ecosystems. Such common ground should encourage pursuing the benefits of a close collaboration between science and design, embracing the potential of combining expertise geared towards a proper decision-making framework that respects building and ecological needs (Johnson et al. 2001).

Integration of design and ecological awareness requires designers to change their temporal and spatial dimensions of observation (White and Pickett 1985), including the concept of place conceived as a set of particular functions in constant change and therefore, unique.

- **Landscape Flux and Uniqueness of Place**

It is well known that in architecture every place is unique. So are the clients, designers, and the physical and performance requirements. Properly addressed, these singular properties should result in singular designs. This idea is not far from how a landscape and its changing events are understood. Open *nonequilibrial* ecological systems emphasize the unique combination of landscape attributes constantly interacting with inner components and exogenous forces (Johnson et al. 2001, p.313).

This thesis aims at an evaluation method that embraces the complex issues of environmental change in time and space highlighting the individuality of a place yet simple enough to be applied in any type of building-landscape combination. Thus design becomes as a flexible process when facing changing environmental conditions, where key-building issues are interrelated with critical ecosystem characteristics. To do so an integrated analysis should be able to determine whether the landscape is capable of coping with the physical and functional outcomes of this new "built event." The conclusions of such analysis would allow human interventions in nature to fit their socio-economic goals without compromising the ecosystem's qualities that motivated such initiatives in the first place. In short, the not-to-build strategy usually advocated in conservational rallies may no longer be considered the only answer facing environmental degradation concerns.

The ultimate goal would be to deliver an evaluation framework that would ultimately address how "ecological processes form landscapes, and design affects their ecological functions" (Nassauer 2001, p. 217). This thesis proposes an integrated analysis framework upon the likely reciprocal feedback between building design and specific disciplines concerning the critical relationship between built and natural environments.

- **Landscape Ecology and Building Design**

Gaining accurate understanding of a building's role in natural environments requires selecting the appropriate body of knowledge that thoroughly explains the possible implications of any human action in nature and its possible outcomes. From the scientific field, the discipline of Landscape Ecology is the integrative science that focuses on the way ecological systems are arrayed in space and time.

As specified by Forman and Godron (1986, p. 7), "Much of the broad field of Ecology, …has focused on the 'vertical', that is, the relationships between plants, animals, air, water, and soil within a relatively homogeneous spatial unit (See figure 19). By contrast, what makes landscape ecology unique is its focus on the 'horizontal', that is, the

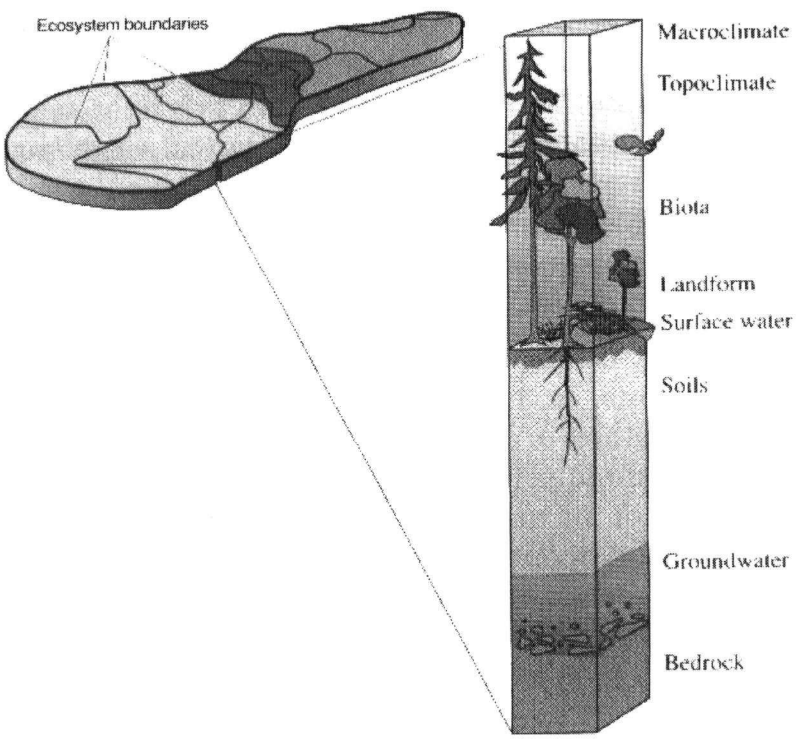


Figure 19. Source: (Bailey 1996)

relationship among spatial units" (See figure 20).

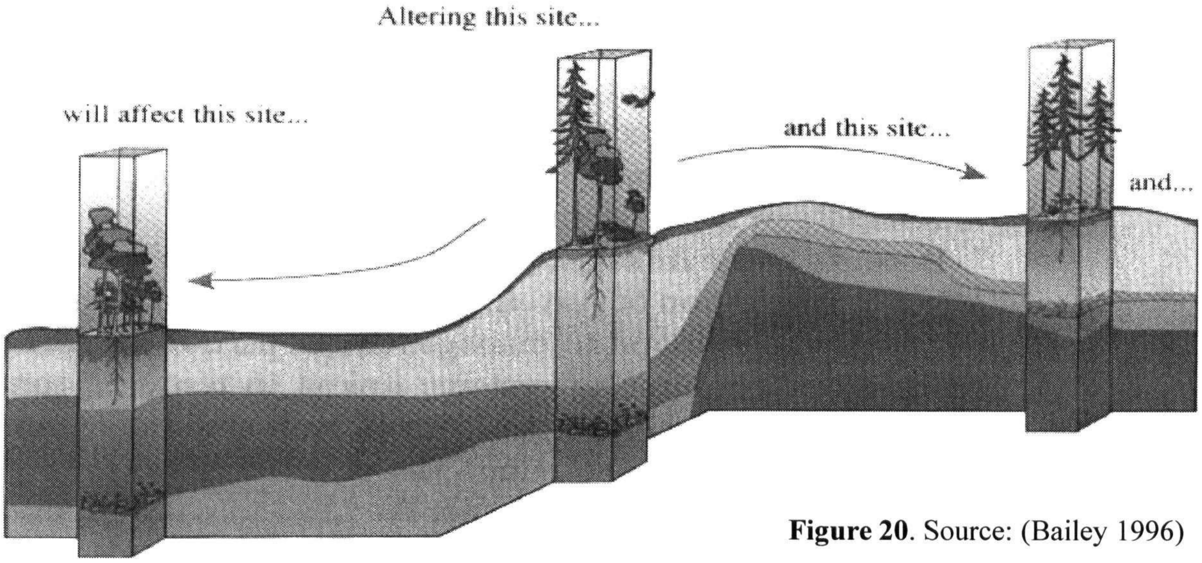


Figure 20. Source: (Bailey 1996)

The horizontal concept highlights the importance of spatial distribution in landscape structure and how this landscape's configuration is determined by the flow of ecological inputs/outputs through ecosystem boundaries.

Although Landscape Ecology has risen as a motivating force both in the domain of theoretical ecology and in applied fields such as biodiversity conservation planning (Sanderson and Harris 2000), it is often described as an interdisciplinary, problem-solving science "bridging the gaps between bio-ecology and human ecology (Naveh 1995, p. 43, cited in Jensen and Bourgeron 2001). Subsequently some extrapolations of key concepts from Landscape Ecology[19] into building design strategies will be herein pursued and assumed to be at the core of the hypothesis.

In the field of design and especially in architecture, the notion of "vertical" environmental properties defined by ecology have traditionally shaped environmental concerns in building design: the energy crisis boosted earlier environmental awareness in design and drew attention to the sun as one of the key ecological features in environmentally friendly practices. The sun's energy became "…the most direct ecological energy that we can employ as an architectural system" (Crowther 1992, p.40).

[19] See **APPENDIX I: Key Concepts in Landscape Ecology**

The action of the sun (or the lack of it) continues to be a driving force in shaping and configuring the building envelope as the principal heating, cooling, and day lighting system of the building (Crowther 1992) (See figure 21). Following this practice the sun continues to represent one of the most reliable sources of renewable energy and therefore cutting-edge technological improvements in solar power are being included among the most environmentally sound strategies in sustainable design (See figure 22). Contemporary designers are now well aware – despite the fact that environmentally-friendly practices may not be widely addressed in all designs – that any ecologically mature project needs to incorporate an ecological analysis of the rules and functioning of the site's ecosystem (Yeang 1999, p.96).

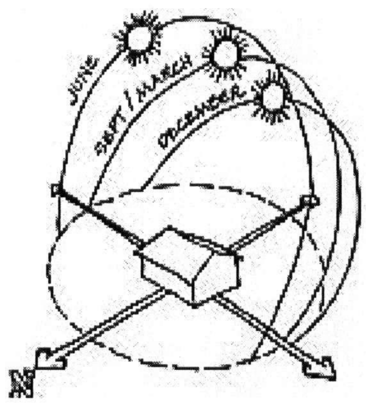


Figure 21. Source: (Center 2002)

The lack of horizontal notions in vertical analyses imposes the risk of conceiving a static ecosystem's characterizations and fixed ecological scenarios. Recognizing horizontal connectivity and ecological flow across different landscape units is of special meaning when it comes to identifying interactions between a single built structure and its unexpected connections to immediate and farther ecosystems.

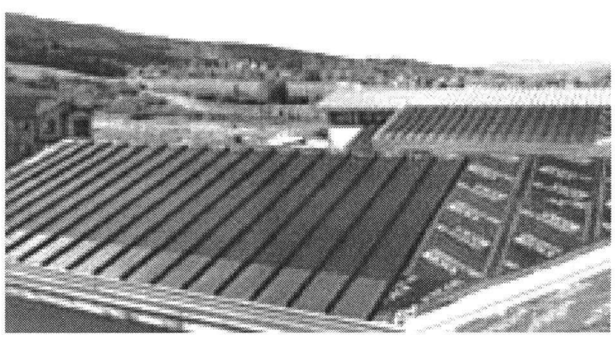


Figure 22: Building-integrated photovoltaic roofing helps power this home improvement. Center. Silverthorne, Colorado (Photo courtesy of Burdick Technology Unlimited) (ColoradoEnergy.org 2000)

By focusing on the landscape's ecological exchanges taking place across landscape boundaries, at the natural gap,[20] the spatially explicit nature of the phenomena may be emphasized. (Sanderson and Harris 2000) How buildings may specifically induce changes in the landscape structure is yet to be

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[20] See: **The Isolated Intrusion: Stresses over the Natural Gap**, p.20

determined. However the physical nature of buildings and their connecting infrastructures assume some sort of responsibility for these changes. Modifications to spatial and temporal distributions of energy and matter fluxes, and type and size of habitats at the ecological unit scale (Bo-jie and Li-ding 1999), are among the possible changes.

2.2 PROPOSED SYNTHESIS FOR INTEGRATED ANALYSIS

An increasing number of intersecting issues between design and ecology suggest a fresh look at design when it comes to integrating some of the factors that may be affecting the landscape and the building. Understanding the properties and conceptual domains supporting the complexities of interaction within and between natural and artificial systems synthesis is required.

Buildings may be characterized in terms of their *energy performance*, *morphology*, and *use,* and general properties such as *comfort*, *heating efficiency*, and *space distribution*. Similarly it is common to find in ecology concepts such as *ecosystem*, *community*, and *population* and properties such as *diversity*, *stability* or *persistence*. Some of these concepts and properties cannot be measured directly, and require a constructed theory to define them (Ford 2000, p. 8). Among the different approaches proposed in ecological research, *upward inference*[21] is established as a method of inferring and using these concepts to construct scientific explanations.

Classification, Synthesis, and Scientific Inference: Lessons from Ecological Research

Currently ecology and other applied sciences continue to observe the same natural phenomena that inspired earlier naturalists. Yet, their concept of *classification* has evolved as new properties for the natural system are constantly being discovered (Ford 2000).

Recently incorporated knowledge from new findings in science is continuously adding complexity to our understanding of the natural systems.[22] As a consequence, proper classifications become strategic tools for synthesising and making scientific inferences for the purpose of achieving

[21] **Upward inference** refers to a process of making inferences about general properties. The process of developing an inference for an over-arching theory from a set of specific investigations and where the theory contains concepts that do not have a direct equivalent concept by measurement (Ford 2000, p.280).
[22] Actually, nature has not changed in complexity. It is our understanding of nature that rather moves toward a more accurate understanding of nature's complexity (Note of the author)

scientific understanding. Defining a hierarchical classification will enable the thesis to focus on those key concepts, allowing further inference regarding ecosystems' properties as the sink of external interventions, and the building as the intervening factor.

• From Natural, through Functional, to Integrative Concepts

Applying the same criteria, one may ask: how can a building's energy performance be measured and assessed as a significant factor in the process of environmental change? Defining an assessment methodology that would provide answers to such inferences lies at the core of this thesis. Such methodology should allow non-linear approaches and enable building ecological assessments prior to the actual building's design stage. Hence further conclusions regarding key ecological and building interactions can deliver ecological consistency for design. Upward inference for artificial systems analysis is proposed.

Energy performance is not measurable in itself as it is comprised of factors and properties (See figure 23) such as energy consumption per square meter, building configuration, number of occupants, and even particular activities within it (Baker and Steemers 2000, p.4).

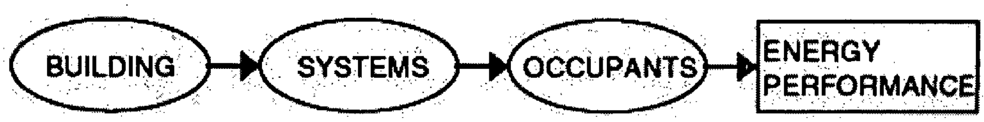
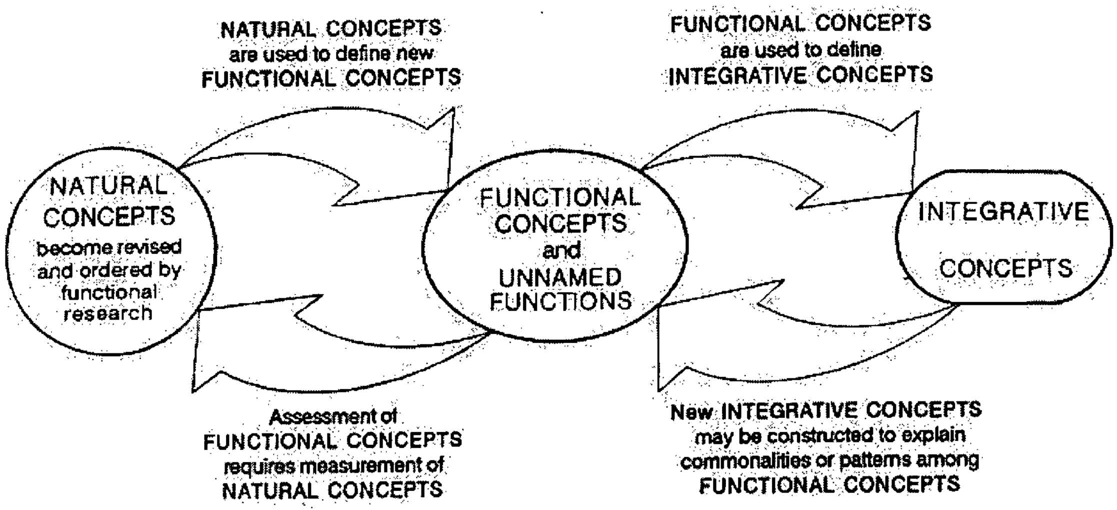


Figure 23. Source: (Baker and Steemers 2000)

For this example, desired answers would be determining a specific landscape resistance against a building's system properties, and/or how likely landscape constraints effectively affect such particular artificial systems. Is it possible to link a building's energy performance with landscape resistance? If energy performance is not measurable by itself, then quantifiable components "feeding" such a function become the basic concepts for an upward inference that would eventually form the basis for a theory that may later explain the concerned property. These basic measurable factors in ecological research are referred to as *natural concepts*. In the field of ecology, a *Natural Concept* defines and classifies measurable or observable entities or events, such as frequently common objects (i.e., organisms) or features of the environment (i.e., rainfall). Thus a natural concept allows measuring the function, process, or structure, which, in turn, become the *Functional Concepts* of the landscape system. In other words functional concepts describe structures or interactions of natural concepts.

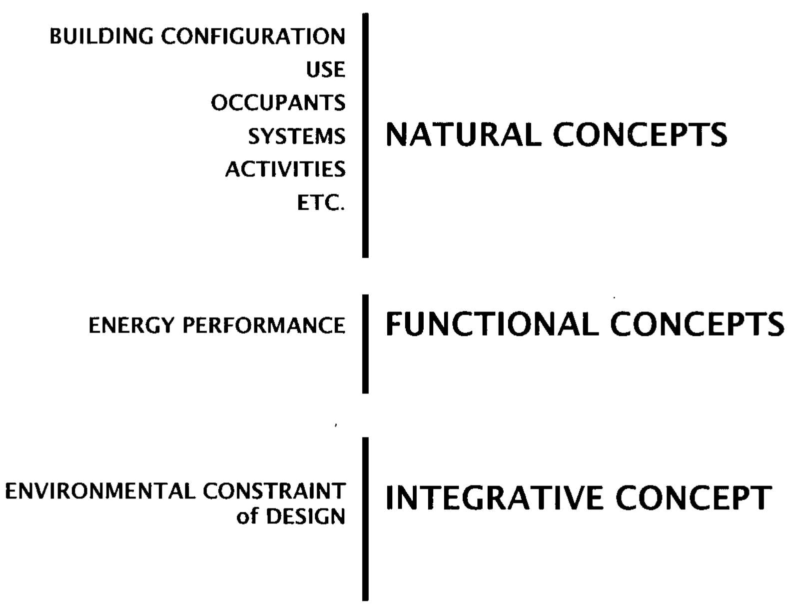
A determined arrangement or assembly of functional concepts shape the organization or functioning of an ecological system. These organizations referred as *Integrative Concepts* are "…theoretical constructions about the organization or properties of ecological systems." (Ford 2000, p.279-83) (See figure 24)

Figure 24. Source: (Ford 2000)



Taking into account the energy performance example, the building's configuration plus other *natural concepts*, defines the *functional concept* of energy performance (See figure 25).

Figure 25



As functional concepts from both systems continue to be simultaneously "inferred", the *integrative concept* of environmental change regarding these participating functions may be established.

Acknowledging physical and time limitations, it is not the goal of this thesis to measure the countless natural and functional factors from design and ecology, which eventually play a part in the processes of environmental change. These concepts are considered as given information by participating experts within an evaluation procedure. Rather the assessment method focuses on developing a framework that integrates key functional concepts previously identified, allowing inference of integrative concepts.

As a result, inferred integrative concepts may define the capacity of a building's configuration and performance to compromise certain ecological functions of the landscape, and likewise, the capacity of ecological properties to constrain building's functions. By conceiving the interaction of both artificial and natural systems to be participating actors in the same function of change, previously autonomous natural regimes of change become altered by artificial factors and thus a new type of change dynamic takes place in the landscape.

- **From Natural Disturbance Regimes To Artificial Disturbance Regimes**

Landscape dynamics, including its configuration and change patterns, are the ultimate result of combining diverse natural processes with human interventions within a landscape mosaic (Zonneveld and Forman 1990). Accordingly environmental interactions may range from effects on the local site ecology to encompass much broader effects.

This complex scale scenario relies on a common misunderstanding of the actual extension of a building's environmental participation: "due to the physical footprint, buildings in natural environments are usually linked to the fundamental unit of a landscape the site, which in turn, represents a challenge when it comes to measuring ecological exchanges within it" (Zonneveld and Forman 1990, p.61). Although buildings are usually morphologically related to the configuration of the site[23], the possible modifications they cause beyond the site scale are only noticeable once the interaction between site and

[23] **Site** as a landscape element, is described by Zonneveld and Forman (1990) as the unit composed of a biotic community growing in association with a specific type of soil.

building begins affecting the organization of larger sites–or *site clusters*[24] – and, ultimately the landscape's organization. In other words, the building reacts and intervenes at a site level, but the exchange processes become measurable once the structure of a site cluster changes, affecting higher levels of organization within the landscape.

The disturbance[25] theory represents a powerful model to understand all management of human activities (Pulliam and Johnson 2001, p.61) and their consequences as a changing force acting upon and beyond a determined site. A conceptual extrapolation of the natural disturbance phenomena can result in a notion of artificial disturbances. Doing so becomes a key strategy in bridging the gaps between design and ecology, particularly in terms of language and intercommunication.

Following with a synthesis strategy, human-made structures may be considered not as an alien intrusion, but as an event in nature, and therefore analyzed along with other factors traditionally related to the study of natural disturbances. The persistence of human-made structure intrusions and the rising scarcity of absolute pristine natural environments create a type of disturbance regime increasingly common in natural environments and hardly distinguishable from absolute natural disturbance events[26].

2.3 SYNTHESIS AND CONCEPTUAL INTEGRATION FOR AN EVALUATION METHOD OF ENVIRONMENTAL CHANGE

Disturbance events in nature are being increasingly (and sometimes imperceptibly) determined by human-made environments, direct or indirectly. This thesis aims to address this reciprocal connection between human-made environments and the ecological functional contexts of surrounding natural environments. The method explicitly bridges the gap between science and design, articulating a common language or "shared vocabulary" to be used by the different disciplines eventually involved in the problem solving process. Such shared vocabulary would back up the analysis referring to specific disturbing properties of a building (ecological functional concepts in design) interacting with key dynamic factors of landscape change (landscape functional concepts of change).

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[24] **Site clusters** are defined by Zonneveld and Forman (1990) as the organization of sites within an ecological hierarchy. They describe a series of sites connected by a significant exchange of matter.

[25] Forman and Godron (1986, p.9-10) define **disturbance** as: "an event that causes a significant change from the normal pattern in an ecological system such as an ecosystem or landscape".

[26] Herein presumed as not being affected by any explicit human action. (Note of the author)

Natural concepts supporting these functional concepts (See: From Natural, through Functional, to Integrative Concepts, p.40) will be assumed as already available information, analyzed and supplied by experts from design and scientific disciplines. The articulation of the functional concept will be the base and focus of the evaluation tool on environmental change. This tool's ultimate goal will be assessing the intimate relationship between different buildings and landscape configurations that have not been previously disturbed by buildings.

Since a common ground of conversation and understanding is proposed, the conclusions of such theoretical concept articulation may also encourage designers in general and architects in particular to participate within multidisciplinary decision-making teams pursuing environmental plans, by sharing the language, methodologies, and assessing approaches with scientific disciplines.

Towards a Conceptual Integration of Natural and Artificial Systems

To date the infinite biological complexity of nature with its constant changes makes it difficult to measure and evaluate environmental quality purely based on biological data (Greco and Petriccione 1991). Assessing qualitative responses from the landscape when facing intrusions of human-made structures, and translating them into a comprehensive conceptualization of the phenomenon may present even more complications.

This section intends to describe a method of conceptualizing notions of environmental change, where ecological and building design matters are articulated, so they can deliver synthesized information on environmental variations linked to landscape and building properties. If achieved, further inferences can be made allowing environmental change forecasting. The ultimate goal would be to reduce traditional uncertainties as a result of the interaction between these two complex and usually contrasting systems.

- **Background for Correlations Between Ecosystem Health, Ecological Integrity, and Sustainable Environments**

The idea of a sustainable natural environment engages human responsibility in maintaining an ecosystem's key attributes. As such, these attributes may be susceptible to variability in short and/or long-term fluctuations, which if dismissed, may irreversibly affect the proper functioning of the entire system. Oscillations in the landscape imply changes, which may be a consequence of either internal or external forces (or both, as suggested by this thesis for the reciprocal effects of natural and artificial systems interacting in a same place).

Adaptability[27] and *stability*[28], *both changes in the norm of ecosystem functioning,* become key attributes of a sustainable environment (Forman 1999, p.502). This means that the health of an ecosystem depends on its capacity to remain stable or to adapt itself when facing changing forces.

The metaphor[29] of ecosystem health, borrowed from Rapport, Constanza et al. (1998), implies the idea that ecosystems, like the human body, can and do become dysfunctional due to forces causing changes in the organism. Defined as such, this implies that the health of an ecosystem is dependant not only on its internal functions, structures and biophysical features, but also on interactions with foreign forces intervening in the landscape. The capacity to remain stable or to adapt without losing "health" is here understood as *ecological integrity,* which can be considered as the "most important or sensitive attribute of an ecological system" (Forman 1999, p.499).

Ecological integrity is established as the conservation of ecosystem organization as a primary resource of ecosystem health, and, consequently of a sustainable environment[30].

When ecological integrity is diminished, impact sensitivities of an ecological system increase, imposing risks to the overall ecosystem health, and consequently, to human health as well. Defined as such, it may be possible to depict likely sources of environmental change by focusing the analysis on the landscape functions or dysfunctions (Rapport et al. 1998, p.20) defining such organization.

Defining Integrative Concepts in Ecological Integrity

The method of *upward inference* mentioned before, starts by focusing on the overarching attributes of ecosystem health, and their conceptual integration as by-products of ecological integrity.

[27] **Adaptability** is as the pliable capacity permitting a system to become modified in response to a disturbance. (Forman 1999)

[28] **Stability** is understood beyond the landscape unit or ecosystem. In fact, is effectively a mosaic stability, where interactions among neighbouring elements dampen fluctuation from disturbance (Forman 1999)

[29] As any other metaphor, it also highlights the importance of human judgement, when it comes to defining health properties. Thus, one may adventure the overall tendency of this judgment is heavily constrained by a social value of nature (Note of the author).

[30] This statement intends to define a final correlation between the concepts of sustainability, ecosystem health, and ecological integrity, as challenged by Rapport, Constanza et al. (1999, p.45).

In fact, these overarching attributes are considered by this thesis as the *integrative concepts* of a landscape system, therefore pursued as the ultimate notion in these ecosystems' analyses with various inferences on matters of health and sustainability for both the landscape and the structure intervening in it.

As mentioned before[31], *integrative concepts* form the organization of properties in an ecological system, and cannot be directly measured. They are proposed, instead, to be the articulating equation between landscape dynamics and exogenous modifying forces, in this case the human-constructed environments, and as such they become the attributes to address in environmental planning, if further assumptions regarding ecosystem health and sustainable environments are to be accomplished.

According to Mageau's definitions (1995), the original overarching attributes in ecosystem health are *Vigour*, *Organization*, and *Resilience*. In order to determine the integrity of an ecosystem, a primary notion of *stability* is required, introducing the system's capacity to respond to different changes in time, and therefore addressing the time scale as necessary for analyses in landscape modification processes. Responses to disturbance may differ substantially from one system to another. One landscape may change "drastically but return rapidly to its initial state (resistance capacity), whereas others may change only slightly but recover very slowly to its initial state (resilience capacity)" (Forman and Godron 1986, p.434). Moreover, the concept of resilience only considers a capacity of "recovery" in time, whereas certain ecosystems may be perfectly capable of "resisting" a given change. Thus, both concepts of resistance and resilience should be regarded as separate components yet clearly susceptible to interactions.

Consequently, this thesis introduces the notion of *resistance* as a complement to *vigour* and *resilience*. Assuming that ecosystem organization is a result of three attributes complements Mageau's definitions of overarching attributes in Ecosystem Health. Thus, the three main overarching attributes of ecosystem health would be established as follows:

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[31] See: **CHAPTER II, From Natural, through Functional, to Integrative Concepts**, p.40

• **Productivity Vigour** depicts "the primary productivity, or throughput of material or energy in the system". It refers to the energy or level of activity at a certain unique equilibrium of a given ecosystem, in order to function properly. This sustains the idea of uniqueness and vulnerability of a place to exogenous inputs if a particular nutrient flow necessary to maintain life within the context of particular conditions in place is interrupted or modified. Nonetheless, a vigorous ecosystem does not necessarily imply a healthier system. For instance, particular aquatic ecosystems may present major problems because of high levels of throughput originating from increased input of nutrients due to land disturbance and run-off (Rapport Defining ecosystem health 1998). Such a situation would indicate that, although vigorous, it is a highly sensitive ecosystem.

• **Resistance to changes** is the capacity of a landscape, when exposed to an environmental modification or perturbation, to withstand or resist variations on the structure (Forman and Godron 1986, p.434). With no further variations in the ecosystem's organization, the concept of resistance deals with short-term scale perturbations and therefore advocates accurate projection of possible changes before any major modification occurs without further chances to recover itself to previous natural states.

• **Resilience after changes** is a measure of the ability of a system to cope and accumulate effects caused by exogenous impacts and still to persist such as it is (Hollings 1986). The notion of system persistence implies that no qualitative changes or major landscape modifications take place in the system after long periods of stress. The system's capacity to "bounce back" or to return to its original state after perturbations (Rapport Defining ecosystem health 1998, p.28), is indeed a double edged sword; although it defines the capacity of an ecosystem to face long term or cumulative effects, it also suggests that only two stages of resilience exist: persistence or extinction (Mehandjiev 1991). With no intermediate options, long-term management forecasts that anticipate stress-related impacts become critical in order to assure that resilience properties will not be overcome provoking further irreversible changes. It is also important to understand that major changes will not be noticeable in the short-term, but once they have occurred, little chance of recovery remains. Following the strategy of upward inference, *stress* becomes the functional concept articulating long-term scale of building impacts with landscape resilience capacities, which are discussed further on.

As mentioned previously, upward inference, which seeks understanding of overarching attributes for ecological integrity, requires the specification of key ecological attributes: vigour, resistance, and resilience. In order to predict such key attributes, like resistance, the modification forces (to be resisted) should be specified, as well as the resisting capacities of the system. A landscape is resistant when it is capable of resisting what? What specific landscape components allow the inference of resistance capacities?

Likewise, questions can be conversely applied in building design: when can we define a human-made structure effect as a disturbance? Furthermore, disturbing what? The type and number of capacities can be altered, increased, or diminished and this depends on specific embodied characteristics in the landscape facing a change, and the modifying force exerting the change. This interactive dynamic introduces the next step in this upward inference: the notion of *functional concepts* for both, the natural and artificial system.

Narrowing Functional Concepts for the Landscape System

- **Fragmentation of the Landscape Structure**

Taking into account the explicit relationship between the flow and exchange of ecological matters, and the necessary physical network of biomass to drive them, introduction of spatial gaps or *fragmentation* of the matrix may have an effect on these flows and ultimately on the ecological integrity. Alterations of the physical landscape structure are usually "the major and most easily perceived channels through which human actions affect wildlife community" (Crist, Kohley, and Oakleaf 2000). As a function of spatial configuration within the matrix, fragmentation becomes a critical indicator with which to infer modifications of ecological integrity.

Referred to as *habitat loss* and *isolation* by ecologists, conservationists, and land managers (Vuilleumier and Prelaz-Droux 2002), fragmentation has been the main characteristic of landscape dynamics on earth since the Miocene period. The concept of fragmentation is related to the idea of *habitat quantity* as a factor of species survival, and suggests the concept of an area-dependent extinction rate, which can be inferred by defining the actual size and connectivity of *landscape elements*[32] (Harms and Opdam 1990).

In the context of evolution, species such as human beings have become well adapted to fragmented landscapes (Potts 1997). It is possible to infer, considering evolutionary patterns, that human beings "are apparently compelled to fragment" (Sanderson and Harris 2000, p.28).

Fragmentation may arise in a new landscape that differs substantially in a number of ways from the old landscape. Shape, size, proximity, and contrast of each new habitat patch (an area composed of the same habitat type) are all factors that eventually determine how the fragmentation affects ecological integrity.

Some of the critical changes the new landscape may present due to fragmentation are (Fisheries and Wildlife 1999):

► Reduced quantity of the original habitat (i.e., habitat loss): there is simply less habitat and this loss continues until the last of the original habitat is removed, destroyed, or converted.

► Increased "edge" habitat: Each patch of "new" habitat that moves in creates a new edge between the new and the former habitat.

► Accelerating ecological processes: for example, moisture gradients change from edge (usually drier) to interior (more moist) patches. Rates of predation, brood parasitism, and competition may be greater within and along the edge of habitat fragments.

Although human beings are not the only species in the natural world that have adapted themselves to fragmented situations, the increasing rate of landscape fragmentation world-wide due to human activities has accelerated the loss of critical biomass, eclipsing the ability of other species to evolve accordingly (Sanderson and Harris 2000), thus, facilitating species extinction rate. Human-induced fragmentation can be considered among the most severe. Any land pattern transformation due

[32] See **APPENDIX I**: Key Concepts in Landscape Ecology

to increasing fragmentation may severely compromise the integrity of ecological systems through loss of native biomass (Collinge 1996).

In integrative terms, fragmentation becomes a critical functional concept in landscape as a result of the interaction of the structure or intensity of one modifying force (i.e., a building) with another structure embracing the change (i.e., animal habitat) (Gulinck and Wagendorp 2002).

- **Disturbance of Landscapes**

In absolute terms, "*disturbance* is any discrete event in time that disrupts an ecosystem, community, or population structure…and depends on the temporal and spatial scale" (White and Pickett 1985). Therefore from an ecological point of view a disturbance may affect the vertically overlaying components (rock, soil, landform, vegetation, atmosphere [climate], animals, and humans including their artefacts) commonly referred to as *land attributes*. From the landscape ecology point of view, a disturbance may also affect the horizontal components of a landscape or mosaic (patches, corridors, and matrix), usually indicated as *elements* (Zonneveld and Forman 1990, p.13). In more relative terms disturbance "is a departure from the normal domain (environmental, biological) of an ecosystem" (White and Harrod 1997) toward a situation of change in the landscape whether it is temporal or permanent.

- **Stress over landscapes**

While disturbance can be considered as a discontinuous event in time leading to biomass destruction, stress is a continuous and regular occurrence which prevents the accumulation of biomass (Middleton 1987). Stress describes the effects on any organism under cumulative impacts throughout time that may lead to irreversible changes or simply extinction.

Most landscape changes imposed by building intrusions on previously undisturbed landscapes may be deemed direct and explicit. Native vegetation removals, road construction, and landscaping activities are among these changes. These types of landscape modifications are clearly referred to as short term changes and therefore, so is the nature of the disturbance. However, once the building is finished and its systems are working, other direct and indirect changes may take place in the long term of the structure's life span, and certainly beyond once the structure is disposed or abandoned.

Some of these changes, although mostly invisible to untrained eyes, may provoke profound ecological reactions such as flushing[33] or evasive movements incurred in energetic cost associated with heightened metabolic rates, nest evacuation, or abandonment (Theobald, Miller, and Hobbs 1997). Ultimately, stressed ecosystems become increasingly vulnerable to later disturbances and may show indications of "impaired primary productivity, reduced biodiversity, alterations in biotic structure that favour short-lived opportunistic species, and reduced population regulation, resulting in larger population oscillations and more disease outbreaks" (Rapport Dimensions of ecosystem health 1998).

In conclusion, landscapes may be understood by the provision of a common geomorphologic origin and a common environmental change regime (Mooney and Godron 1983, p.19). Hence, landscape *structure* and *change processes* are both intimately connected to the notion of disturbance, stress, and/or fragmentation events, whether being these modifying forces provoked by natural or artificial means.

As part of this continuing equation of time and spatial scales, different levels of fragmentation, stress and disturbance, can result in uneven effects in the landscape. For example, if disturbance is high and stress low, or vice versa, some species will prevail over others, whereas the combination of high stress with high disturbance allows no organism to survive: the combined adversity being too extreme (Middleton 1987). The resulting ecosystem's composition will depend on the type of ecosystem's components and their potential to face disturbance, stress, or fragmentation, or the three types of adversity in different combinations.

Forecasting accurate causes and effects across the natural environment is certainly hard to accomplish if not impossible. However scale dependency of ecosystem's change events suggests that dysfunctions at the fine spatial scale may effectively have larger consequences on broader scales, and,

[33] Animals typically take flight or rapidly leave the place, in response to human presence.

though starting as isolated alterations in the landscape, they become more ubiquitous over time (Rapport Dimensions of ecosystem health 1998, p.36).

This pattern of consecutive changes throughout the landscape due to the stressing processes somehow emulates the way buildings are progressively displayed in the landscape (and apparently isolated one from another) in time within the natural environment without major noticeable landscape changes. However the cumulative effects of such individual changes – as in the case of single structures scattered in a region – over time and within a larger landscape may constitute a more complex pattern of environmental change (Theobald, Miller, and Hobbs 1997).

Narrowing Functional Concepts For The Building System

Whether building-induced modifications are disturbing, stressing, or fragmenting depends on the spatial and time scales within which such modifications take place. These scales apply to both the landscape and the disrupting building. For instance, likely changes created by a building near a sensitive stream will not necessarily be the same at the edge of a wooded patch within certain slope rates (White and Harrod 1997), nor will the impact be the same throughout the building's life span at the same location. In fact, buildings can be contributing factors equally affecting both the host ecological system, and some other type of natural change event taking place on-site or nearby.

This section introduces the notion of *building functional concepts*, which in certain combinations with those functional concepts described for the natural system complete the final function of landscape environmental change regime. The physical area affected by placing a building on a landscape mainly dominated by nature is usually small. Forman and Godron (1986, p.85) described these types of effect on small areas as *disturbance patches*, leading to a key question in landscape ecology: how is a landscape actually affected using the definition of a new disturbance patch? Such an initial change event configuration should not confuse the analysis, and the designer should be aware of some scale dependencies between an affected landscape unit and other connected ecological units beyond.

In terms of spatial and temporal scale dependencies, some key aspects of human-made structures being placed in natural environments would allow the inference of environmental change. Those intrusions usually occur under conditions of:

► **Isolation**: Whether it is *naturalness* or natural resources, penetrating natural environments in the first place suggests a certain condition of isolation (See figure 26), at least from other artificial features more commonly found in urban environments. A new object in the landscape will in one way or another disrupt a landscape element, whether this is a patch, a corridor or a matrix[34]. By doing so the building starts an intimate relationship with that given element, eventually altering its ecological functioning. Such alterations become more serious when the intrusion affects interior habitats less used to matter exchanges that generally occur at the edges or between landscape elements (Forman and Godron 1986, p.501).

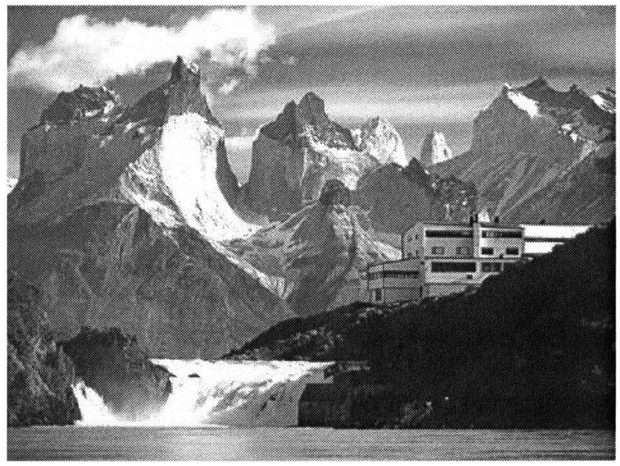


Figure 26. Explora Hotel in Patagonia, Chile. Modified from (Discover 2003)

Isolated conditions, in view of time and spatial scales, suggest that intruding structures are irregular and rare disturbance events in the natural environments, therefore adaptability is apt to be low (Forman 1999, p.503) in such environments. Low adaptability is aggravated by these unexpected intrusions, but can most specifically be attributed to the absolute absence of "ecological shock absorbers" thresholds between two dramatically different systems. Keeping in mind such specific modifying attributes of isolation, structures under these conditions may be defined as "ecologically intense"[35], whereas in the city, buildings share an ecological extensiveness with other urban features, dissolving their ecological responsibility as individual structures, therefore acting as a whole. The

[34] Further explanations on these terms can be found in **APPENDIX I**: Key Concepts in Landscape Ecology
[35] Ken Yeang (Yeang 1999) defines the skyscraper and other large urban structures as **intensive buildings**…"because of their scale and volume of consumption of energy and materials. The massive scale of such buildings often means that issues are not addressed or are negated because they appear daunting and unmanageable, specially to the inexperienced or uninformed designer."

actual size of isolated new structures in nature may be small, compared with the physical extension and complexity of the host ecosystem, but direct and indirect environmental changes may go beyond those perceived by the naked eye.

► **Abruptness**[36]: On temporal scales, landscapes are subject to fluctuations and sequences of change. In spite of short-term oscillations, most landscapes (not encountering human influence) follow a long-term tendency that Forman and Godron called *metastability*[37] (Forman and Godron 1986, p.431). In turn, landscape instability means small environmental changes are equally responsible for altering long-term tendencies toward new regimes of oscillation. Consequently a new type of landscape, landscape element, or site cluster's configuration takes place. A tendency toward metastability after successive changes is a usual consequence of disturbance regimes[38] models (See figure 27), whereas major changes in the landscape configuration are accelerated mainly at initial stages of disturbance (White and Harrod 1997, p.139).

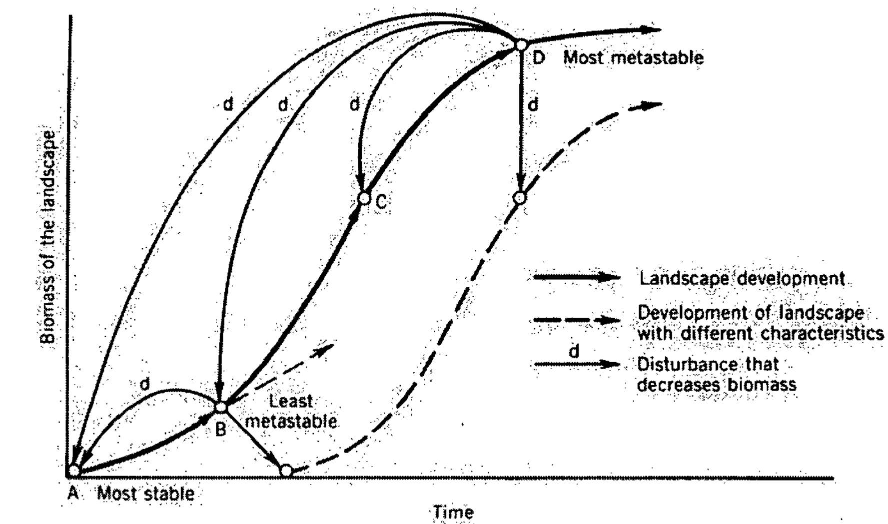


Figure 27: "A metastability model for an ecological system. Biomass accumulates through succession, and most disturbances decrease biomass. Increasing metastability means that greater environmental changes are necessary to disturb the land" (Forman and Godron 1986). Such a statement establishes the primary effects of isolation and abruptness, when intruding pristine locations.

Despite maintaining the idea of human-made structures as environmental change events in nature, this thesis does not consider them entirely detrimental. In fact, some environmental change events, whether disturbance, stress, or fragmentation, not only form part of a landscape system, but

[36] **Abruptness** can be defined only with reference to the rates of change that characterized the ecosystem before and after disturbance (White and Harrod 1997, p.129).
[37] **Metastability** is when a system is in relative equilibrium —it oscillates around a central position— and may also escape to a different equilibrium position.
[38] **Disturbance regimes** conform to the differences among parameters of single disturbances. These parameters are separated into measures of disturbance force or intensity, and the effect on the ecosystem or severity (White and Harrod 1997, p.135)

also, under certain levels of intensity and frequency, can even assist in enhancing biodiversity by producing landscape heterogeneity (Forman and Godron 1986, p.468). By contrast, spatial homogeneity and event's monotony throughout time (even if these are the results of ongoing environmental change regimes) may reduce diversity because only one component of the regional biota will be able to persist (White and Harrod 1997, p. 155)

• **Building Energy Performance**

In both natural and artificial systems flows of energy and materials are the engines driving everything else. "Though its constraint intensity and range of activity make the urban environment different in character from the natural environment, they are the same in at least one fundamental respect: both depend on the same basic processes" (Lyle 1985, p.4). These processes are ignited first by energy inputs. Then the energy is used to serve a variety of functions such as building, organizing, and maintaining different types of structures, and finally, in developing systems for storage and transport. As the primary energy source in ecosystems, the solar radiation captured by soils and plants starts the energy flow along food chains and webs from green plants to herbivore consumers, and then to carnivores. At each step, energy dissipates progressively, and finally reradiated to the atmosphere as heat (Nassauer 1997). The proper flow of the energy circuit then relies on maintaining those structures in order to avoid premature energy losses. Energy is never lost, but always transformed. This is most apparent in consideration of the broader scale of natural cycles, where general energy inputs occur as radiation generated by the sun, that is then absorbed and functionally processed by the natural environment, and ultimately reradiated as heat (Nassauer 1997). At the scale of landscape dynamics however, energy flows follow dual paths of increasing complexity and degradation (Lyle 1985, p.229): at each step of the energy flows process, natural functions such as building, organizing, maintaining structures, and developing systems of storage increase in complexity, whereas losses in the form of heat occur as successive results of each function.

Like ecosystems, buildings depend upon internal and external energy transfers. Externally they belong to a broader system –the built environment– where energy is captured and processed in various functions transforming original energy inputs toward final radiation. However functions within artificial systems operate in different ways than in the natural system. Artificial systems tend to by-pass natural flows by drawing energy and materials (i.e., fossil fuels) usually stored in the natural system, and making the urban process highly dependent on larger regional and global energy balances (Lyle 1994, p.24). Since these resources are not replenished they fall under a degenerative succession within urban maintenance operations, whereas final releases are not only in the form of heat radiation, but also as a variety of matters ranging from sewage to toxic metals and carbon dioxides, ultimately settling in natural sinks. This degenerative process equally affects everything from small plots to whole ecosystems (Nassauer 1997). Within certain spatial scales, isolated buildings intruding on natural environments may be considered as the final physical extensions of a degenerative system, delivering vast amounts of waste, heat and pollution. The overlapping of energy flows between two different systems results in a functional disruption of the natural energy flow, with the isolated building acting as the final exchanging boundary between both. Coordinating land development that respects these flows –as one of the foundations in ecological integrity– requires implementing some new approaches that integrate ecosystem functioning and human activities as intrinsic components of the same system (Vuilleumier and Prelaz-Droux 2002). Designers should regard the building as "a form of energy and materials management or as a prudent resource management" (Yeang 1999, p.127), and be well aware of the inputs and outputs throughout a building's life cycle (See figure 28, next page).

Throughout their life spans, buildings –as embodying energy exchanger functions– interact with global and local ecosystems at several phases affecting ecological compositions at different scales in time and space, and through consecutive stages of energy conversion throughout their ecologically active life, including the phase of final disposal or abandonment. The multiple complexities derived from a building's energy performance at different points in time leaves room for assuming an artificial system's participation in accumulating stress over the environments, which will finally diminish original ecological carrying capacities, rather than causing abrupt physiological modifications to the landscape.

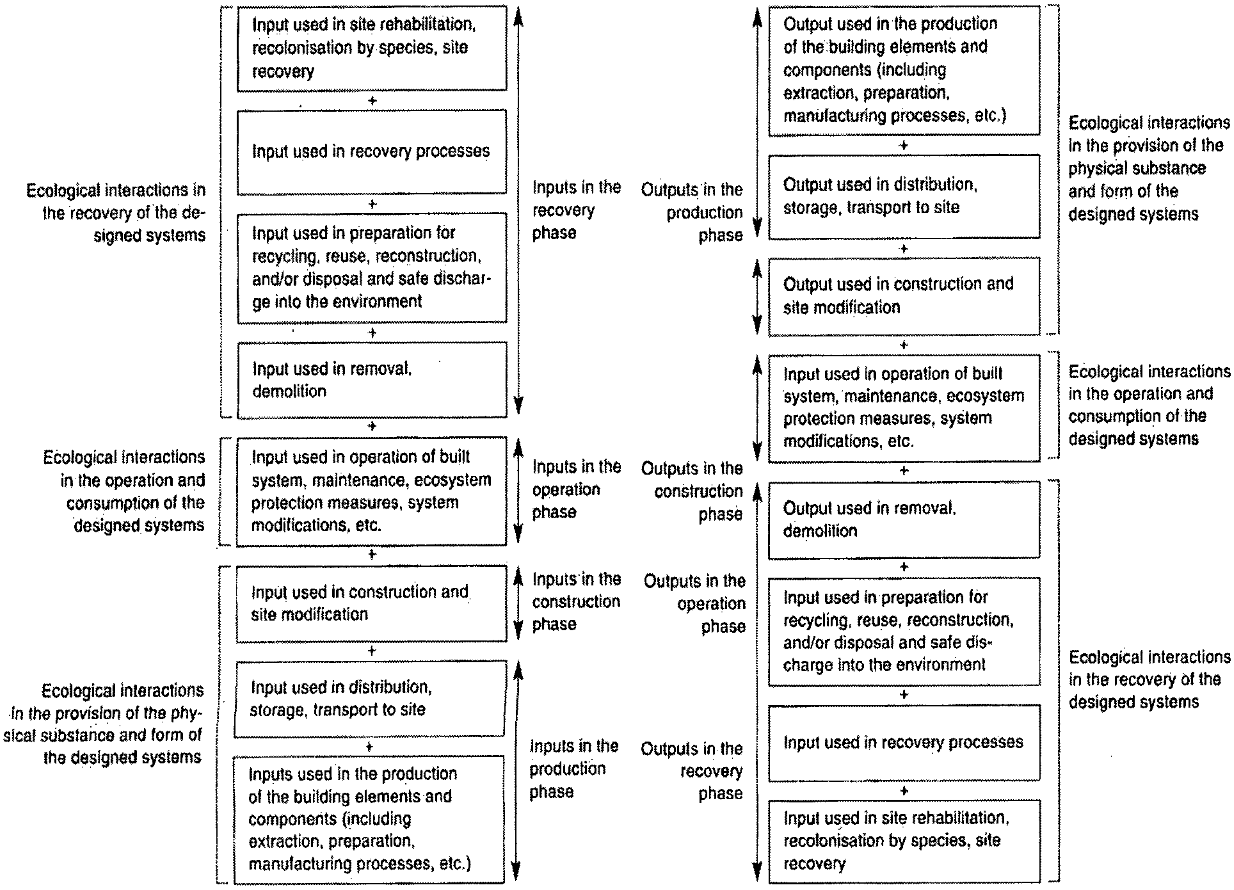


Figure 28. Source: (Yeang 1999)

Accordingly, buildings from an energy performance point of view are assumed to play a key role in stress scenarios, despite some specific disturbances derived from construction phases and waste disposals. Finally, it is again necessary to recall that buildings –as ecosystems– are open systems. From a holistic point of view, this function of reciprocal energy exchange[39] between both systems suggests that the relative position of either the ecosystem within a landscape system, or the building within that landscape could ultimately affect either system's configuration and performance. The particular idea of location becomes a critical concept when it comes to establishing the final energy exchange equation.

- **Location And Position of the Building in the Landscape**

[39] Indeed, the flow of energy inputs and outputs can be analysed to and from the building, as well as to and from the ecosystem. (Note of the author)

In the natural environment, location patterns of natural features (i.e., plants, water bodies, species habitats, etc.) respond to various combinations of ever-evolving conditions.

As a consequence of climate, topographies and soil compositions, the location of a specific plant, for instance, provides shade to the ground, gas exchange and more moisture to the air, and certain nutrients to the soil, creating a unique ecological situation. Animals, in turn, if adapted to such conditions, add new steps in the local food web, completing the ecological mosaic. Thus, successive adaptations shape physical places, species behaviour and nutrient interactions within the landscape dynamic. For a long time, human beings distributed themselves in very much the same way (Lyle 1985, p.241). Whether based on natural intuition, trial and error, or accurate analyses, ancestral human settlements seemed to pursue locations more suitable to human purposes and the ecosystem's sensitivities supporting such activities.

Keeping in mind that energy and matter exchanges do occur between landscape elements (prior to any human intervention), it seems clear that this exchange may be severely affected by a physical interruption of the network in the matrix (physical arrangement and connectivity of landscape elements). The allocation of infrastructures has proven to be an important agent of change affecting fundamental ecological processes (Theobald et al. 2000). Thus, the significance of ecological impacts is largely dependent on the spatial distribution of the proposed actions and on specific conditions of the affected natural receptor (Antunes, Santos, and Jordao 2001).

- **Morphology of the Building**

Among the several complexities involved in natural-artificial interactions, morphology of the intervening factor is one of major interest. It is in the physical configuration of the building, that is its shape, proportion, volume and spatial arrangement of components, where the designer tries to interlace the various meanings of social, economic, environmental, technical, and aesthetic constraints, and, at last, to expose the cultural value of the artefact. Related to the multi-layered nature of a building's attributes, the concept of morphology may be considered as a key functional concept in building design. Ecological implications, both outward and within the building, may be inferred as a consequence of a given building's morphology: shape and energy consumption, building envelope fenestrations, and artificial light effects on wildlife, structural geometry and fragmentation patterns, etc. In other words, morphology is referred to as the physical layout of a building actively interacting with its local context.

Following the notion of openness, where the built system can affect and be affected by a certain ecological context, the function of building morphology is presented from two disrupting perspectives: direct and indirect: as a direct disrupting function, a building's morphology imposes a physical footprint, which may eventually displace or remove other physical components previously present on site. Thus, large volumes of built mass may disturb several levels of ecosystem components –both vertical and horizontal– by displacement or removal (i.e., vegetation cover and topsoil removal, animal habitat displacement, stream course modification or interruption, etc.). Indirectly, such physical intrusions affect areas and means of connectivity means in a so-called landscape network, promoting fragmentation patterns upon biotic and abiotic components of an ecosystem, as well as building-effect distances over wildlife habitats shifting species composition due to human-presence sensitivities (Theobald, Miller, and Hobbs 1997). Hence, along with physical modifications to the landscape structure (i.e., fragmentation, isolation, segregation, etc.), building physical configurations may impose either short-term consequences (disturbance effects) due to physical removal or displacement, or long-term consequences (stress effects) due to ecological network alterations.

Unfortunately, these correlations between building configurations and further modifications upon landscape dynamics have not been extensively covered in the consulted literature, and further research needs to be conducted in order to define accurate ecological consequences caused by a specific physical building's layouts and configurations.

Traditionally, architecture has been considered (regardless of its cultural significances) as a technological assemblage where structure, systems, form and technology are displayed to take full advantage of outdoor natural conditions toward less energy-intensive performance, thereby minimizing depletions of global resources in the natural environment. This is how, from earlier ecological approaches to more current green building practices (Wines 2000), architecture is promoted to take

"…its inner form from efficient and healthful interior solar and climatic space planning. It acquires its outer spaces from its interface with the radiation of the sun and the daily and seasonal microclimate" (Crowther 1992, p.34). Yet, the arrangement of functions embodied in this interface (building envelope) is sustained by active or mechanical means, (i.e., off-site energy sources supporting on-site operations). Nature in turn, is mainly sustained by passive means (i.e., one species' waste equals another species' food). If both systems, natural and artificial, are to overlap, then the building's morphology should embrace more passive features encouraging local dependencies of the human structure on local natural processes. Extensive research has been accomplished regarding building environmental performances due to external natural conditions, and how these can affect energy performance, indoor air quality, and occupant comfort (Baker and Steemers 2000; Crosbie 1994; Crowther 1992; Lyle 1994; Mendler, Odell, and Hellmuth Obata & Kassabaum. 2000; Smith 2001; Thompson and Steiner 1997; Yeang 1995, 1999; Zeiher 1996, among others). This is a positive starting point in extending current knowledge in building design towards less ecologically disrupting structures.

The Natural Concepts: Expert Input Supporting Functional Concepts:

At the foundation of the upward scientific inference, *key natural concepts*[40] are suggested to provide critical and measurable information regarding each specific functional concept in both landscape and building systems.

Considering the way functional concepts are proposed to be understood for both landscapes and building systems, processes of ecological modification due to building disruptions should be neither identified nor assessed by isolating the different attributes or functions intervening in the process: as building performance cannot be estimated without considering local ecological functions, ecological performance cannot be estimated without considering building functions.

The description of *functional concepts* aims to clarify specific functions that may take place as a result of the disturbance of a new building and eventually to encourage the analysis of certain issues

[40] A review in detail of these natural concepts form part of the evaluation method description, and can be consulted in **Chapter III, Phase 1: Formulation of the Functions of Change,** p. 81

(herein referred to as *natural concepts*) related to each discipline that may be intricately participating in such disrupting functions. Thus, natural concepts are assumed to be key indicators of a landscape's carrying capacity and a building's disruptive capacities. Specific identification and evaluation of these natural concepts is assumed to be obtained by experts in each field, and brought to the round table in a coordinated effort of environmental change evaluations.

Conclusion: Reducing Uncertainties by Synthesis and Integration

Although some human disturbances may mimic natural disturbances in kind, intensity, and frequency (Mooney and Godron 1983, p.83), the intrusion of buildings on undisturbed landscapes presents a double problem: besides being intense events (based on the notions of isolation and abruptness), they may modify the local regime of natural disturbances (White and Harrod 1997, p.135). Such overlap between both disturbance-type regimes, artificial and natural, may complicate accurate predictions used in current assessment practices.

To date, a number of methodologies have been proposed to evaluate ecological impact assessments. The aim of these methodologies is to facilitate an understanding of past, present, and future conditions in the landscape, through comprehensive description of the ecosystem's patterns, processes, and functions (Lessard 1995). They all intend "to synthesize our knowledge of ecological systems and commonly describe the biophysical and social limits of a system, the interrelations of its ecosystem components, and the uncertainties and assumptions that underlie a given assessment effort" (Jensen, Christensen, and Bourgeron 2001, p.13).

Regardless of the varying approaches, methodologies for ecological impact assessment share some characteristics. To analyze the likely impacts[41] they describe the development scheme that may represent a source of changes and the ecological system itself, which may be distressed or modified. For this thesis, functional interactions between the building and the concerned ecological system, which is mainly dominated by natural features and processes without previous and noticeable human-made disruptions, constitute the development scheme.

[41] It is worth noting that this thesis does not refer to environmental changes as impacts, avoiding qualitative judgment upon them, and focusing solely in evaluating the facts.

This investigation does not aim to propose a new ecological assessment methodology, but rather to complement previous ones. The final goal is to integrate an analysis that may reduce uncertainties generated in the process[42]. The proposed model suggests taking a closer look at the ecological and building attributes that may alter or change ecological integrities, considering all of them as active functions of the same modifying process.

If correctly assumed, these functions become susceptible to theoretical articulation. Therefore further understanding of reciprocal interaction may improve the accuracy of forecasting ecological modifications. Hence, ecological assessment is encouraged to include the notion of building *attributes* of environmental change, whereas building ecological assessments should include the notion of *ecological attributes* from the place susceptible to disruption or modification.

Anticipating contexts of environmental change means integrated analysis should be pursued at the very first stages of conception. Therefore, instead of using elaborate computing assessment tools and running performance checklists based on detailed building data, an integrated analysis of available expert knowledge is proposed. Better yet, if accurate expert data from each field is obtained, building and landscape attributes can be integrated to minimize disruptions in the building process and reduce uncertainties derived from current and future development planning.

[42] See: **CHAPTER I: Problems and Distortions of Environmental Planning and Building Design,** p. 23.

CHAPTER III

Methodology

"If you look where you are going, you will certainly end up where you 're headed"

M.E. Jensen, N.L. Christensen et al (2001)

3.1 PARTICIPATION OF BUILDING IN ENVIRONMENTAL CHANGE

The above aphorism suggests that any thorough examination of a landscape implies not only the need for understanding but also for a sense of direction in the analysis (Jensen, Christensen, and Bourgeron 2001). The phenomenon to be analyzed is the potential participation of buildings in landscape environmental change regimes. The sense of direction is derived from the notion of a functional participation of these structures in environmental change regimes.

Following this premise, the proposed method explores an assessment methodology geared towards characterizing potential scenarios whenever buildings intervene in undeveloped landscapes. This new relationship between an intruding building and a previously undeveloped landscape establishes uncertain outcomes that are considered by the method not necessarily as impacts, but as *environmental changes*.

This method assumes these intruding buildings to be new modifying factors in the landscape (Antunes, Santos, and Jordao 2001) or, better yet, to be *new functional participants* in a previous environmental change regime. The aim is to shift the notion of traditional inventory-like approach towards these functional participants to a more integrated framework of analysis. As such this framework assumes interactions between building and landscape processes to occur as part of a whole, where a single function of change is derived from several interacting factors and at several different scales.

Accordingly, this thesis stresses the role of buildings intruding in natural environments as not necessarily detrimental. Moreover, they are suggested as valid factors relating to a landscape's change regime, if appropriately anticipated and designed, without jeopardizing its ongoing ecological integrity.

If properly addressed, the functional participation of these buildings may not only avoid unexpected negative changes in the land but may also enhance current ecological functions currently in place. Hence, this method proposes an assessment framework that embraces and strengthens ecological integrity as a base for sustainable development thinking[43].

Progressive Analysis in Integrative Thinking

Neither natural systems nor artificial ones are fixed and constant (Lein 2003). Accordingly, ongoing environmental change regimes are assumed to be intrinsic in the receptor system (the natural environment) and the stressor (buildings) may form part of it. Thus the interaction between receptor and stressor becomes a regulatory process of change.

Using the existing nature itself as a baseline with which we can compare this regulatory process, buildings are herein assumed to be *disturbance events*. Moderate disturbances in the landscape can rapidly increase heterogeneity while severe disturbances may decrease or increase it. On the other hand, when undisturbed the horizontal structure tends to progress toward homogeneity (Forman and Godron 1986)[44]. If the link between landscape disturbances and heterogeneity is considered to be a reference point in land use planning and architectural design, then environmental perturbations caused by buildings are then not necessarily wrong as long as the attributes of ecological integrity remains unaffected. In other words, buildings may be placed in the natural environment as soon as they do not overcome the landscape capacities of resistance, resilience, and vigour.

Unfortunately current approaches towards socio-economic prosperity and its derived structures are increasingly sustained on ecological deficit (Rees 1996). Despite this, sustainable development has become the current catchword touted as the foundation for socio-economic prosperity. If properly understood, then functional, historical, and evolutionary limits of ecosystems should be recognized as the mandatory framework for these human-induced changes (Johnson et al. 2001, p.328), creating the limits and priorities for sustainable development.

[43] See: **CHAPTER II: Background for Correlations Between Sustainable Environment, Ecosystem health, and Ecological Integrity**, p. 44
[44] See: **CHAPTER II: Natural Disturbance Regimes To Artificial Disturbance Regimes**, p.42

Addressing landscape's environmental change regimes requires improving an interaction between buildings and nature, which is likely dysfunctional to date. Avoiding any possible changes (commonly referred to as impacts) is not necessarily the only strategy available when planning human interventions in nature.

By respecting the limits of ecological integrity, man-made structures on the landscape may become active (and "healthy") components of an ecosystem's ability to function properly (Brown 2001), and the interaction of natural and artificial systems to be an integral part of the landscape changing regime.

"It is like looking down on a city at night where lights blink on and off, but the total amount of light remains nearly constant" (Forman 1990, p.263).

References for simultaneously addressing human development and ecological integrity can be extracted from the goals of ecosystem management, as stated by Grumbine (1994) and the Keystone Center (1996) (See Table 1):

Goal	Grumbine (1994)	Keystone Center (1996)
1	Maintain viable population of all native species in-situ	Maintain ecosystem integrity
2	Represent, within protected areas, all native ecosystem types	Sustain biodiversity and ecosystem processes
3	Maintain evolutionary and ecological processes (i.e., disturbance regimes)	Sustain vibrant, liveable and economically diverse human communities
4	Manage over periods of time long enough to maintain the evolutionary potential of species and ecosystems	Incorporate community and stakeholder values in the design and implementation of ecosystem management initiatives
5	Accommodate human use and occupancy within these constraints	Integrate the ecological, economic, and social goals, of stakeholders in an ecosystem

Table 1. Extracted from (Jensen, Christensen, and Bourgeron 2001, p.15)

According to Table 1, notions of ecosystem function, composition, and structure, should be consciously incorporated in planning processes and building design proposals whenever human processes are accommodated in the landscape. How can we accurately assess the interactions between these components? How much uncertainty[45] are we coping with, when assessing such interactions?

It is clear that the different possible scales for possible interactions between a built intervention and a landscape unit presents a complexity that falls within the domain of different disciplines, which often occurs with interdisciplinary problems (Campbell 2001, p. 28). "When systems become too complex to deal with all the parameters directly, simplification of one or more parameters becomes necessary. In other words, a model, or an abstraction of the system is required" (Treweek 1999, p.293).

In order to address scale complexities a progressive analysis is suggested that may be applied to different types of human intervention in nature: from the city in the river basin to the building in the riparian ecosystem, from a seasonal productive activity to a more permanent human settlement allocation.

Scale Analysis in Environmental Planning

Progressive synthesis and integration are proposed as thinking tools when addressing environmental interactions. Among the attributes of environmental change scale is a key notion particularly when it comes to complex systems such as a building or a landscape. Possible outcomes from any sort of analysis will depend on the scales of time and space assumed for both the interacting components (established through inventories), and the interaction itself (functional analyses).

Our understandings and assumptions of scale fix the scope of analysis, and therefore produce the following conclusions[46].

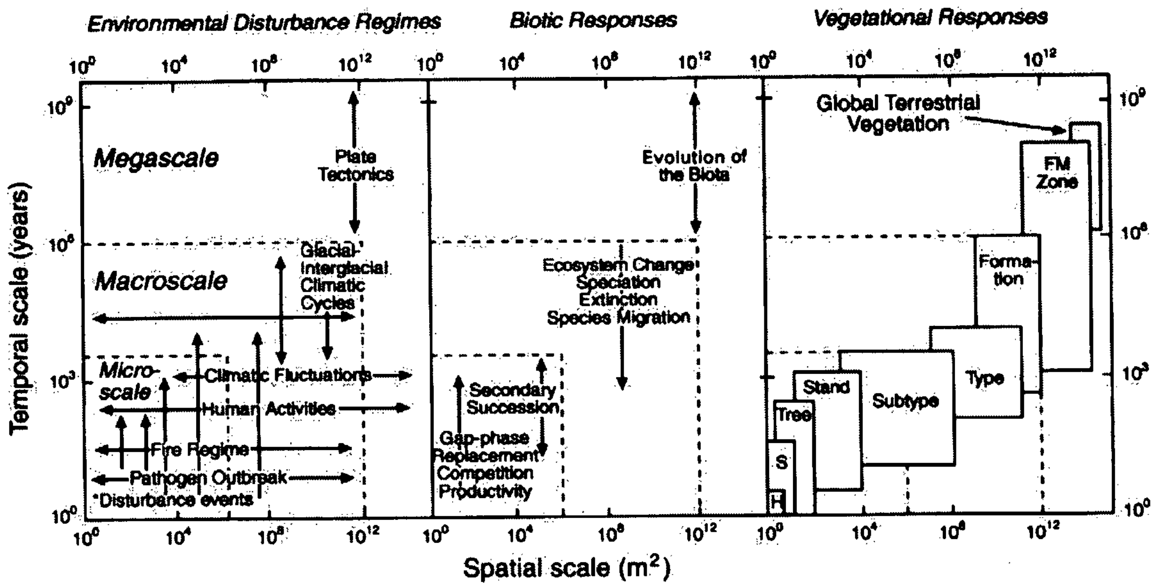
As commented in Chapter I, changes in the natural environment due to the intrusion of built systems (including from cities to single structures) have been extensively covered especially regarding global scales (Campbell 2001; Canada 1991; Goudie 1994; Jacobsen and Firor 1992; Lauwerys and American Museum of Natural History. 1969; Meyer 1996; Potts 1997; Statistics Canada. 1994; Tolba

[45] Uncertainty may be defined as a by-product deriving from complexity; and the multiple factors intervening on the artificial-natural relationships can make it yet more complex (Treweek 1999).
[46] Having in mind the practice of design is herein considered as a continuous endeavour where scale is the ever-changing constraint, and the proposed procedure is not restricted to be applied only on building design and other human-made structures, but also on landscape planning processes, urban design, etc. (Note of the author)

1992; Turner et al. 1990)[47]. In fact the multiplicity of scales and interaction between natural environments and artificial systems (See figure 29) suggests that the aim of sustainability (as a notion of biosphere scales) may rather be accomplished at finer scales (Forman 1990, p.266).

Figure 29.

Extracted from (Shugart 1998)



Thus sustainability on global scales may be conceived of more as a primary goal than as a framework. The following analysis intends to narrow down the finer scales, which support a framework of ecological evaluation.

• Spatial Scale in the Function of Change

One of the basic conceptual premises in ecology is that everything is connected to everything else. Understanding this premise allows us to infer multiple effects from a single force of change, both upon vertical (ecological prospective) and horizontal (landscape ecology prospective) arrangement of landscape components. The complexity of scales regarding these components also suggests that

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[47] See also **CHAPTER I: Global vs. Local: The Missing point in Environmental Design,** p.25

although originated at the specific site of development, changes can be spread out across the landscape, evolving both in extension and location (Jacobs 1981).

Environmental Impact Assessments (EIA) usually entail differing time and space boundaries (See figure 30). Among them, the *project* and *ecological* boundaries are of special concern in this thesis as a means to narrow down and individualize environmental interaction among other broader processes possibly compromising ecosystem modification.

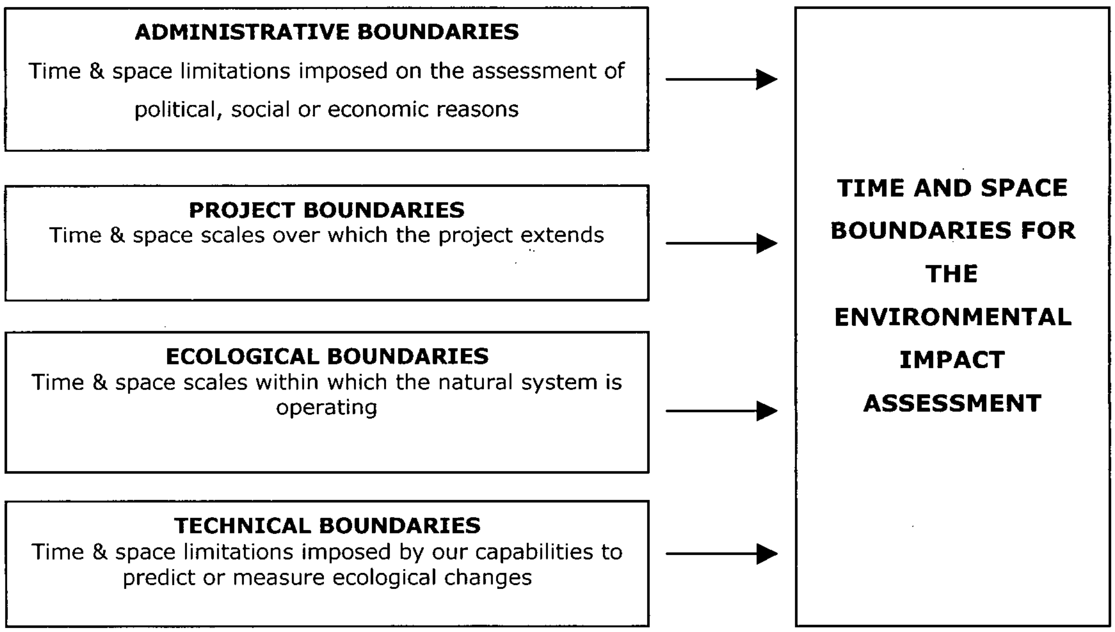


Figure 30. Modified from: (Beanlands and Duinker 1983; EPA *What is a watershed?* 2002)

The method proposed attempts to simplify consecutive spatial scales from stressor and receptor's systems, which are not necessarily based on political boundaries or technological matters but rather on ecological linkages and key significances. A progressive identification of the artificial and natural boundaries compromising ecological integrity will determine the scale of analysis for the proposed framework.

Ecological processes take place at different spatial and temporal scales and subscales within a broad natural system (See figure 31).

	Indicative mapping scales	Basic mapping unit
Ecozone	(1:>50 000 000)	>62 500 km^2
Ecoprovince	(1:10 000 000–50 000 000)	2500–62 500 km^2
Ecoregion	(1:2 000 000–10 000 000)	100–2500 km^2
Ecodistrict	(1:500 000–2 000 000)	625–10 000 ha
Ecosection	(1: 100 000–500 000)	25–625 ha
Ecoseries	(1:25 000–100 000)	1.5–25 ha
Ecotope	(1:5 000–25 000)	0.25–1.5 ha
Eco-element	(1:<5 000)	<0.25 ha

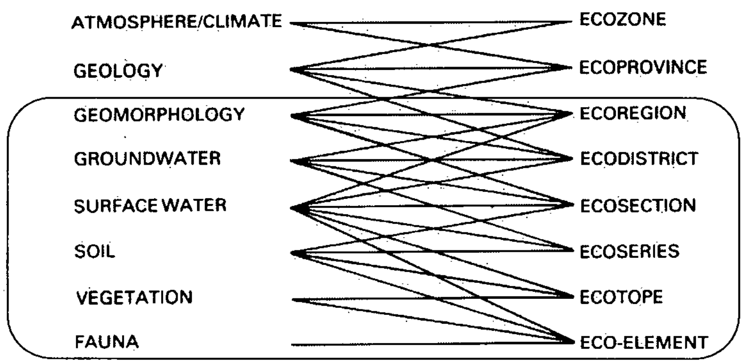


Figure 31. Modified from: (Ravera 1991)

This system, which in addition to the biosphere, is composed of continents, biomes, ecoregions, landscapes, and local ecosystems units (Forman 1990). The figures above give a clear picture of some scale significances relating to particular natural features. For instance, scales from ecoregions to eco-elements, are closely related to key ecological elements such as water structures, vegetation and fauna. On large scales, from continent to ecoregion for example, ecological phenomena tend to have more diffuse boundaries rather "determined by a complex of physiographic, cultural, economic, political, and climatic factors"...and are usually "tied together relatively tight by transportation, communication, and culture, but are extremely diverse ecologically" (Forman 1990, p.266). Such complexities may be hard to address in environmental planning.

Opposite to these larger and more complex scales of analysis the building and the host site cluster make up the finer scales. Thus, the building envelope is proposed as the ultimate physical intersection between both the site and the building (where natural and artificial systems overlap). The building thus becomes the finest representation of progressively larger scales of artificial structures such as road networks and city boundaries, which in turn connect urban areas through their rural-urban fringes, and finally intersect with undeveloped land (See figure 32).

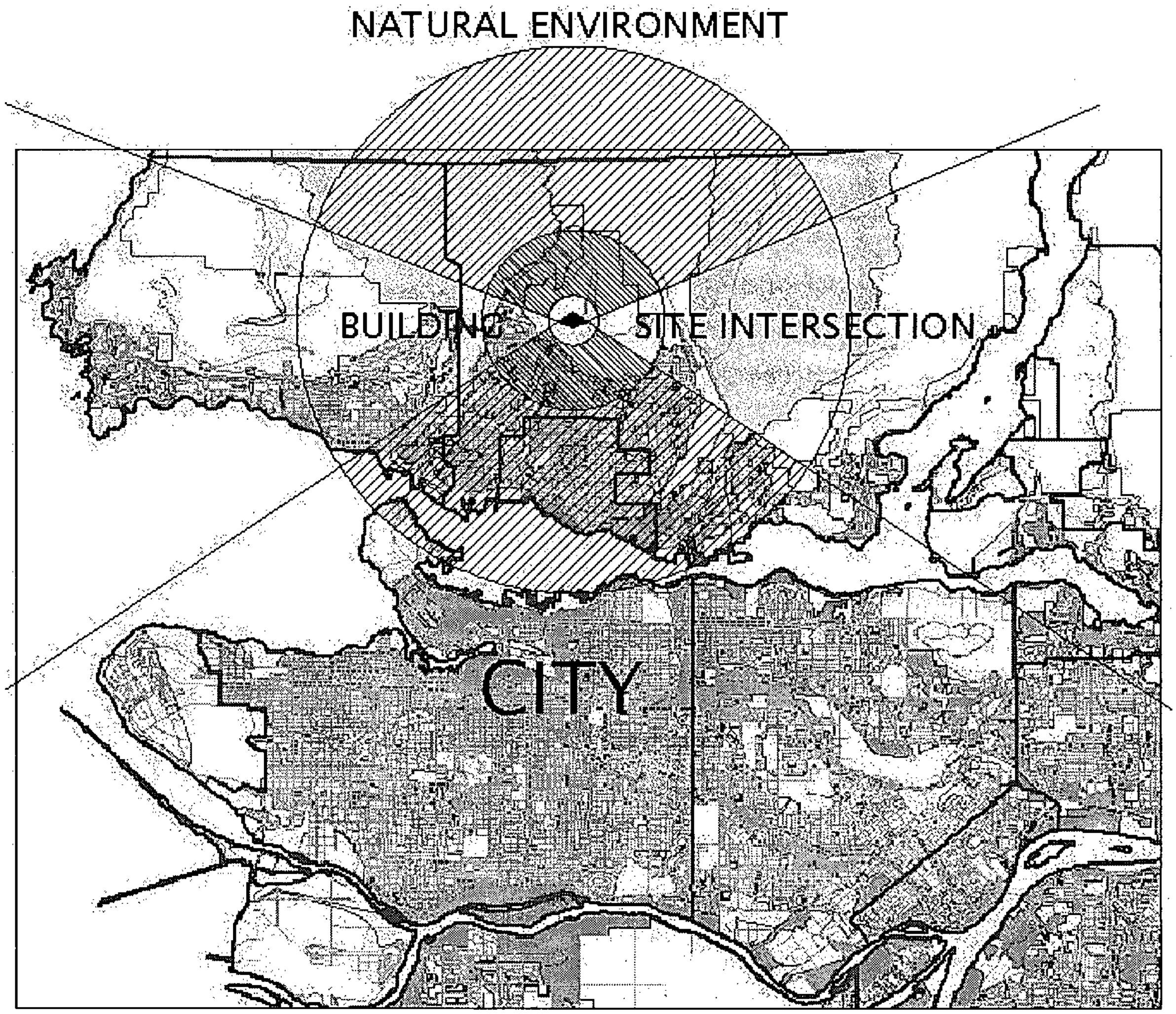


Figure 32

The progressive overlap of two different systems at different scales from urban to nature, and from a building envelope to ecoregional contexts, impose a complexity which is somewhat difficult to address simultaneously in one single planning process. Some form of simplification in reducing the factors composing the problem of intervention (Bailey 1996, p. 31) is required.

Assumed at the ecoregional scale, the *drainage basin system* is proposed as the larger scale of analysis considered in this method.

Figure 33

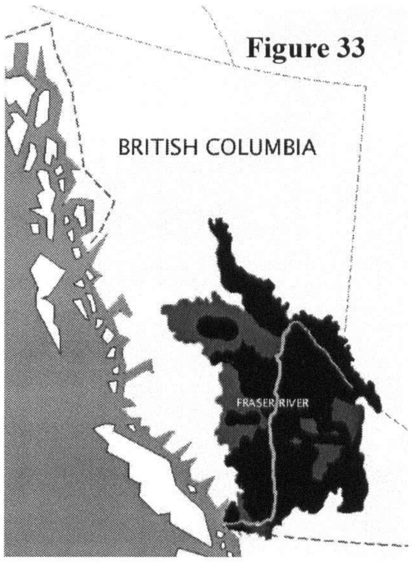
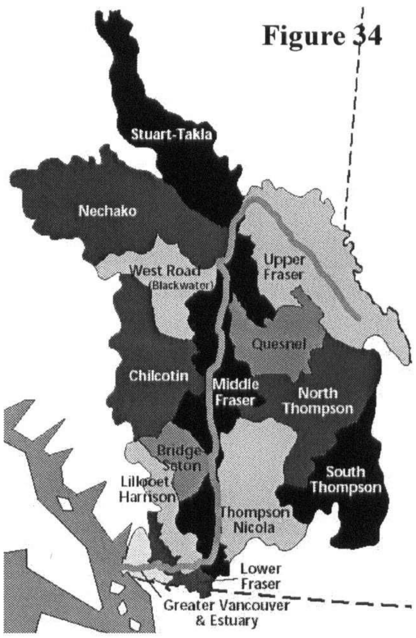


Figure 34



The Fraser Basin: Modified from (Council 1997)

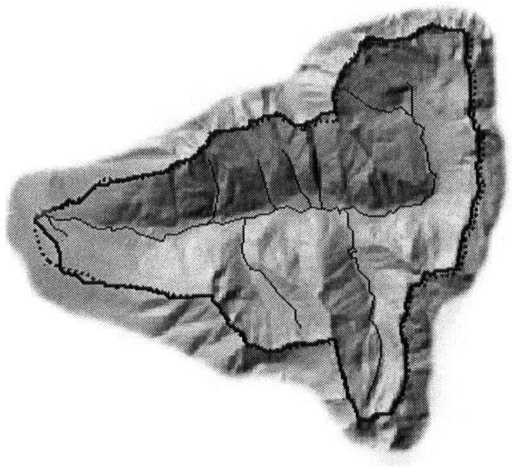
The US Environmental Protection Agency defines a drainage basin as "the area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel" (EPA *Terms of environment* 2002). The importance of having a scale at the level of drainage basin resides in the notion of a continuous ecological interrelationship between components, such as ecosystems, people, economy and cultural heritage, among other factors, within the limits defined by an extensive ecological feature.

The case of the Fraser River in southwest British Columbia, Canada, defines the Fraser Drainage Basin to be of vital socio-economic and ecological importance[48] to the entire province (See figures 33 & 34). Drainage basins supersede political and administrative boundaries, and its sustainability as a whole relies on the ecological integrity of its components and vice versa. It could also possibly be the larger spatial scale where inhabitants maintain a cultural identity bound to a major ecological feature.

[48] From an environmental, social and economic point of view, the Fraser Basin covers more than 25% of BC's land area and contains more than 2/3 of its population. Activities in the Basin also contribute 80% of the province's gross domestic product and 10% of Canada's gross national product. (Council 2002)

Drainage basins in turn are made up of *watersheds*. One step down in the scale progression, these represent all of the stream tributaries that flow to some location along the stream channel (See figures 35 & 36).

Figure 35. Watershed Delineation (Laboratory 1999)



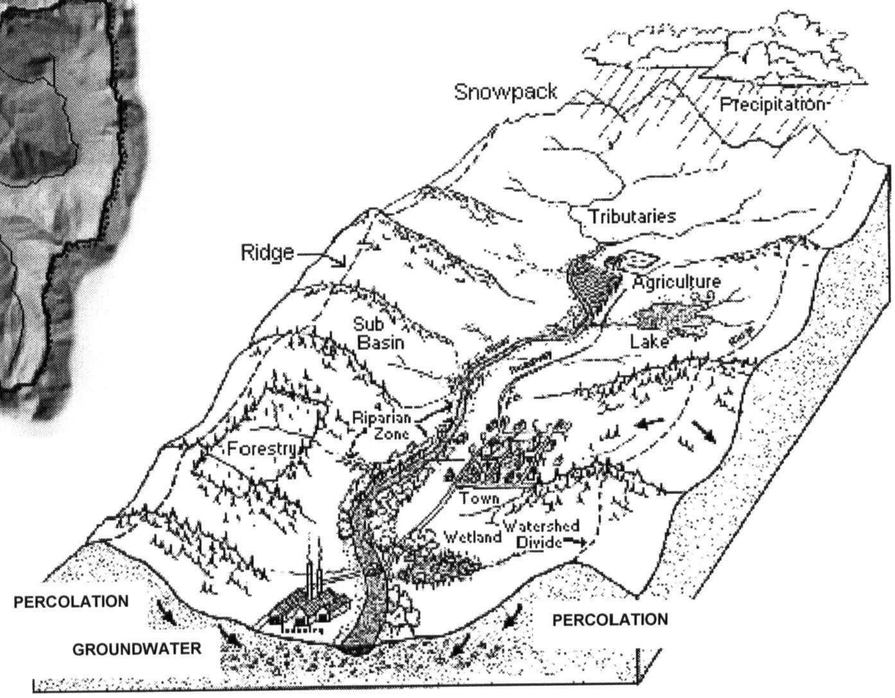


Figure 36. Diagram of a watershed (EPA *What is a watershed?* 2002)

Watersheds are considered ideal units of analysis in ecological planning (Aberley 1999) and sustainable land use, and since many biological phenomena and human activities are water-dependent the watershed becomes a natural unit of study when assessing ecological stress (Berka, McCallum, and Wernick 1995). The protection and sustainable use of water and terrestrial resources depends on the ecological integrity of watersheds. Consequently, any project threatening a watershed's ecological integrity should be scrutinized.

Human activities have vastly altered the structure of watersheds and their ecosystems through the accelerated conversion of forest land and wetlands into agricultural or urban land, modifications of hydrological pathways, and concentrated industrial development (He et al. 2000).

An analogous situation can be observed at the Capilano watershed, located within the Fraser Basin, which has endured noticeable changes in its land cover (See figure 37).

The closeness and progressive intrusion of urban environments into natural ones not only presents direct threats by physically overlapping ecosystem structures such as watersheds (See figure 38, 39 and 40), but also indirectly by exerting pressure on land protection policies (like those defining a water reservoir) due to real estate market speculation.

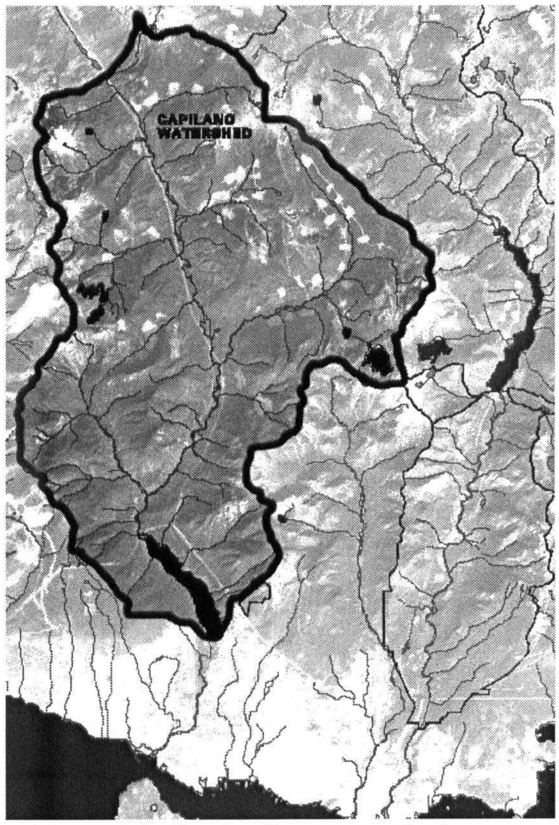


Figure 37. The Capilano watershed (GRVD 2000, used and modified with the permission of GRVD)

Figure 38

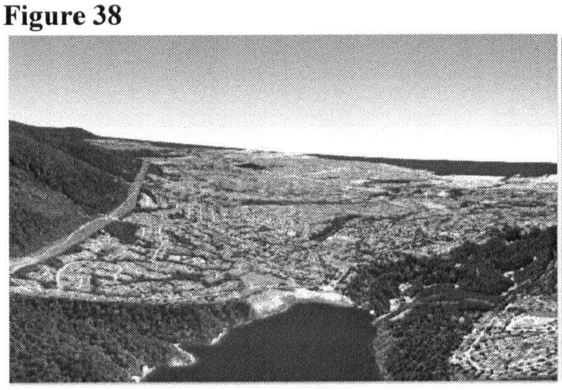
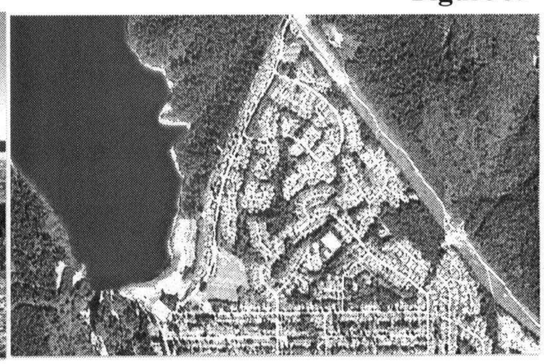


Figure 39



This image looks southeast from a vantage point above Capilano Lake. The shoulder of Grouse Mountain can be seen to the left and the Capilano River is visible heading off to the south, at the right edge of the image. The path of the Hydro transmission line can be seen as a light green swath heading west into the distance, marking the current northern boundary of urban development in the area. Source: (Vancouver 2002)

Figure 40. Source: (Clague, Turner, and Shimamura 2002)

Although likely restricted by the so called Urban Containment Boundaries (UCB) [49], eventual extensions of these urban developments in space ultimately respond to numerous factors such as land use requirements, real state speculation, and above all, to a social value placed on nature, which altogether represent variables for urban growth susceptible to change over time (BC 2002). Eventually, what is embraced as having great ecological value today, even in terms of human health,[50] may alter land use, affecting the ecological integrity of such particular natural features due to urban interventions, and affecting that of other features chosen to replace the role of the former reservoir, such as a drinking water supply. An example of these threats, which hover over current land use policy, is the ongoing debate about development pressures in the Capilano Watershed in North Vancouver, BC. At the centre of this debate is the issue of a faster connection between the city of Vancouver and the potential

[49] Urban containment boundaries (UCBs) are lines drawn on municipal maps designating the urban and rural parts of municipalities or regional districts. The purpose is to concentrate growth within already developed areas and to preserve the rural, agricultural, and resource lands outside of that area. This approach also decreases municipal costs as the need to provide new road, sewer, water and storm drain services is reduced or eliminated. UCBs are indeed an important element of urban planning designed to control urban sprawl and facilitate development of compact, complete communities describing the limit of urban servicing and urban type development

[50] The Capilano watershed contains the Capilano Lake, which is one of three reservoirs that provide water to Vancouver

Olympic Village located in Whistler. According to the Richmond-Vancouver chief Medical Health Officer John Blatherwick:

"It's time for Greater Vancouver to put an end to its closed watershed policy and allow construction of a safe alternative highway to Whistler. The death toll on the Sea to Sky Highway is unacceptable", and that the highway *"would also boost Vancouver's chances of winning its bid for the 2010 Winter Olympics…I believe if we're going to put the 2010 Olympics into Vancouver you can't keep killing people on the Sea to Sky Highway. You could drive a road up through, particularly, the Capilano watershed. You can do it and still preserve the protected watershed"* (Alliance 2001, as quoted in The Vancouver Sun newspaper, October 24, 2001, page B7).

In summary, the definition of spatial scales can been fixed by the building envelope and the host site cluster at the finest scales, and major landscape mosaics and watersheds as the largest extension of analysis (See figure 41), leaving regional scales only as a reference that could be incorporated in broader analyses.

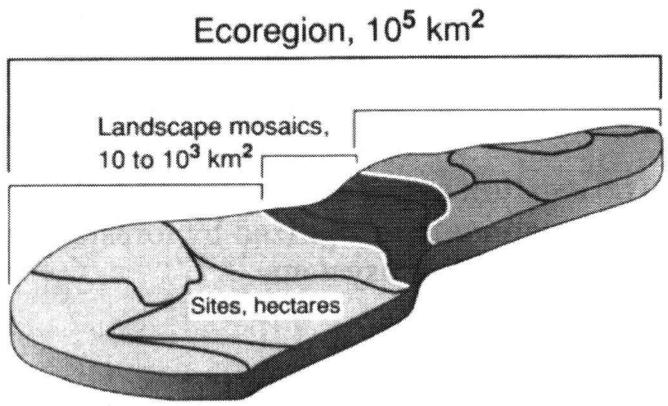


Figure 41. From (Bailey 1996, p.24)

• **Temporal Scale in the Function of Change**

Another important aspect of environmental change regimes are the frequency and the magnitude of the changes (Antrop 2000).

As explained by Forman and Godron (1986), within early stages of minor environmental change, landscape characteristics fluctuate around a central position and the landscape remains in equilibrium. Such performance is possible due to resistance attributes of the ecosystems present in landscape. When the level of force increases further more, the original landscape equilibrium can be passed over temporarily and then recovered due to its intrinsic resilience capacities. If resilience capacities however are overcome by larger oscillations, a new equilibrium may take place and changes become permanent within the same landscape. Finally, drastic forces may cause the predominant landscape equilibrium to disappear, and as a consequence, a new type of landscape will take place.(Forman and Godron 1986) (See figure 42).

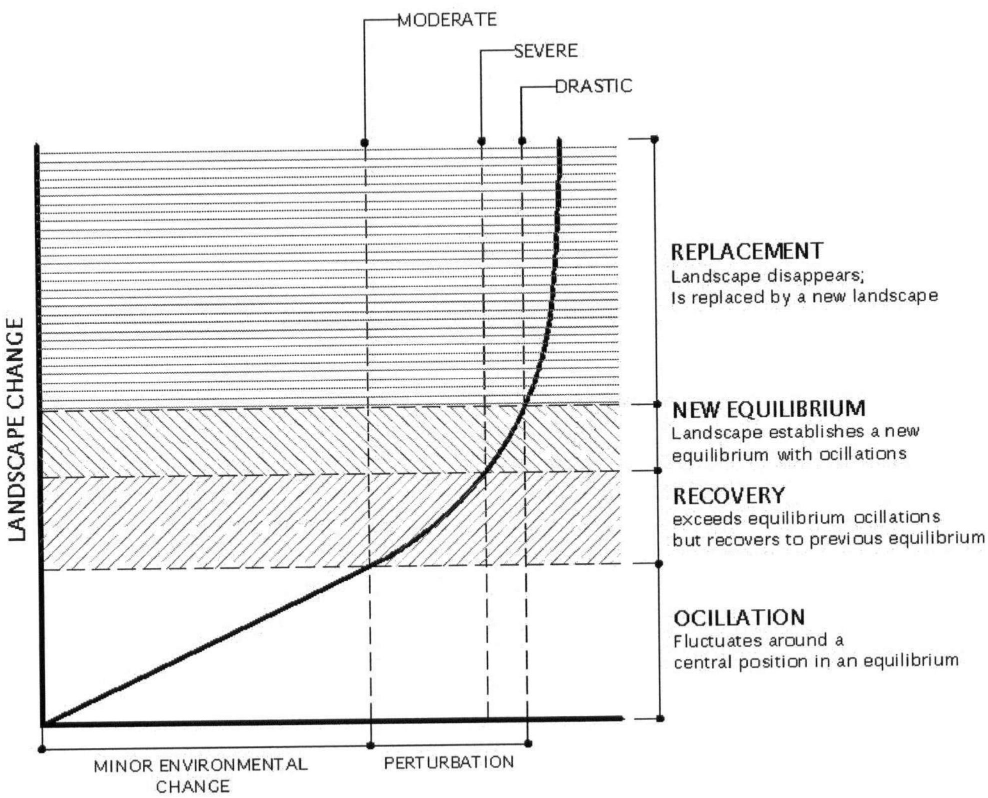


Figure 42. Effects of increasing force on a landscape: Modified from (Forman and Godron 1986)

If such attributes of landscape modification have been properly assessed (and agreed upon), and potential scenarios of environmental change convened, interdisciplinary decision-making teams may establish those suitable strategies addressing the forecasted landscape modifications, whether in terms of facing resistance, or recovering, or landscape replacement outcomes. In other words, natural concepts have to be characterized by experts in each related discipline, as a base for defining the functional concepts of change (also described as the likely participation of artificial and natural systems in environmental change). Once functions of change have been established upward inference may enable decision-making teams to propose forecasted potential scenarios of landscape modification, and therefore may lead to suitable strategies addressing those environmental changes. This is in sum, the basic structure of the method to be proposed.

3.2 METHOD FOR A FUNCTIONAL ANALYSIS OF ENVIRONMENTAL CHANGE REGIMES

"The solution of every problem is contained within itself. Its plan, form, and character are determined by the nature of the site, the nature of the materials used, the nature of the system using them, and the nature of the life concerned, and the purpose of the building itself."

—Frank Lloyd Wright

Inventories and physical characterizations of natural and artificial systems may be indispensable steps towards planning modifications to the landscape, but they are far from enough (Lein 2003, p.90): landscapes are dynamic, as are the configurations of buildings. The nature of these composing elements changes in time, as do their interconnecting relationships (Antrop 2000). "Understanding the dependence of form on processes and recognizing that human and natural processes are constantly at work modifying the land illustrates the need to incorporate a process orientation in design." (Lein 2003, p.90) This orientation should be inspired by an "overlay" of the intervening object (stressor) over the host environment (receptor).

Recognition and Interdisciplinary Analysis of a New Disturbance Regime

As mentioned before, natural forces intervening in landscape change regimes, such as stress or disturbance, may affect not only various intensities and frequencies, but also the composition and structure of the on-site and other ecosystems connected across the landscape increasing risks of a sequence of landscape fragmentation[51]. Increased forest edges due to fragmentation processes are considered major factors contributing to the reduced distribution of wildlife species on a broad geographical scale (Yahner 1998). Likewise a proposed building location initiating processes of fragmentation due to land cover removals may initiate unexpected processes of spreading cumulative stress in the long run, through those new openings across the landscape. Keeping this in mind, the method assumes that the effect upon receptors is the consequence of either a single stressor or the combination of several. Both components and processes are thus connected, and knowing what is there and how they interact, provides the base for explaining the forces that shape environmental change regimes, and serves as a source for all subsequent exercises in prediction and functional analysis (Treweek 1999).

- **Framework Approach**

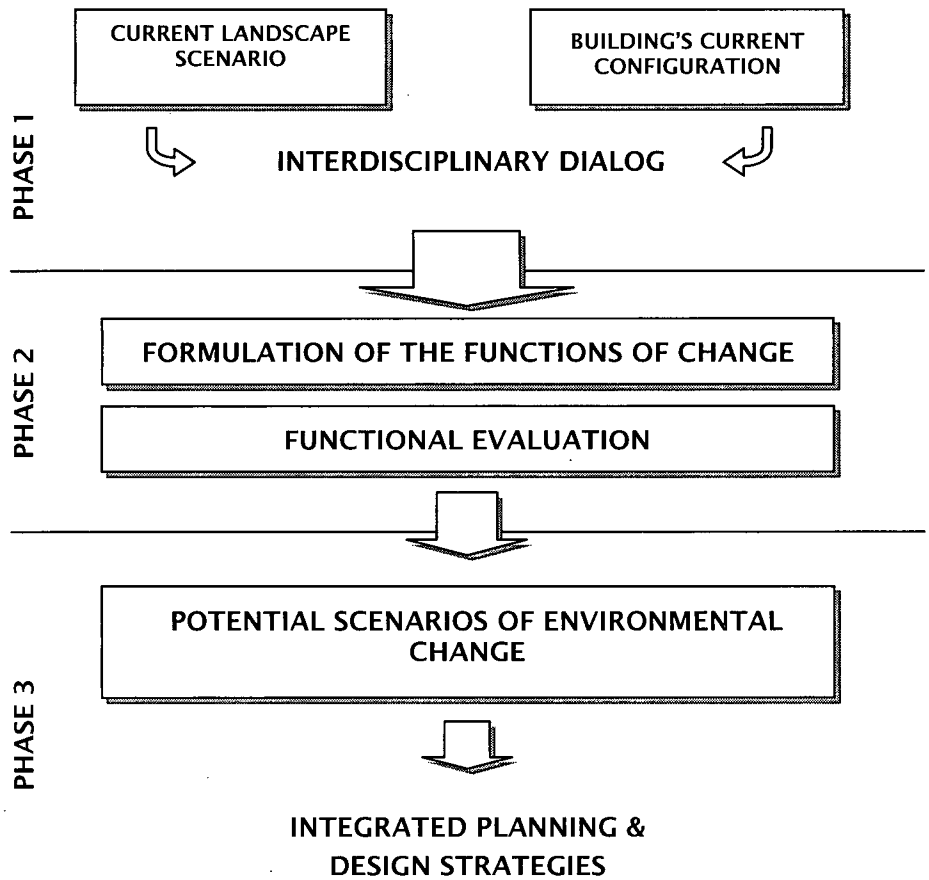
Since the aim of this method is to support and complement Environmental Impact Assessments (EIA) and other highly detailed evaluation processes, a simplified method for addressing the integrated nature of environmental change regimes and potential deterioration of the landscape is proposed.

The goal is to encourage straightforward evaluations enabling further management strategies in finding either suitable landscape attributes for a given building's configuration, or a proper building's configuration, so the limits of ecological integrity on a given landscape are maintained. Identifying possible roots for an environmental change scenario allows proactive management procedures in order to avoid trespassing thresholds of irreversible and unexpected modifications to the landscape (See figure 43, next page).

In other words, the method seeks to enhance the planning process by predicting potential scenarios of what may happen or how the landscape may evolve after human structures are located on a given landscape. Such predictions do not imply future conditions will be accurately forecast: in fact, "prediction implies that certain assumptions about the future can be explored and evaluated" (Lein 2003, p.145), and therefore, successful forecasts cannot be guaranteed.

[51] See: **CHAPTER II: Narrowing Functional Concepts for the Landscape System,** p. 48

Figure 43. The framework shows a three-phase process including an interdisciplinary analysis of natural concepts, formulation of the functions of change, and a final forecasting of potential scenarios of change.



Buildings and Landscapes: Components in the Function of Change

The search for understanding human interventions in nature has extended investigations in general, toward characterizing the components of both artificial and biophysical processes. Yet, the awareness of component interaction remains more unclear than the mere definition of participating components (Campbell 2001, p.418).

A first attempt of interaction simplification is extracted from Treweek (1999), who establishes some key requirements for an ecological assessment:

► an interpretation of the proposal and its associated sources of ecological stress or disturbance ('stressors')

► information about potentially affected ecological 'receptors' (their spatial and temporal distributions).

In more than a simple characterization, Treweek proposes that thorough understanding on any landscape evaluation process should start from the integration of available information about sources, stressors, effects, and receptor characteristics that are all participating in the same function of change (See figure 44).

Isolated inventories do not necessarily explain the process, only the physical characterization of the components. Under this ongoing interaction, both stressors and receptors endorse a dynamic function that may challenge the limits of ecological integrity.

If the landscape is regarded as the factor susceptible to modification, and the building referred to as the action igniting those modification scenarios, this thesis alternatively calls those receptor attributes *sensibilities* against change, whereas stressor attributes are also defined as the *constraints* being imposed by a built system upon the landscape.

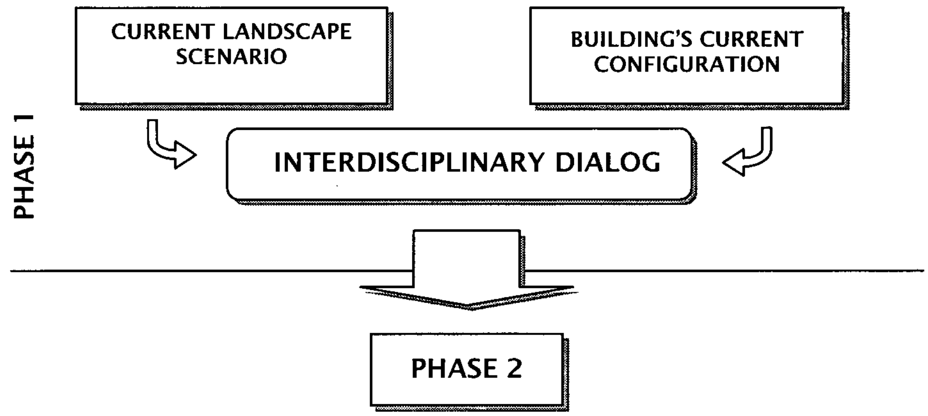
As dynamic factors, the attributes of *receptor's functional sensibilities* and *stressor's functional constraints* cannot be identified nor analyzed separately, being therefore proposed as interacting factors of the same function of change.

• Phase 1: Formulation of the Functions of Change

The overall purpose of this first phase is to achieve a progressive individualization of key natural concepts describing ecologically active features from both the natural and artificial system.

Such ecological features are assumed to be eventual factors in the function of environmental change (See figure 45).

Figure 45



Key natural concepts are advanced adventured from hierarchical inferences within a system [52], and are the result of a synthetic characterization of the participating systems in a potential change scenario. These natural concepts are understood as explicit measuring units of functional attributes. For instance, a number of particular natural concepts "measuring" the landscape functional concept of *vegetation cover* can be identified, by operationally defining this ecological entity and its attributes (i.e.: vegetation cover = function [climate x soil composition x slope x altitude...etc.]). In this case, soil, slope, and altitude (to name a few attributes) would be identified as the natural concepts "measuring" the functional concept of vegetation cover. Thus, natural concepts can be used to help in formulating functional interactions. Their analytical significance is determined by their level of implication in susceptible key ecological processes that, in turn, may help in maintaining ecological integrity.

This method, in fact, promotes instances of expert interaction and suggests thinking flow rather than a meticulous set of mathematical indicators for each interaction involved in the process.[53] Indeed, measurements of causes and effects can make the analysis more quantitative and clear, but statement of assumptions can make it more open and objective (Beanlands and Duinker 1983), especially

[52] See: **CHAPTER II: From Natural, Through Functional, To Integrative Concepts,** p. 40
[53] Rather than suggesting specific measurements and indicators, this thesis aims to open room for debate about integrated environmental planning and design. The accurate definition of indicators of functional environmental change belongs to further investigations.

considering the multiplicity of components and subcomponents intervening in processes of environmental change while maintaining levels of ecological integrity. It is certainly not practical to characterize all of these processes and their components. It is therefore accepted that progressive inference suggesting key indicators introduces subjectivity within the analysis.

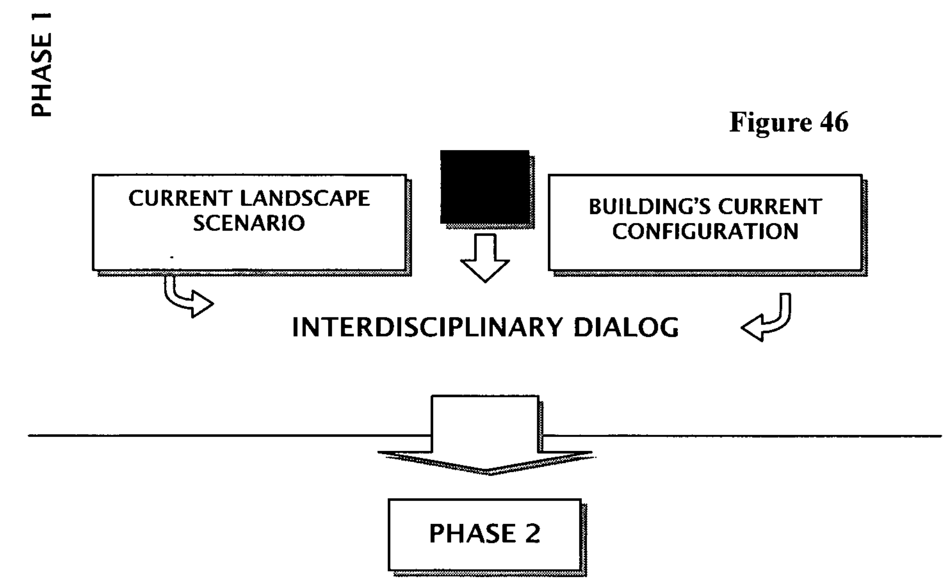


Figure 46

Indeed, traditional ecological assessments usually collect only the information needed for achieving specific goals (Steiner 1999), introducing unavoidable gaps of subjectivity in any analysis on what may be called a black box of uncertainty (Condon 2002) within such a framework of analysis (See figure 46). Moreover, subjective analyses certainly show discrepancies from project to project and from site to site, depending on available information and the way this is manipulated by experts [54]. Somewhat different from traditional inventory-like approaches, this method proposes selecting natural concepts while keeping in mind possible interactions within a particular system with their system's counterpart (natural vs. artificial systems), following the precepts of integrated analysis and its functional meaning. Traditional ecological assessments tend to use inventory-like evaluations, including quantitative support of various structural elements of the natural system, but do not necessarily explain the dynamics between these elements. Similar problems may be found in building assessment, where describing the numerous components embodied in the building may allow understanding functioning performances, but not exact definitions of the actual ecological implications.

[54] For the purposes of this method, information supporting natural factors is assumed known and available, spotlighting the framework explanation in the progressive synthesis and articulation of functional concepts.

These approaches give little direction to how projects may interact with those functional and structural elements across a landscape, especially biotic ones (Beanlands and Duinker 1983). Thus specific factors with high significance over potential processes of environmental change are selected according to expert recommendations and prior environmental evaluations. Thus experts involved in the process will be inferring further hierarchical ecological relationships within a consecutive procedure of upward inference. In this case some key natural concepts for both systems are suggested based on reviewed literature (See table 2).

Table 2. Key natural concepts in landscape and building configuration

LANDSCAPE'S KEY NATURAL CONCEPTS		**BUILDING'S KEY NATURAL CONCEPTS**	
Vegetation Cover	**VC**	Building L.C.A. (Total Energy)	**BLC**
Landscape Connectivity	**LC**	Run-off Function	**ROF**
Physiography (Slope, drainage, etc)	**PH**	Intensity of Human Use	**IHU**
Keystone Species Habitat Distribution	**KH**	Enclosure Physical Configuration	**EPC**
Water Dependant Ecosystems	**WDE**	Embodied Energy	**EE**
Nutrient Cycling	**NC**	Recycling Potential	**RP**

For the purposes of this investigation, landscape and building key natural factors have been suggested and summarized as in Table 3. These concepts have been selected according to the reviewed literature, either regarding its key implications in both landscape and building dynamics, or due to its hierarchical role in the system's composition. Suggestions in terms of the number and nature of these factors are regardless of the inclusion or exclusion of others, with case-to-case variability. However, their definition is driven and contained by the scale limits inferred from handling river basins and watersheds as the larger extension of analysis, and the building envelope and

f	VC	LC	PH	KH	WDE	NC
BLC	■			■	■	■
ROF	■	■	■		■	■
IHU		■		■	■	
EPC	■	■	■	■		
EE					■	■
RP	■	■			■	■

Table 3. Potential interactions' identification

the site cluster, as the smaller one[55]. Once key natural concepts have been defined for both systems, and are agreed to be critical for measuring functional attributes, a first attempt at identifying interactions that may have some effect on the course of landscape change regimes is anticipated between them (See table 3). When doing so it is important to conceptualize the receptor attributes, keeping the stressor firmly in mind and vice versa (Beanlands and Duinker 1983).

• **Phase 2: Functional Evaluation**

After the primary identification of potential interactions between key natural concepts are carried out, functional attributes[56] regulating such interactions are suggested. This particular step aims to synthesize the likely broader range of functional interactions at different frequencies and magnitudes (time and spatial scales) under a rather simplified evaluation structure, while establishing the "receptor" condition of the landscape and the "stressor" condition of the building (See figure 47).

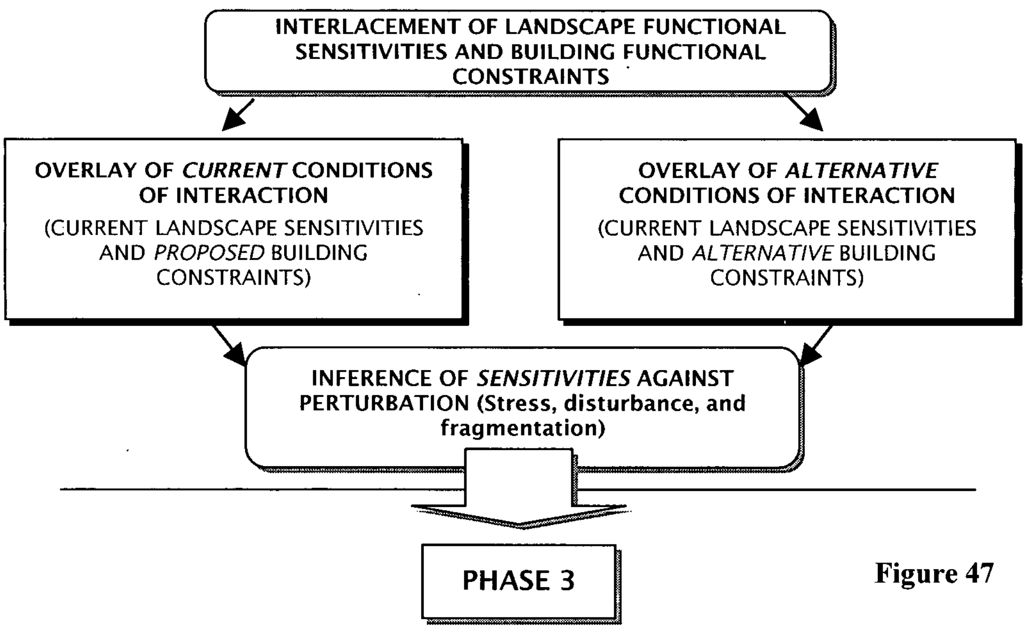


Figure 47

The ultimate goal is to define how *sensitive* the landscape is, and how *constraining* the building is. This function of change has been recognized as imposing a new kind of environmental change regime, presumably different from the one formerly in place. (See figure 48).

[55] For more in detail information about some of these concepts, refer to: **APPENDIX II: Some Suggested Key Natural Concepts Characterization**

[56] See **CHAPTER II, Narrowing Functional Concepts for the Landscape System,** and **Narrowing Functional Concepts For The Building System,** pp. 48-52

Figure 48

NATURAL SYSTEM (Receptor)
Landscape functional sensitivities to:

FRAGMENTATION
(Modification of the physical network in the landscape)
DISTURBANCE
(Short and intense event of perturbation)
STRESS
(Long event with varying intensities of perturbation)

$$\left(f \right)$$

ARTIFICIAL SYSTEM (Stressor)
Building functional constraints due to:

ENERGY PERFORMANCE
(Input-output of energy cycle throughout building's life-span)
LOCATION
(Relative positioning within the landscape)
MORPHOLOGY
(Physical configuration and layout of the structure)

This function of change seeks to shorten the gap between the planned development and the final real development, or better yet, between the original landscape regime of change and the potential change regime after development. Acknowledging and addressing the uncertainties involved in forecasting scenarios is an objective of this framework.

The conceptual graph in figure 49 depicts the effect of planned and autonomous development upon the functioning of landscape structures where the shape of the spiral movement represents the type of functioning (circular, rectangular, triangular). The planned development **(P)** attempts to change the existing autonomous functioning of the landscape **(A)**, causing new unplanned, opposing autonomous development **(O)**. The final real development **(R)** will seldom fulfill the entire realization of the planned one (Antrop 2000). The possible interactions between A and P are not necessarily equally reciprocal. For instance, the way a morphological aspect of a building fragments a landscape, is not necessarily equal to a fragmented landscape affecting the morphology of a building (place an example). Human structures are the odd factors intervening in the natural system, not the other way around. "Ecological resources are considered susceptible when they are sensitive to a stressor to which they are, or may be, exposed"

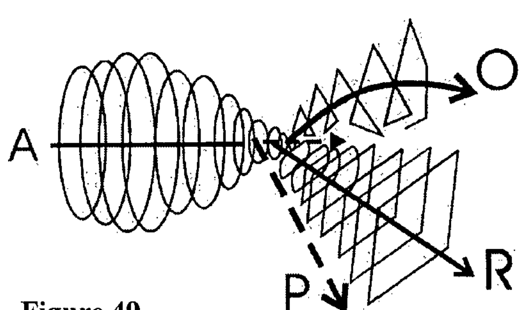
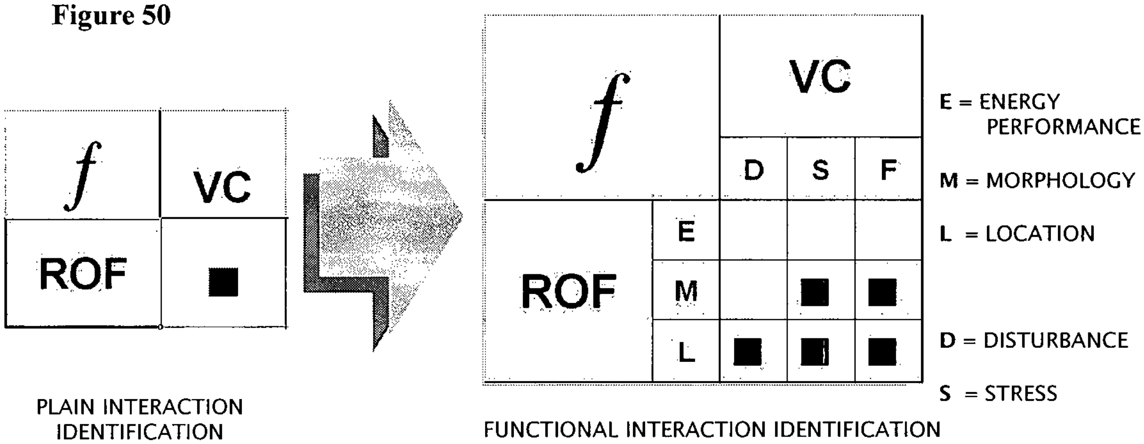


Figure 49.

(EPA *Ecological risk assessment* 1998, p.29). Hence the landscape's sensitivity is being exposed to a stressor's actions. Considering these functional sensitivities and constraints as integrating a function of change, the initially identified interaction between key natural factors can now be more accurately specified (See Figure 50).

Figure 50



LANDSCAPE'S KEY NATURAL CONCEPTS	
Vegetation Cover	**VC**
Landscape Connectivity	**LC**
Physiography (Slope, drainage, etc)	**PH**
Keystone Species Habitat Distribution	**KH**
Water Dependant Ecosystems	**WDE**
Nutrient Cycling	**NC**

BUILDING'S KEY NATURAL CONCEPTS	
Building L.C.A. (Total Energy)	**BLC**
Run-off Function	**ROF**
Intensity of Human Use	**IHU**
Enclosure Physical Configuration	**EPC**
Embodied Energy	**EE**
Recycling Potential	**RP**

The identification of different functional interactions and levels of landscape exposure to stressors' action will depend on how well the available information on stressor sources and characteristics, exposure and contact opportunities, characteristics of the ecosystem(s) potentially at risk, and reference ecological effects, were investigated or known by experts from similar situations (EPA *Ecological risk assessment* 1998). The data collected and selected by experts in order to establish natural concepts' characterization, must also be gathered into a format that gives clear indications of probable outcomes in a forecasted scenario of change.

Table 4. Complete analysis of functional interactions

Table 4 shows an example of a table combining the results of an interdisciplinary evaluation of key natural concepts. As a result of the exercise, the scope of analysis starts narrowing down the interactions for some of the main functional attributes from both systems, eventually affecting the autonomous functioning of the landscape.

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	f		VC			LC			PH			KH			WDE			NC		
			D	S	F	D	S	F	D	S	F	D	S	F	D	S	F	D	S	F
1	BLC	E		■									■							
2		M	■	■									■	■		■			■	
3		L		■	■															
4	ROF	E								■										
5		M		■	■		■	■	■	■	■					■			■	
6		L	■	■	■						■				■	■				■
7	IHU	E										■								
8		M					■						■	■		■				
9		L					■					■	■			■				
10	EPC	E		■			■						■							
11		M	■		■				■							■				
12		L	■		■	■	■	■	■				■		■	■				
13	EE	E														■		■		
14		M														■			■	
15		L															■			
16	RP	E					■													
17		M					■									■			■	
18		L		■			■	■								■		■		

Results from collecting, classifying and selecting data generate preliminary hypotheses about the probable participations of the two systems in defining a new change in the landscape. If correct, identifying each of these combinations may release valuable information regarding ecological sensitivities, landscape carrying capacities, and/or building factors of environmental change, which may endorse suitable design approaches and management strategies responding to such attributes and constraints. They would also allow the review of the process, if planning, implementation, and monitoring procedures require it. However, accepting trade-offs when adopting planning strategies –as a desirable purpose of integrated analyses– not only requires identifying potential functional combinations for the receptor-stressor relationship, but also some level of *dynamic measuring*: the method seeks to acknowledge the new environmental change regime taking place in the landscape, as well as to understand this new regime, and to measure and plan it. A conscious recognition of the limits of ecological integrity may help to anticipate the ecological trade-offs of planning and design and the likely risks of trespassing (or not) on these ultimate limits. Doing so requires some sort of representation of potential scenarios in environmental change.

- **Phase 3: Representation of the New Environmental Change Regime**

"*Modeling and simulation facilitate one of the main goals of planning, that of prediction*"

(Lein 2003, p.145)

What are the requirements for achieving this prediction? At this stage of research, the question of measuring environmental change and finding the proper mathematical indicators for evaluating this particular phenomenon have been heavily stressed by the framework idea. Questions naturally arise: Is science sophisticated enough to measure ecological change? Additionally, is current knowledge in design disciplines sufficiently aware of the ecological implications of human-made structures, so that it can support and complement science in achieving exact mathematical measurements in such regard? According to consulted research resources, it may not. However, any prediction worth considering must rest on some evidential basis (Rescher 1998 cited in Lein 2003, p.145). With the remarkable progress made in ecological sciences and the increasing sophistication of building design and technology on one hand, and the relative isolation of these disciplines on the other, interdisciplinary expert evaluation may still be the most valuable resource in environmental assessment. Dialog between disciplines is explicitly encouraged.

An adaptive scenario, as is proposed by this method, should allow reiterative analyses of a situation of environmental change through a "looping" mechanism, where primary interactions of natural concepts are initially defined. Then, such interaction is stressed under the notion of functional attributes possibly affecting the phenomenon. These two first steps constitute the *functional evaluation*. From this evaluation, particular scenarios may be projected where, for example, specific location conditions may endorse processes of disturbance, stress, and/or fragmentation. The scenario projection is evaluated in terms of how the limits of ecological integrity will be encroached, anticipating changes.

The evaluation method uses a *discriminant function* technique described below. Such analysis would classify whether the change is bearable, suitable for that particular landscape and building configuration, or ultimately, accepted as it is beyond the consequences. If by any means levels of change are detected and somehow considered detrimental, the analysis moves backwards and reviews the most compromising functional interactions, suggesting mitigation strategies or alternative approaches that may project a different scenario (See figure 51).

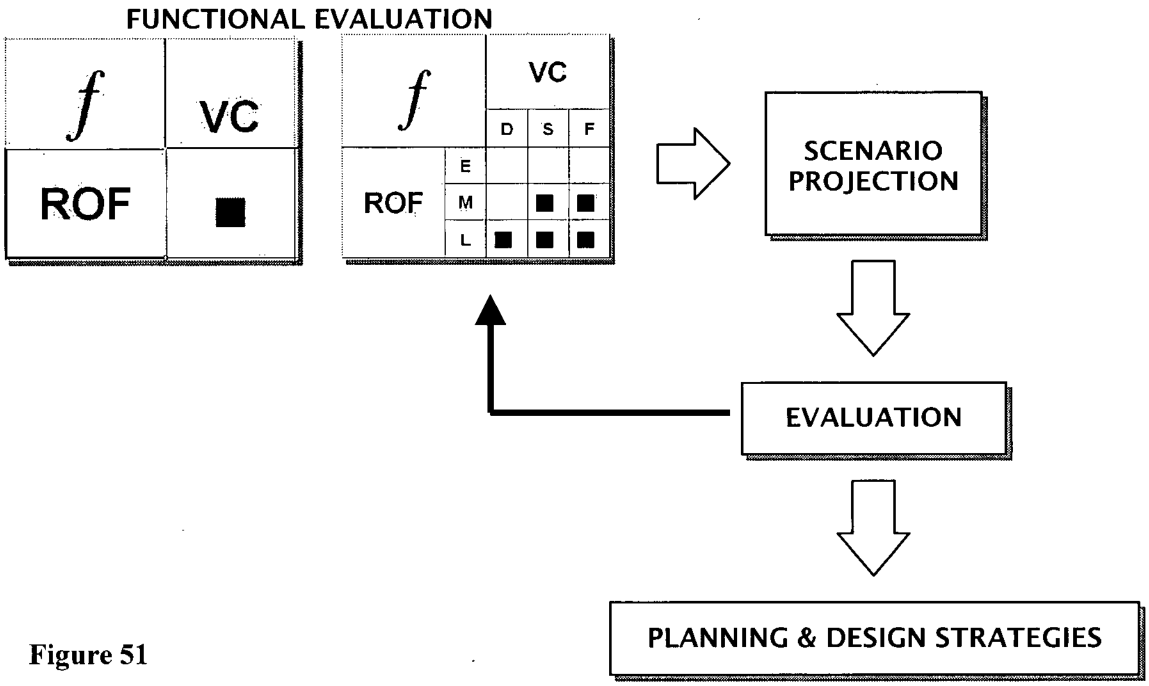
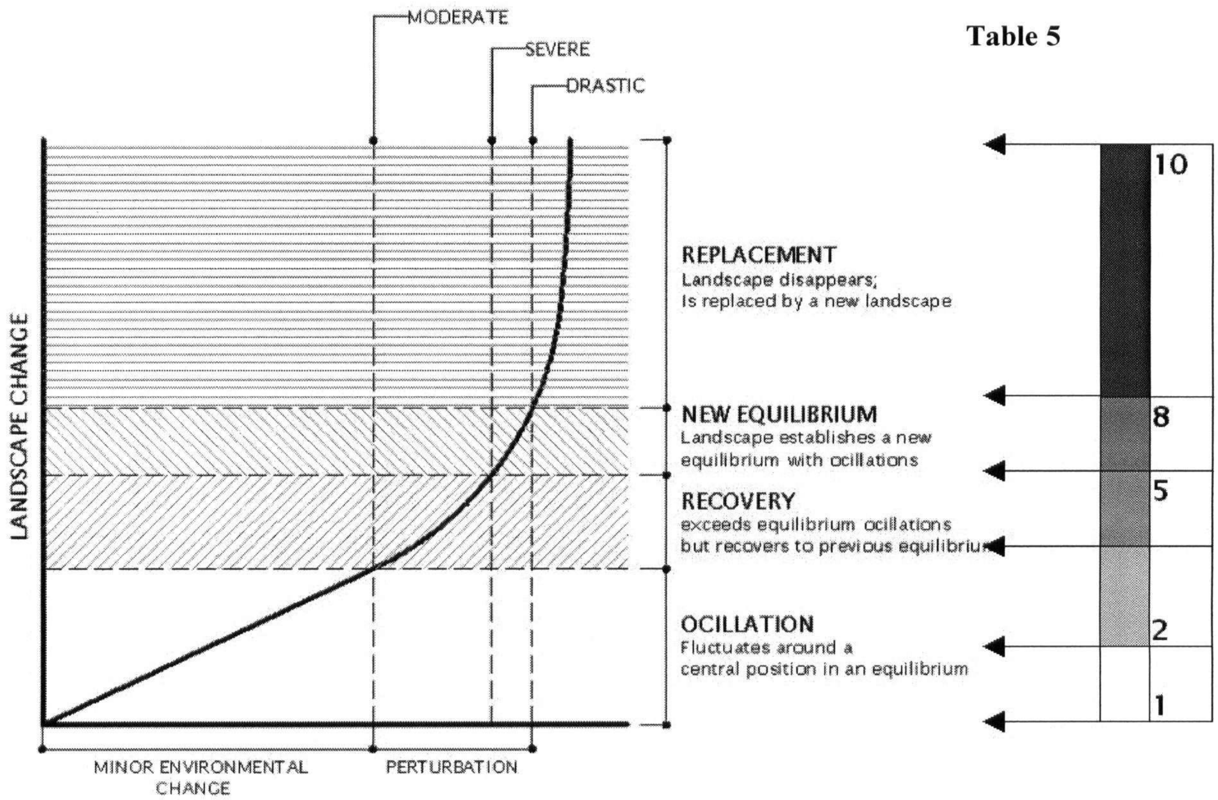


Figure 51

Attempting prediction requires acknowledging the impracticability of forecasting accurate scenarios, and because of this, exact measures of functional interactions have been dismissed as a primary concern for this method. However the investigation accepts and indeed promotes the idea that a definitive set of measures for environmental change indicators should be accomplished and developed by a collaborative process between science and design. Acknowledging a lack of accurate measurements in environmental change due to building intrusion on natural environments, an expert discriminatory analysis may help identify relationships between qualitative criterion variables. A discriminatory analysis gives measures to each interacting variable and delivers a discriminant function.

The discriminant function uses a weighted combination of variables to classify an object, or as in this case, the combination of a specific natural concept. This function is therefore a derived rating defined as the weighted sum of values on the individual interaction measurement (Lein 2003, p.109). The rating reference to establish different levels of change[57] is borrowed from the notion of a landscape's capacity to embrace changing forces, and its derived consequences (See table 5).

Table 5



Until higher sophistication is achieved in measuring environmental change, especially through interdisciplinary analyses, expert judgement remains the most valuable resource. Different techniques allowing systematization in collecting expert judgment evaluations may be taken into consideration, as well. One of them is the *Delphi* method, which was developed to structure and quantify expert opinions into something meaningful and to increase the effectiveness of experts making forecasts as a group (Lein 2003, p.206). Referring to Figure 52, following the procedure of natural concept interaction

[57] See figure 42 in **CHAPTER III, Temporal Scale in the Function of Change**, p.75.

analysis (A), a *discriminant function* is applied to any possible combination of functional concepts (B) engaged in each of those interactions, and an overall weighting for the given scenario is performed (C).

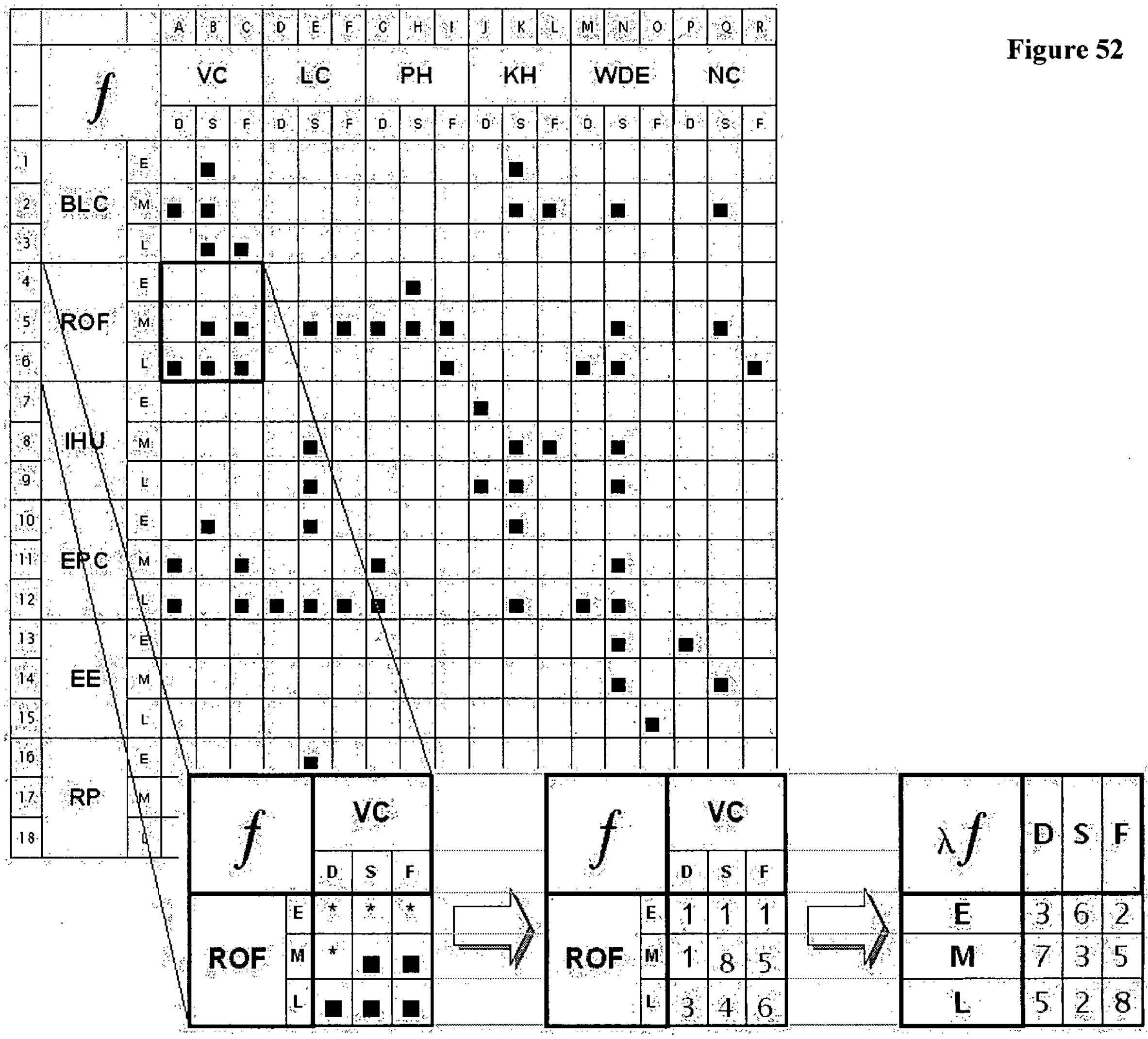


Figure 52

A B C

...where each overall function, say, ED, MS, LF, etc, is defined as:

$$f\lambda \ ED = \beta_1 \ [ED] + \beta_2 \ [ED] + \ldots \beta_n \ [ED] \ / \ \eta\beta$$

$f\lambda$ = function discriminant value

$\beta_1, \beta_2, \beta_3 \ldots$ = weight value associated to each functional interaction (i.e., β_1[ms]=8)

$\eta\beta$= Number of key natural factors' interactions

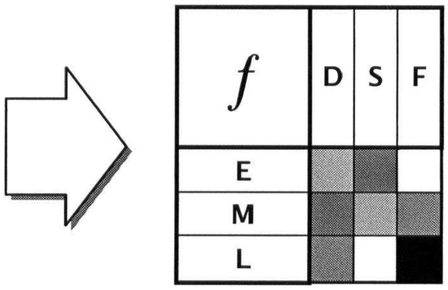
Ed= energy perf. | Disturbance

*NOTE: WHEN ENVIRONMENTAL CHANGE IS NOT PERCEIVED, IT IS DEFINED AS MINIMAL (1) ASSUMING THAT SOME LEVEL OF CHANGE ALWAYS OCCUR.

The final discriminant value of these stressor-receptor combinations can be synthesized and graphically expressed either in terms of their precise weighting, or as moderate, severe, or drastic environmental changes[58] and its assigned grey shades (See figure 53).

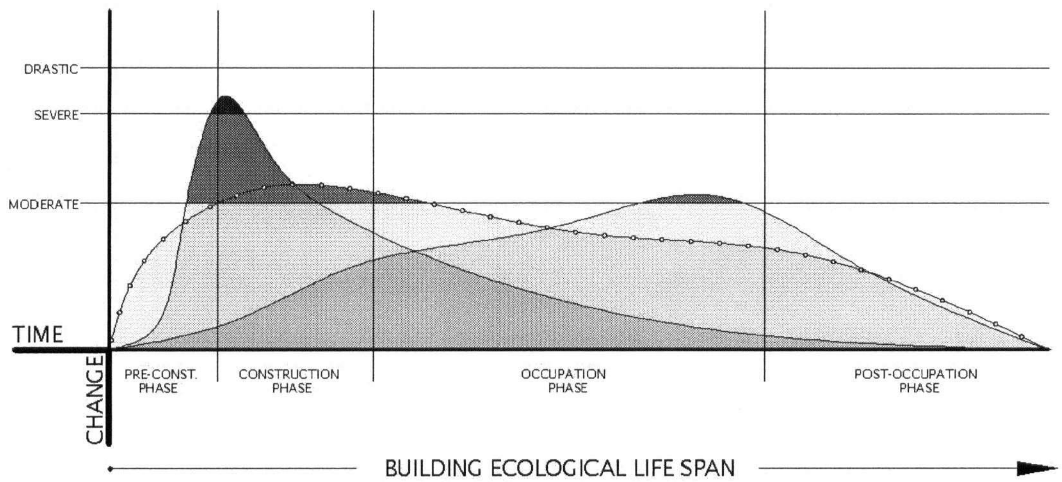
Figure 53

f	D	S	F
E	3	6	2
M	7	3	5
L	5	2	8



Assessing the actual ecological performance of stressor-receptor interactions requires acknowledging present and potential conditions of change over time. Recognizing change dynamics in time may help to establish accurate strategies for ecological mitigation and/or restoration at the adequate phase of change. Either focusing on the natural conditions (receptor sensibilities) while facing changes, the proper conditions of the changing factor itself (stressor constraints), or both, specific patterns of dynamic change will occur and eventually differentiate one from another, and thereby awareness of such patterns is required to propose successful procedures (See figure 54).

Figure 54



[58] The proposal is extremely selective regarding the functions of interaction, resulting in a method of simplified representation. However, keeping the method simple may be more helpful in evaluating environmental change by addressing the limits of change, rather than exhausting energies using accurate measuring methodologies.

If scenarios of change are properly anticipated, such strategies may regard cases where a stressor's layout is fixed in which case the suitable landscape sensibility has to be found, or where a stressor's location is pre-determined, in which case the suitable building configuration for that location has to be properly designed.

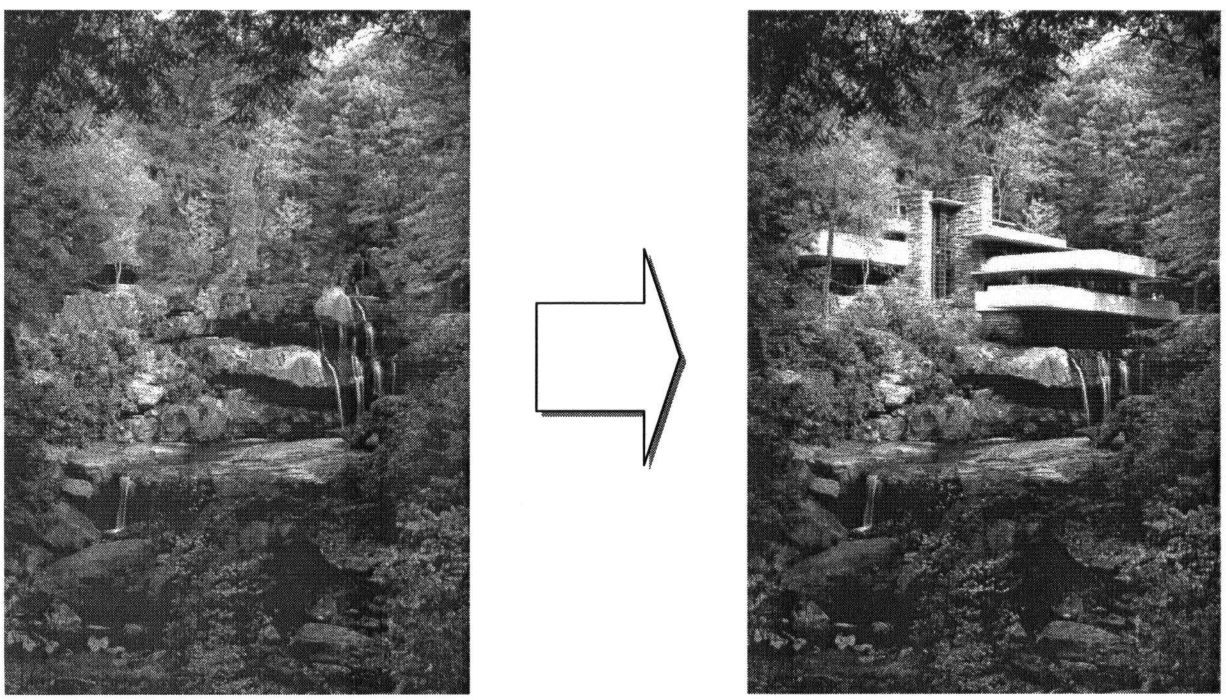
Thus some aspects of the landscape may be suitable for development due to a correct synchronization between low constraints and a strong persistence of critical ecological attributes. However, levels of constraints that will not harm appropriate levels of ecological integrity of the natural environment must remain within limits. Such integrity can be generally defined as a mosaic of plants and animal communities consisting of well-connected, high-quality habitats that support a diverse assemblage of native and desired non-native species, the full expression of potential life histories and taxonomic lineages, and the taxonomic and genetic diversity necessary for long-term persistence and adaptation in a variable environment (Graham 2001, p.507). Environmental constraints on development may exist in the specific area of the project, or in areas surrounding the site. The extension of the interactions between the site cluster and broader scales of time and space will be determined by both the boundaries of analysis and the nature of the function under study. For instance, if a previous analysis of landscape natural factors determines that high levels of sensitivity to stress and cumulative impacts are present, then the time scale of analysis should be expanded to match the cycles of resisting attributes of the natural system.

Likewise, life cycle analysis for buildings may become critical in order to define the actual performance of a structure over time, and whether changes of the structure, types and intensity of use, energy inputs and outputs throughout its life span, and allocation actually match the history and projection of those natural cycles. "Landscape evolution is based on the dynamic interaction between structure and functioning and also on history, which makes each landscape unique" (Antrop 2000). If a building layout and its environmental performance consider the landscape structure and functioning as a reference of configuration and performance, then the building becomes unique to that particular place.

As an analysis tool focused on the trade-offs between human structures and undeveloped landscapes, this method is intended to provide a diagnostic tool for interpreting a resulting interaction, and not simply a mapping procedure for a current situation.

3.3 SUMMARY

The problem of buildings intruding in natural environments described in Chapter I, and the conceptual integration of natural and artificial factors within a unique process of environmental change explained in Chapter II, ultimately became embodied in a method of environmental change characterization. This method expresses the ideas and goals of an environmental assessment that promotes analyses of functional interaction between an artificial stressor and a natural receptor as forming part of the same function of change: the new environmental change regime. Moreover, this thesis assumes that every time a particular landscape is intervened by buildings, preservation is not an option. In fact, the thesis' approach assumes that every time an ecosystem is intruded, something changes, whether that change is noticeable or not (See figures 55 & 56).



Figures 55 & 56: Falling water house, Frank Lloyd Wright (Chez 2002, modified by the author)

Therefore, inherent natural characteristics are not preserved. Processes of change have been identified as intrinsic to nature and should be addressed every time an intervention is agreed to occur. By doing so, an intervention recognizes the dynamics of the place, and the relationship between the building and the host ecosystem become truly unique, which represents both an ecological and an architectural goal.

Regardless of the framework summarized below, it is important to emphasize that the core objective of this thesis is to promote an integrated collaboration between science and design with a goal of solving the problem of dysfunctional intervention of buildings in natural environments. Hence the method is presented only as a systematic expression of such collaboration, and therefore stands as a broad example for other potential applications in integrated environmental planning and design.

Phase 1 consists of formulating the function of change. Summarizing existing conditions and providing critical background information to help improve basic understanding of the area that will be affected configures the initial approach of the method. Since both the building and the landscape are considered to be participating factors in the same function of change, the inclusion of expert professionals from each discipline is necessary to perform a careful collection and selection of data that will effectively characterize the participating factors, and lay the groundwork for further interaction analyses (See figure 57). In other words, the formulation of the *problem of intervention* takes place. Building issues like envelope materials, roof slopes, physical footprint, energy consumption, unit

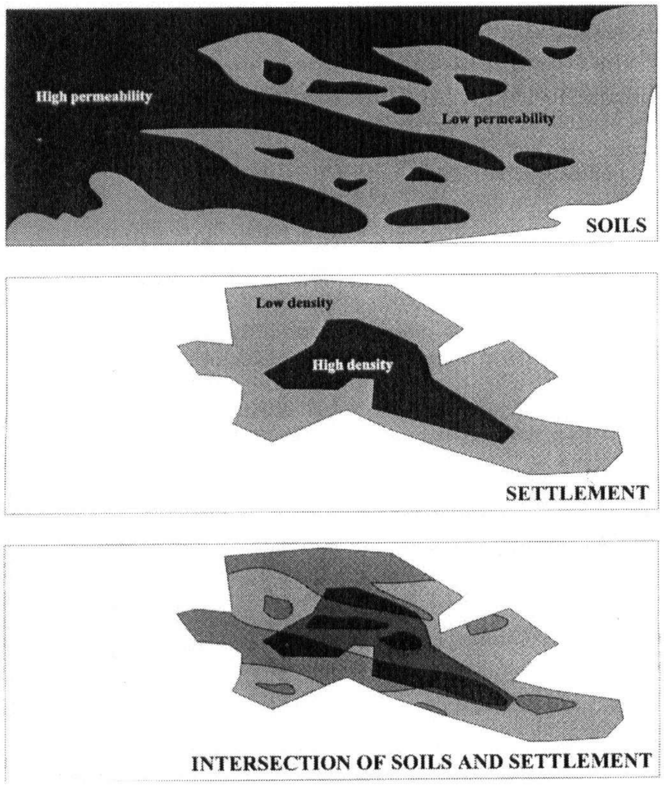


Figure 57. Identification and intersection of system related issues. (Modified from Turner 1998)

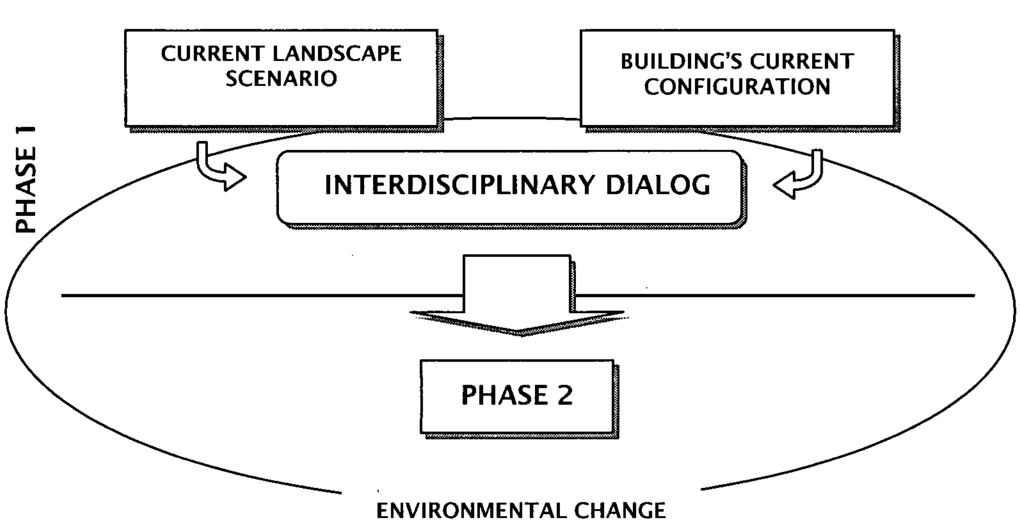
connection to the ground, densities, water recycling mechanisms, etc., are all aspects of the building that can only be reported and assessed by design professionals. Likewise, nesting seasons and areas, migration corridors, soil permeability, predator-prey relationships, rainfall rates, etc., are all natural issues only identifiable by experts in the field of ecology.

This process of definition, description and documentation of the problem should include professionals with expertise directly related to the level and type of problem under consideration and the ecosystem where the problem is likely to occur. The problem formulation should also include development goals such as successive expansions of the project, and management purposes such as ecological restoration procedures, conservation of particular natural cycles such as nesting seasons, etc.

The overall purpose of the first phase is to achieve a progressive individualization of key natural concepts describing ecologically active features from both the natural and artificial system. Such ecological features are assumed to be eventual factors in the function of environmental change and their integrated assessment becomes the base for **Phase 2**.

The inter-relevance of every natural concept is defined by an interdisciplinary dialog between experts in an agreed context of environmental change (See figure 58).

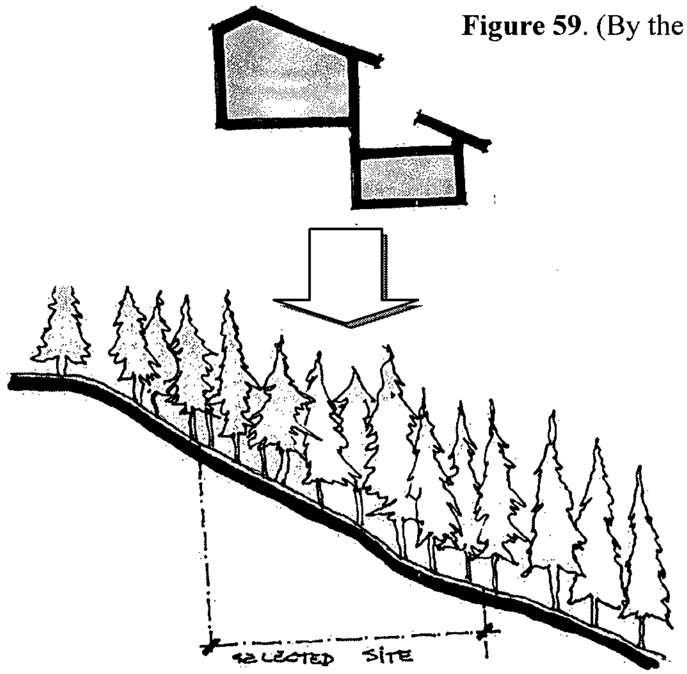
Figure 58



Having defined the natural concepts for the artificial system (the stressor) and the natural system (the receptor), the integrated assessment of possible interaction between both is performed in **Phase 2**: Functional Evaluation. In a simplified manner figure 59 shows the aim of a development process to place a particular building on a slope.

If the selected site is fixed as a mandatory requirement, then the building assumes responsibilities over the local environmental change regime, regarding functional interaction between building natural concepts such as storm water runoff (ROF) speeds and enclosure configuration (EC), natural concepts such as Physiography (PH), landscape connectivity (LC), soil permeability and stability, on-site rainfall rates, vegetation cover (VC), etc. Using table 3 from page 82 (see figure 60), such contacts should be understood as interacting and affecting one other [59].

Figure 59. (By the author)



f	VC	LC	PH	KH	WDE	NC
BLC						
ROF	■		■		■	■
IHU						
EC	■	■				
EE						
RP						

Figure 60. Example of interactions' identification

In such site conditions, recommendations on emulating the slope so the building will not

[59] This exercise is only an example intending to show the connection regardless of any other potential interactions

contrast natural features are usually proposed (See figure 61) in ecological design practices (Mehta et al. 2002).

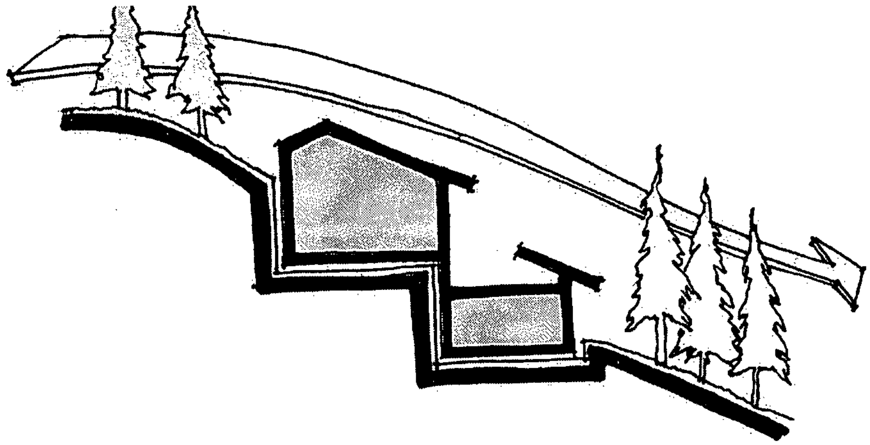


Figure 61. Traditional approach in Ecological Design (By the author)

However, emulating slopes with a given natural percolation factor by using impervious surfaces such as those usually associated with building envelopes, although aesthetically coherent with the surroundings, may increase runoff speeds and consequently develop a higher risk of erosion down the slope. Because roofs tend to be smooth and steeply inclined they have fast rainwater discharge (Turner 1998, p.304). In other words, although this building uses the same slope, this envelope proposal will actually increase runoff, and therefore erosive velocities will develop further down the slope.

In order to more accurately assess this potential environmental change, the method uses Table 5 (see table reference, page 83) in order to identify what has been called *landscape functional sensitivities* and *building functional constraints*. Thus for the interaction between building runoff (ROF) and landscape physiography (PH), a collaborative team may determine that changes in the landscape may be compromised due to functional interactions such as:

► the building's **morphology** (roof slope, envelope materials, physical footprints or forest clearance extension) will be compromised:

- **Disturbance** (in this case abrupt erosion) due to a dramatic increase of erosive velocities during major rainfall. Individual construction sites can contribute massive loads of sediments to small areas in short periods of time. (Kaufman 2000)
- Some **stress** due to changes in the local hydrology due to increased stream sedimentation throughout time, even due to minor rainfall events (the soil has lost permeability because of new impervious surfaces on site).
- Landscape **fragmentation** may occur due to erosion of the vegetation cover

► the building's **location** will also determine erosion paths (landscape **fragmentation**) depending on topography and soil composition. In combination with other natural conditions, location will also modify the extension and magnitude of potential **disturbance** and **stress** events. Serious stress events may take place when selected sites are located near riparian ecosystems or on the slope of nearby streams.

► in this particular situation, the interdisciplinary team may determine that there are no functional interactions between the stressor's energy performance and the receptor's physiography.

Being defined as such, functional interactions can be expressed as in table 6 to determine a scenario projection. Continuing with the expert assessment, an evaluation contrasting this scenario with a discriminant function for environmental change may determine that runoff must be somehow decreased. Otherwise the landscape down the slope from the site will be entirely replaced due to exceeding on-site ecological integrity attributes and therefore seriously affecting both the forest and the nearby stream's structure and functioning. Moreover, development goals may require maintaining location conditions due to pursued vistas and aesthetic value. The overall process of projecting and evaluating scenarios of environmental change forms part of the **Phase 3** within the method. As a

f		PH		
		D	S	F
ROF	E			
	M	■	■	■
	L	■	■	■

Table 6

conclusion of such integrated assessment, the building's morphology should be carefully addressed as responsible for adhering to landscape constraints. If concluded thusly, a number of design strategies can be implemented, such as changing the roof slope direction, designing water retention and drainage systems and incorporating vegetated roofs that will reduce the rate of discharge (See figure 62).

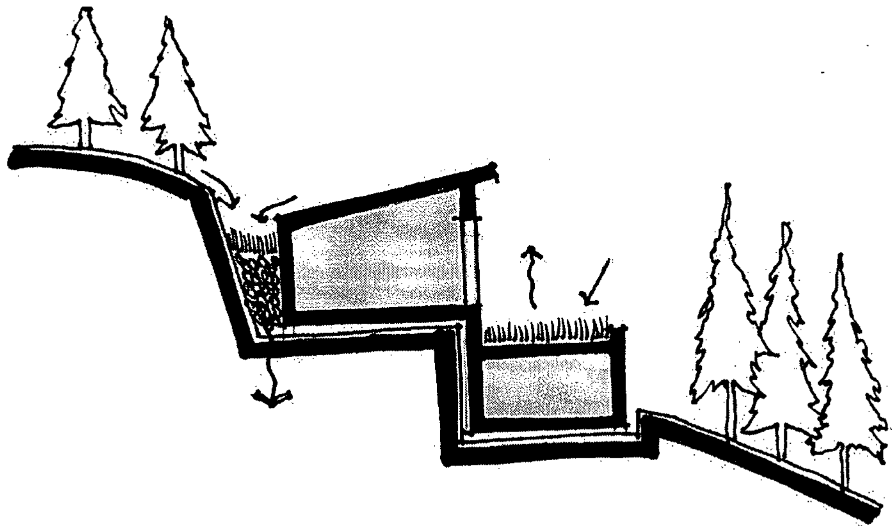


Figure 62. Design response addressing local environmental change regime (By the author)

As a result of this procedure, trade-offs can be identified and proper strategies arranged and designed accordingly. It is important to keep in mind that avoiding intrusion should also be considered as one of the possible alternatives, if other alternatives do not meet ecological integrity requirements. On the other hand, ecological enhancement is possible to achieve if proactive planning and design strategies are considered and implemented after accurate analyses of the environmental change regime.

CHAPTER 4

Conclusion

4.1 CONCLUSION

"Sustainability is not an adjunct to the architectural idea, it is *the architectural idea."*

(Johns 2003)

This thesis examines the degenerative processes of planning procedures and buildings intruding in natural environments as the result of a dysfunctional social value of nature. Alterations to the landscape are assumed to embody a notion of detachment of artificial processes from those of nature, considering the last as both the source of economic benefit and the sink of waste as the current by-product of human entropy processes.

Attention to the socio-cultural approach to the natural phenomenon of landscape modification aims to explain unexpected changes in the natural environment by exceeding ecosystem health attributes, even when complex environmental assessment procedures have been performed. As urban demands for available land and the need for natural resources increases and diversifies, a balanced relationship between built and natural environments, the former depending on the latter, becomes a growing challenge.

The likely isolation of "social" artefacts intervening in previously undeveloped natural environments is examined to stress the functional interaction between natural and artificially contrasting systems as developing a new environmental change regime. This thesis proposes a systematic analysis of those functional attributes within each system that would ultimately evidence environmental change.

Yet, this "new" environmental change regime is not evaluated under any qualitative judgement (therefore notions such as impact, depletion, damage, collapse, etc, are avoided). This new regime is conceived instead as a phenomenon of specific spatial-temporal scale characteristics where different natural and artificial factors converge into a unique process of land modification. Once the intervening factors have been analyzed and the interaction specified, a coherent process of decision-making including environmental planning procedures and architectural design can be completed. Hence such planning, design, and implementation processes can be based upon well-informed agreements regarding the type and magnitude of environmental change.

The proactive nature of this method encourages multidisciplinary teams to carefully examine the functional characteristics of a proposed project before committing to unforeseen and irreversible changes in the landscape.

As an overarching methodology the problem of inappropriate environmental change is addressed by a conceptual and functional dialog between scientific and design disciplines. This dialog is not only aimed at design and scientific disciplines sharing a base vocabulary but also at integrating environmental assessment methods that would address both artificial and natural dynamics as factors for the same function of change.

Indeed, the latest paradigms in ecological thinking and arising disciplines from scientific fields such as Landscape Ecology are scrutinized and their analytical procedures synthesised in an effort to inform the design process of its responsibility in the overall process of environmental change.

■ Ecological Thinking in Design: A Dialog Challenge

Revisiting core concepts from scientific fields and especially understanding how theories about the natural environment are constructed have been a driving strategy within this thesis to specify the potential and actual role of design within processes of land modification. Among these concepts, the vertical scope of ecology and horizontal scope of Landscape Ecology have been reviewed and discussed (Chapter II). Certainly, planning and building endeavours have the potential to affect such dynamics, and coherent evaluations of such interventions may have the chance not only to maintain natural dynamics but also to enhance them. Recognition that Ecology is "…the scientific study of the interrelationships among organisms and between organisms, and between them and their living and nonliving environments" (Poole et al. 2001), should be internalized into design fields so that their physical outcomes are addressed as another component within ecological systems.

Disciplines such as Landscape Ecology, Conservation Biology, Restoration Ecology and Ecosystem Management have already demonstrated that they have developed and are still developing different ways of embracing change, while conserving the integrity of natural systems. Indeed, many of these disciplines present opportunities to improve the intervention of artificial systems in the natural environment by emphasizing the concept of *matrix management*, where large tracks of land are functionally linked to interstitial resources and processes, and the latter with areas of greater human use. (Johnson et al. 2001, p.330) This approach may also work in other settings, such as those with no previous development, which are therefore more sensitive to interventions.

For the purpose of understanding a new ecological paradigm that entails building interventions in the natural environment, this thesis has arbitrarily defined the boundaries of the receptor system, and proceeds to "...treat the various forces as either endogenous or exogenous to the system." (Sanderson and Harris 2000, preface) To do this, this thesis fixes the spatial and temporal scale of analysis for stressors and receptors, both as converging factors of a unique environmental change regime.

The growing overlap of environmental subjects has encouraged this thesis in promoting a common ground of analysis and understanding for both scientific disciplines and design processes not (traditionally) involved in environmental evaluations. In fact much of the discussion proposed herein came out of the question of how designers can plan their built interventions in nature without endorsing, consciously or unconsciously, the spread of a degenerative artificial dynamic.

Thus the core intent of this thesis is not only to develop an evaluation procedure but also to offer an integrated vision of an ongoing and yet dysfunctional relationship between building interventions in natural environments and those ecological features most likely to be affected by this expansive wave of artificial systems, regardless of any ecological sensitivity or sense of place.

This sense of place has been arguably misunderstood by the latest approaches in architectural design. In the recent past environmental problems driving ecological awareness in design have mainly been viewed as global in scope. Such an approach distances designers from the problem of placing responsibility for local environmental problems on a global abstraction beyond the building and the affected site. Although the overall effect of human performance may be reflected at this large scale, the starting point for such problems is closer and ultimately the consequence of dysfunctional designs upon natural environments we usually ignore as such.

■ The Proposed Functional Evaluation Method of Environmental Change

A straightforward conceptual synthesis from both ecology and design has been purposely developed without expecting much of a consensus, but seeking dialog between these disciplines. As such, they face common issues and yet, usually perform in relative isolation. Inferred from the complexity of natural dynamics, no set of methods is likely capable of addressing the multiple landscape processes in time and space (functioning factors, controlling dynamics, attributes and resources) especially when facing building interventions within pristine land, fragile vegetation structures and water resources. Indeed, human designed systems add new layers of complexity and disruption upon already autonomous and complex natural systems. An integrated evaluation method that embraces available knowledge from participating disciplines is proposed as a first step towards addressing such complexities. This method does not intend to replace existing and currently fashionable environmental assessment processes, but to enhance and to broaden the scope of the analysis.

This broader analysis pursues a desired balance between built environments and nature integrating *landscape functional sensitivities* (receptor) and *building functional constraints* reciprocally interacting within the same function of environmental change. This method of integration requires assembling technical, scientific, and design information, which although still lacking higher levels of sophistication and accuracy can be derived using readily available techniques. Again, the problem is then conceived of as a consequence of our dysfunctional relation to nature rather than as a technological struggle. In other words, this thesis recognizes the relative value of existing knowledge and available information through embracing adaptive learning and knowledge feedback loops in environmental analyses, while detailing a holistic scope that recognizes a cultural disposition towards nature as the root cause of further human initiatives dealing with the natural environment.

The processes described in this method take into account linkages to critical functions of the landscape such as those supporting riparian corridors, nestling time-spans, or drainage capacities of the soil, along with nature-friendly building practices that promotes habitat enhancement and reduces energy inputs and disposing outputs. In addition, further environmental evaluations such as environmental impact assessments (EIA) can be scrutinized and based on more accurate proposals, reducing unexpected amendments resulting from environmental evaluation procedures.

The goal is to develop proper assessments encompassing entire landscape systems, and to avoid the isolation of functions and components, which usually feed and constrain evaluations on the interaction between natural and artificial systems in space and over time.

Although a simplified methodology is suggested, this thesis acknowledges that every time prediction is attempted, the desired accurate scenarios are somewhat impracticable. Thereby exact measuring of functional interactions is not part of this thesis; rather the attention is placed on a general criterion that pursues versatility and integration.

■ **One Scenario, Several Options**

The scope of this thesis implies that the fact of buildings intruding on natural environments is not necessarily equal to "impact". Instead, this thesis defines the problem as *unplanned environmental change*. Accordingly the problem is addressed by finding alternatives in planning and design, regarding the constraints imposed by attributes of ecological integrity, in balance with goals and objectives of human development. Presented as such, the goals of building intervention in nature can be achieved in more than one way. In fact, the purpose of planning has been described as " the process of allocating functions to their appropriate spatial location… [therefore]…providing an important point of departure from traditional planning approaches and suggest[ing] room for an alternate strategy" (Lein 2003, p.23). "For any facility there are a number of alternatives locations, and for each these are a number of potential development patterns that can result" (Jameson 1976, p. 7-31). Hence the method proposes a straightforward framework where:

► a complete natural characterization of the systems about to interact is performed

► a thorough analysis of functional interactions in the affected landscape

► a projected scenario of change is attempted

► trade-offs between stressor and receptor and its alternatives are defined, so they can inform further strategies aimed at avoidance, mitigation, or restoration and enhancement of environmental change scenarios.

Yet this research accepts and hopes that a definitive sophistication of this method will be eventually accomplished once a collaborative process between science and design specifies accurate indicators for functional combinations. An integration of disciplines is again advocated and this research is another step toward understanding the functional interrelationships existing between built environment and nature.

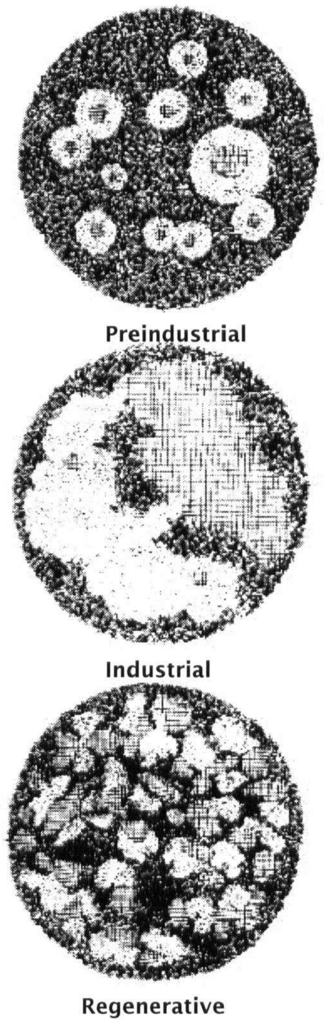
■ Urban and Building Environmental Responsibility Towards Natural Environments

Considering the ongoing demand for available land, overall built intrusions in natural environments are assumed to be unavoidable. Situations with direct connections between built and natural features are not only understood to be the result of further expansions of urban settlements but also as the interface between nature and the urban form within cities. Thus, in bringing nature into urban environments or extending urban environments into natural environments, a thorough understanding of this dual interface is pursued.

Although focusing on isolated interventions in nature may lead to false assumptions, the method conceives human interventions as narrow disturbances in the landscape at first and then causing broader environmental change across larger natural systems. Conceived as such, a sustainable approach to planning and design as the overarching environmental criterion is promoted whenever the built environment meets nature. At regional scales, the edge of the city would be improved through incorporating environmentally qualified buildings at each urban expanding stage. An appropriate environmental planning and design process may reduce human structures' ecological footprints significantly either in isolation or as part of a larger urban-nature interface.

Different patterns in urban development previously researched established that buildings would in one way or another continue to penetrate natural environments. Outcomes of land use conversion have proved that isolated structures in nature can not only provoke environmental change but that they also cause what has been called growth-inducing impact [60]. "The forms and extent of urbanization, including density of population and internal patterns of functional areas and land uses within cities, are the result of two contrasting vectors or forces which operate concurrently but with varying intensities with respect to each of the urban functions." (Mayer 1969) Ongoing and arising urbanizing phenomena such as urban sprawl and counterurbanisation have thus proven to promote an uneven scattered system of built clusters across natural landscapes or in-between cities, which has established unprecedented rates of land consumption without necessarily increasing population densities. Considering the urban form as supporting the system than enhances our quality of life, it becomes an attractive force leading to multiple forms of built environment (Lein 2003). Even under new compacting policies for built environments further intervention of built matters into natural environments is assumed as a continuum and as an intrinsic part of a city's dynamics. To revert dysfunctional expansions of the urban boundary this thesis advocates a "regenerative" (See figure 63, Lyle 1994) integration of natural and urban forms under reciprocal functionalities (See figure 50 in page 86).

Figure 63



■ **Ecological Awareness in Architectural Design**

If the final artificial intervention's layout and its consequent environmental performance considers the landscape structure and functioning as an integral part of the building system, then the

[60] "Such an impact can be defined as the degree to which a project promotes, facilitates, or provides for the increased urbanization and development of the environment surrounding the project" (Lein 2003, p.207).

building becomes unique to that particular place. If both systems, natural and artificial, are to eventually overlap, then building issues such as morphology should embrace more passive means, not only to mitigate changes on-site due to the juxtaposition of high contrasting systems but also to encourage, as much as possible, local dependencies of the building on local natural processes (hosting functions).

The opportunity presented by understanding simple functional concepts of reciprocal dependency between an artificial system and the natural environment enables designers to approach their projects with higher levels of ecological awareness. Thus the architect may embrace a proactive position towards green endeavours and environmental planning by taking active part in interdisciplinary teams evaluating complex environmental dynamics. In other words, introducing the notion of buildings as factors in the function of environmental change promotes a redefinition of the designers' conceptualization of nature from a resource-based approach to a more holistic understanding of their designs' responsibility towards fragile natural processes.

Our built interventions in nature have the opportunity of not only mitigating potential and traditionally unexpected changes in the landscape but also of enhancing those ecological attributes that stimulate the process of intervention in the first place. Maintaining ecological integrity is not only conceived of as a critical requirement for healthy ecosystems but also proposed to be an added value to the built environment. Moreover, balancing the limits of ecological integrity with the requirement of the built environment is presented as the ultimate exploratory approach in pursuing the economic, social and spiritual benefits of nature.

I firmly believe that the natural environment does not need us, especially considering the temporal scale embodied in ecological cycles. Rather, we need nature. Human culture is indeed supported and shaped by intricate natural functions, and the "health" of these processes guarantees our very own. By embracing a profound understanding of this functional dependency on the larger natural system, a "sustainable synthesis of nature and culture" (Forman 2001) may hopefully be accomplished.

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APPENDIX I: Key Concepts in Landscape Ecology

Landscape Ecology defines landscapes in terms of *structure*, *function*, and *change* (Forman 1999), and one of the fundamental premises articulating the theory is that structure influences function and vice versa. Consequently, their interactions lead to change over time (Johnson et al. 2001, p. 314).

According to Forman and Godron (1986, pp.11, 24-8), these concepts are articulated in three core landscape characteristics, as follows:

■ **Structure** of a landscape is the spatial relationship among the distinctive ecosystems or "elements". Patches, corridors, and matrix always compose the structure of the land, or *land mosaic*:

**Patches* are defined as non-linear surface areas differing in appearance from its surroundings. They can vary widely in size, shape, type, heterogeneity, and boundary characteristics (Forman and Godron 1986, p.83).

**Corridors* are narrow strips of land, which differ from the matrix on either side. They might be isolated, but are usually attached to a patch of somehow similar vegetation or structure (Forman and Godron 1986, p.123).

*Among the landscape elements, the ***matrix*** is configured by the most extensive and most connected landscape element type, and therefore, plays the dominant role in the functioning of the landscape (i.e., the flows of energy, materials, and species). Landscape configurations may vary from highly homogeneous matrix containing scattered distinct patches, to highly heterogeneous composed of small patches that differ from one another (Forman and Godron 1986, p.157-9).

The ecological objects, such as animals, plants, heat energy, etc., are heterogeneously distributed among these landscape elements, which in turn vary in size, number, type, and configuration. Determining these spatial distributions is to understand landscape structure.

■ **Function.** The continuous movement or flow of the ecological objects between landscape elements defines the *Function* of a landscape. Determining and predicting these flows or interactions among landscape elements, is to understand landscape function.

■ **Change**, the alteration in the structure and function of the ecological mosaic over time is strictly related to the cycle of disturbing events, modifying the relationship between ecological objects and the landscape elements. Where undisturbed landscapes tend progressively toward homogeneity, moderate disturbance rapidly increases heterogeneity, and severe disturbance may increase or decrease heterogeneity. As opposite to change, **Stability** of the landscape may increase at (a) the physical level (characterized by the absence of biomass), (b) with rapid recovery from disturbance (low biomass present), or (c) with high resistance to disturbance (usually high biomass present).

APPENDIX II: Some Suggested Key Natural Concepts Characterization

Key Natural Concepts in Landscape Dynamics

• **Vegetation Cover** is one of the landscape components more related to land use or environmental change, and perhaps the most affected by direct physical human perturbation (Marsh 1998, p.338).

Classification of vegetation communities may help describing and classifying suitable habitats for animal communities. Key status of vegetation cover, as a base notion of functional support of ecological integrity processes, relies on the several sub-functions depending and supporting its existence and configuration (See figure A & B).

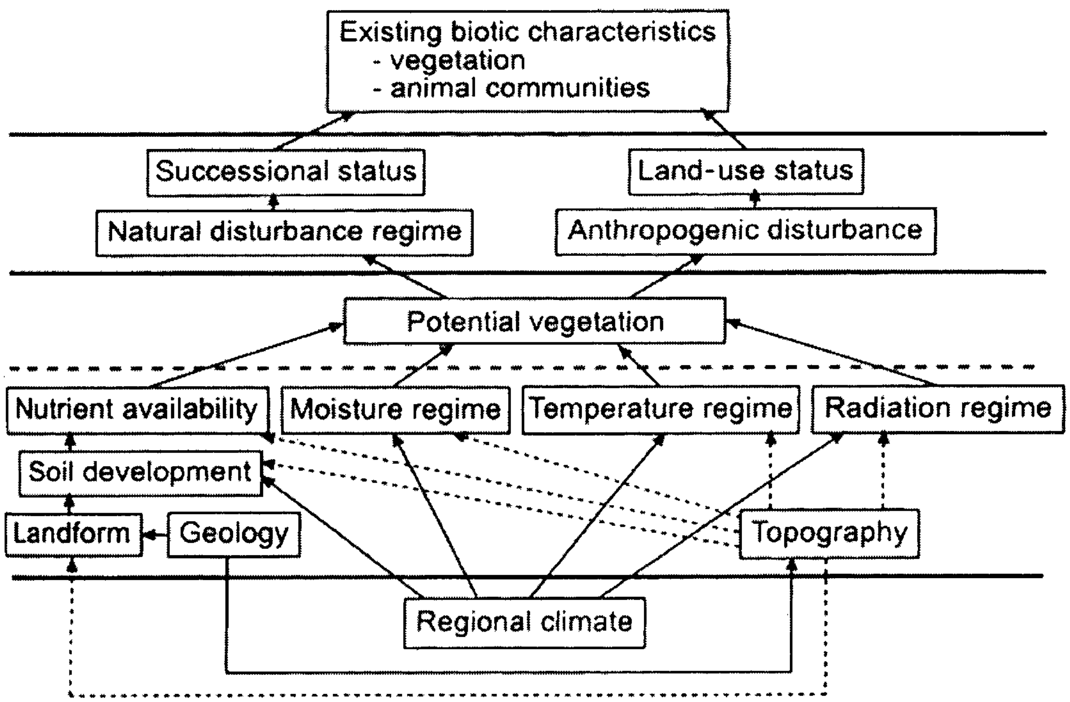

Figure A. Source: (Jensen and Bourgeron 2001,

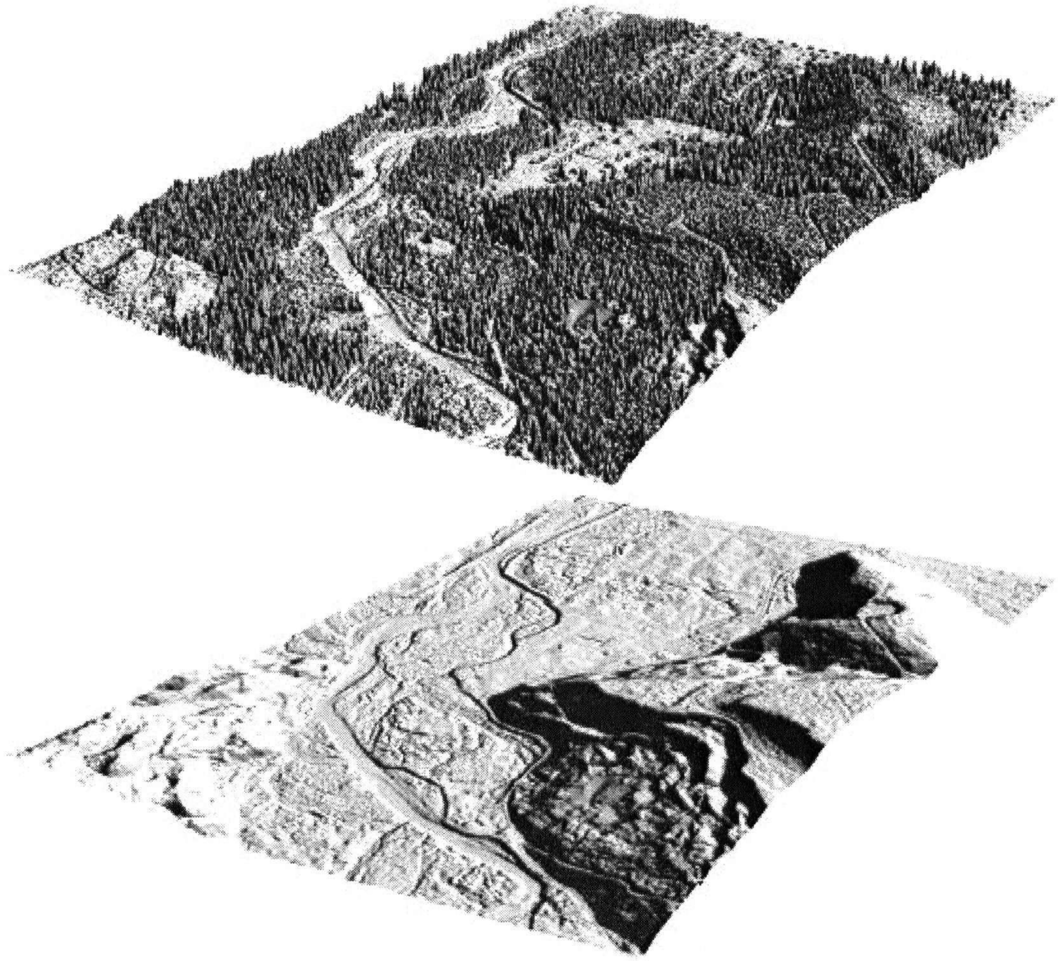

Figure B: Source: The figure shows perspective views of the canopy top and the underlying "bald Earth", derived by filtering the data to remove laser returns from vegetation and buildings. The images are produced from digital elevation models at 1.8 m spatial resolution and depict an area 2.1 x 1.3 km in size. The "bald Earth" image reveals a previously unmapped landslide deposit that was hidden beneath the vegetation cover. (Geodynamics 2001)

This prevalent complexity of vegetation cover due to change processes in time "...superimposes a pattern of various successions stages" (Klijn 1991), and therefore, embodies relevant information regarding landscape responses toward past perturbations at different spatial and time scales. The nature and relative importance of these processes will likely vary across landscape and time (Blois, Domon, and Bouchard 2001), but certainly, removal of existing vegetation preceding most kinds of construction activity (Treweek 1999) may be considered as a critical structural modification.

• **Landscape Network Connectivity** is defined by Forman and Godron (1986) as the structure spatially supporting the matrix[61]. The degree to which all nodes in a system are linked is defined as the simplicity or complexity of the network (See figure C). The notion of connectivity plays the dominant role in the functioning of the landscape (i.e., the flows of energy, materials, and species) (Forman and Godron 1986, p.159) and is central in assuming ecological integrity. For instance, small patches may lose species at a higher rate than larger ones; connections between patches reduce rates of species losses, and can eventually enhance re-colonization (Collinge 1998).

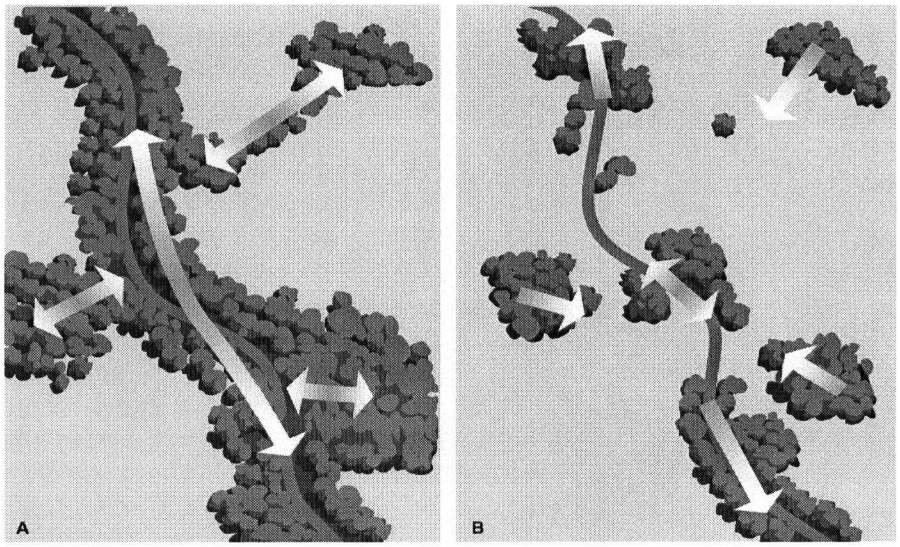

Figure C. Landscapes with (A) high and (B) low degrees of connectivity. A connected landscape structure generally has higher levels of functions than a fragmented landscape (FISRWG 1998)

Hence, as a quantifiable spatial structure supporting qualitative landscape attributes, high levels of network connectivity become a useful referent point, when it comes to assuming ecological integrity and inferring further impacts due to future artificially induced gaps in the network.

• **Keystone Species Distribution**

Only recently the relationship between ecosystem function and biodiversity per se has been addressed experimentally. Now is clear than a certain number of driver species are needed to maintain ecosystem function, and it is becoming obvious that loss of species does influence ecosystem function (Bolger 2001).

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[61] See **APPENDIX I**: Key Concepts in Landscape Ecology

It is also possible to select one or more species and an ecosystem process to represent larger functional community or ecosystem processes (EPA *Ecological risk assessment* 1998). These can be called *keystone* species[62], though its exact definition may vary as much as the value placed upon them by humans. Where does exists some level of agreement is on the notion of "ecological niche, which is the functional role of a species in a community, including the environmental variables affecting the species" (Forman and Godron 1986, p.63). For most species in the community, their influence on other members of the community will be roughly proportional to their biomass in the community. Those species with the highest biomass are called the "dominant species" and are usually competitive dominants. However keystone species have the same or greater influence on the community as the dominants, but they differ from dominants by having a very low abundance or biomass (Department of Biology 2002) (See Figure D).

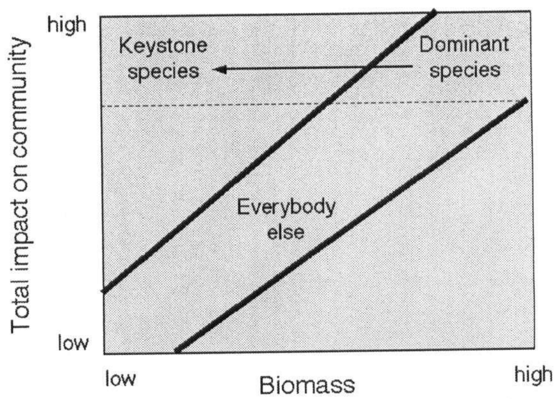

Figure D. Source: (Department of Biology 2002)

Ecologically relevant species often help sustain the natural structure, function, and biodiversity of an ecosystem or its components. They may contribute to the food base (e.g., primary production), provide habitat (e.g., for food or reproduction), promote regeneration of critical resources (e.g., decomposition or nutrient cycling), or reflect the structure of the community, ecosystem, or landscape (e.g., species diversity or habitat mosaic).

Consequently, and regardless the assigned human value, keystone species habitats may be significantly affected by human development.

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[62] According to the current interpretation (Power, M.E. and L.S. Mills. 1995. The keystone cops meet in hilo. *Trends in Ecology and Evolution*, no. 10: 182-4.), keystones are only those species having a large, disproportionate effect, with respect to their biomass or abundance, on their community.
Moreover, those species driving ecosystem processes or energy flows are generally referred as "key" species, but only a few of them are actually keystones.

Key Natural Concepts In Building Dynamics

• Enclosure Energy Performance

If the building envelope is considered an arrangement of technical and physical functions, where energy exchange processes occur back and forth between the natural environment and the indoor environment, then its shape may be suggested to represent one of the key natural attributes affecting its energy performance.

Bearing in mind an integrated notion of openness for both artificial and natural systems, this built boundary exchanging energy becomes not only a building function, but also another ecosystem component. Moreover, depending on exchanging levels of energy, this "new" component may be considered as another function of disruption. Hence, an analysis of the building shape regards the physical envelope as a function component, drawing material or energetic inputs from its environment, building up internal "stocks" and discharging "outputs" back into the environment. If regarded so, designers can find global and operative knowledge about energy and matter exchange enabling them to direct their work toward good energetic solutions. Global and operative approaches build *expert knowledge* about regular building shape trends, even before the project comes into existence and its subsequent singularities (Depecker et al. 2001). According to the study accomplished by Depecker et al., the building configuration is among the main concerns within this expert knowledge. Moreover, optimizing building energy requirement does not only depend on orientation, form and ratio of volume to surface have also great effects (Daniels 1995 cited in Yeang 1999).

This can be clearly seen when building is defined as a high energy consuming structure due to its shape parameters[63]. The high levels of energy and matter exchange will be assumed for the building as a whole, not only due to its explicit energy losses, but also since adequate levels of energy performance will be achieved through other means such closed dependences on site locations[64] (seeking

[63] For more information about shape parameters and energy consumption, also consult: Depecker, P., C. Menezo, J. Virgone, and S. Lepers. 2001. Design of buildings shape and energetic consumption. *Building and the Environment*, no. 36: 627-635.
[64] In fact, a building that do not properly address some given advantages in sun exposure will necessarily need to adapt its physical configuration in order to achieve minimum thermal behaviours, and vice verse.

sun exposures), high performance walls (increasing materials and therefore embodied energy), and relying on more demanding thermal system.

- **Runoff Function**

The rainfall-runoff process is an integrated hydrological system within a landscape, and land-use development substantially alters the spatial heterogeneity of landscape elements, which in turn changes the rainfall-runoff system (Nagasaka and Nakamura 1999). In the case of urban environments, runoff from buildings and streets due rain events may include oil, grease, trash, road salts, lawn fertilizer, lead, metals, and other components that run into surface and most of the time into sewer systems. When rain falls on forested and open, undisturbed land, water goes through its natural cycle. About 30% of the water reaches shallow aquifers that feed plants, another 30% percolates and nourishes deeper aquifers, and approximately 40% is almost immediately returned into the atmosphere through plant evaporation and transpiration. There is rarely any surface runoff. When an area is developed or altered, the way water flows is also changed. As land surfaces are covered with roads, driveways, or impervious surfaces (rooftops, decks, sidewalks, and parking lots), less water can seep into the soil, so runoff increases. This increased runoff is usually channelled into ditches, drainage ways, storm sewers, or road gutters and often ends up in nearby lakes and streams. High flows of water can cause flooding or erosion, as well as increasing sediment in streams and lakes. Fine sediment can also transport nutrients such as nitrate or phosphorus, and pollutants such as sands or salts from icy roads. All of these processes have an adverse effect on water quality.

- **Potential for Re-use**

Material and energy flows are but two different aspects of the same process. Both aspects follow paths from primary natural sources, through human means of management and concentration, and finally dispose back to the natural environment, sometimes in greater quantity (Lyle 1994, p.4) in the form of heat, water and matter waste, and emissions. In this respect it has been argued, that the earth, while being a materially closed system (at practically any relevant level of accuracy), is an open system with respect to energy flows (solar radiation). Therefore, it can be assumed that the availability of materials could pose a more considerable limitation to the sustainability of human development than energy availabilities, at least in principle. A locally obtained material with a low overall embodied energy may also have limited reuse potential than an imported material that can be used several times over (Yeang 1999). Therefore, the use of such materials may be imposing factors of stress over local resources and long-term on site stress due to incapacities for structures' deconstruction and recycling practices. As a consequence, the throughput of materials in buildings, known as materials' life cycle, becomes a relevant issue when determining buildings with a minimum of environmental impact (Thormak 2002). However, materials and energy flows depend upon each other, and when it comes to final building energy performances, it can be seen that materials can be used both to reduce energy flows (insulation materials) as well as to increase the efficiency of material use (as in recycling). Accurate mathematical analysis of building life cycles may add valuable conclusions to final energy outputs into the natural environment covering are of the following aspects:

1- extraction and manufacturing energy use in building production,

2- energy uses in matters transportation during production,

3- renovation and/or destruction,

4- energy uses during erection and demolition or deconstruction, and, finally,

5- energy uses during occupation, maintenance and operation of the building (Adalberth 1997).

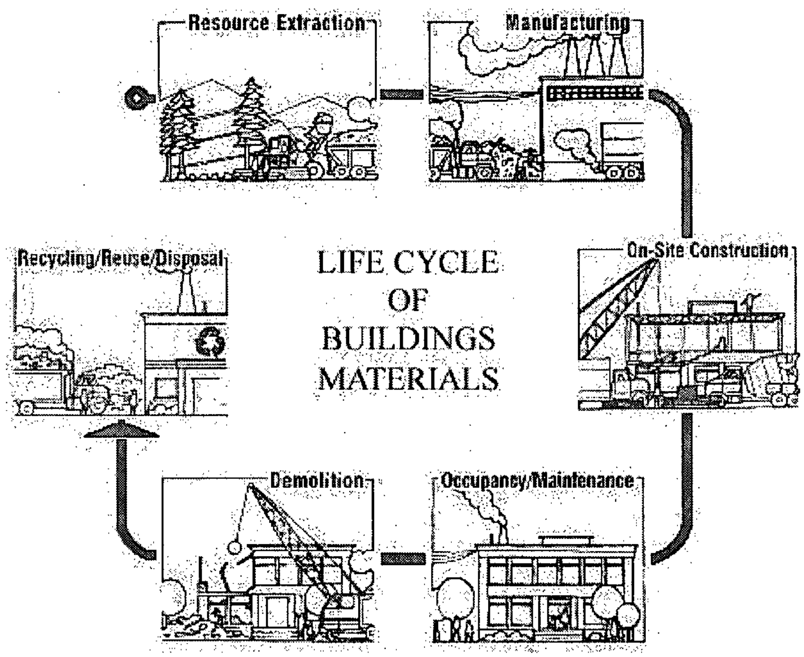

Figure D

This, once again, will not be possible unless detailed information is performed, while the aim of this investigation is to propose simplified models of analysis, especially on prior stages of development and building design. Among the several steps in the building materials' life-cycle analyses (See figure D), deconstructing and recycling processes –as a possible final destiny for buildings– present remarkable opportunities in achieving low final energy requirements, therefore, in reducing final ecological footprints due to excessive energy exchange in the process of building construction, operation and disposal.

Figure E

The study presented by Thormak (2002) suggests that recycling potentials in building design may reduce the embodied energy significantly. Actually, if design strategies include energy efficient buildings in terms of use and operation, the potential energy savings through recycling can be up to 50% of the total embodied energy. Thus, recycling strategies in building design may represent a proper indicator of reduced ecological impact, especially if materials are considered as a human-managed form of energy. On the contrary, that the lack of deconstruction or recycling approaches may impose significant loads of matter input into the immediate natural context due to buildings dispose and abandonment (See figure E).

Following the effort of incorporating building consideration into an ecological perspective the building assessment presented at the round table should regards the notion of entire life cycles as a matter of linear sequence for building performance in time, which are primarily: initiation, design, realisation, operation, renovation, and demolition or disposal (Sa'deh and Luscuere 2001).