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A Theoretical, Interdisciplinary Framework for Environmentally Sensitive Urban Land Use and Development

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Abstract. Environmental problems in urban areas have been increasingly associated with inefficient land use and uncontrolled, low-density urbanization. Thus, one goal of the sustainable city movement is to change land use and development patterns currently deemed wasteful and inefficient. However, many strategies that have been developed over the past decades fail to address urban environmental problems in a comprehensive manner. It is suggested that an integration of strategies from multiple disciplines across different scales is needed. The goal of this paper is to outline a theoretical, but practice-oriented, framework that integrates land use strategies and ideas for environmentally sensitive land use from different fields. It is hoped that such an approach will help to mitigate the shortcomings of a single discipline or strategy in promoting environmentally-sensitive land use patterns and will further the cause of sustainable urbanism.

1. Introduction

Many environmental problems in urban areas, such as pollution, loss of biodiversity, and open space, are attributed to inefficient land use and uncontrolled, low-density urbanization. To mitigate these problems, new concepts for an environmentally sound urbanism are advocated under labels like "green cities," "eco-cities," and/or "sustainable cities" (e.g., Nijkamp 1994, Stren & White 1992, Gordon 1990). The reformed

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sustainable urban areas are to impose less strain upon the environment, mainly through a reduction in resource and energy consumption. An important component of the sustainable urbanism concepts is environmentally sound land use, i.e., denser mixed-use urbanization patterns. Strategies to foster changes in land use patterns, such as environmental impact fees, urban growth boundaries, or transit oriented designs, exist and are being implemented. Nonetheless and despite the enthusiasm amongst planners for sustainable development, progress in curbing inefficient land use patterns is slow.

One reason for the slow progress toward environmentally sound land use may be that strategies to change land use and development patterns can address only single aspects of problems associated with inefficient land use. Strategies tend to mirror either the understanding of a certain profession and their interpretation of the causal relationships in the urban context, or focus exclusively on one land use category, e.g., residential (see Grant et. al. 1996). Environmental impact fees are an example of a narrowly defined strategy leading to suboptimal outcomes. This strategy is based on an economic approach and the premise that sprawling development is the result of artificially low land cost. Impact fees shift the financial burden incurred by development of infrastructure and loss of open space from society to the individual owner in the expectation that the higher cost will reduce land consumption and increase land use efficiency. In reality, however, the introduction of impact fees tends to lead only to the exclusion of lower income groups without changing land use patterns (e.g., Downs 1988).

Kaiser et. al. (1995) feel that policy changes regarding land use need to consider implications for all aspects of urban life and negotiate conflicts of interest as sustainable development encompasses physical, economic, social, and environmental aspects. This would mean that different strategies addressing all types of land use need to be combined and implemented in a complementary fashion. Issues of scale and time must be considered as different strategies address different geographical scales and time frames, not a simple task in an infinitely complex urban environment. Moreover, interdisciplinary cooperation is difficult and often neither emphasized in planning nor in the education and practice of other disciplines.

Frameworks to bridge disciplinary barriers are emerging but often remain at abstract levels (e.g., Nijkamp 1996). A more practical approach would be immensely useful. The goal of this paper is therefore to outline a theoretical but practice-oriented framework that can aid planners in integrating land use strategies and ideas for environmentally sensitive land use from different fields. The framework is to serve as a guide to create integrated packages of land use strategies. It is hoped that such an approach will help mitigate the shortcomings of a single discipline or

strategy in promoting environmentally sensitive land use patterns and further the cause of sustainable urbanism.

The framework is based on three dimensions: 1) costs/implications/catalysts of sprawl, 2) strategies of land use change, and 3) scale. The development process of the framework is reflected in the sequence of this paper's structure. First, costs, implications, and developments that contribute to low-density urban development (sprawl) are briefly reviewed. The review is used to explore the understanding and meaning of sprawl from different disciplines and viewpoints. Instead of trying to isolate a causal relationship or premiere cost of urban sprawl, the framework acknowledges the multicausality and complexity of low-density urban development. Second, land use strategies are evaluated in terms of their main goals and contribution toward environmentally sound urban development. At this point, strategies and ideas from architecture, urban planning and ecology build the core of the framework. In the third section, the framework materializes and its use is demonstrated. It integrates strategies spatially as well as across disciplines to address multiple issues, costs, and causalities. As the framework can be expanded by adding strategies from disciplines other than the ones above, it satisfies a key paradigm of sustainable development - the paradigm of adaptation.

2. Low-Density Urban Development: Costs, Implications, Catalysts

The first dimension of the framework consists of costs, implications, and catalysts of low-density urbanization. Scholarly opinion on the subject is divided. On one hand, it has been argued that urban sprawl is too costly in economic, social and environmental terms to be continued (Ewing 1997, Diamond & Noonan 1996, Real Estate Research Corp. 1974). On the other hand, unplanned urban growth patterns have been recognized as an optimal solution for societies, which put individual choice first (Gordon & Richardson 1997). Both arguments have validity; they reflect the conundrum of weighing individual versus societal values and costs which characterizes the problem of land use patterns and urban development. However, the notion that continued sprawl is leading to unbearable costs for individuals and society is gaining momentum. Some key arguments focusing on the various costs of sprawl may illustrate the magnitude of the problem.

From an environmental point of view, urban sprawl induces environmental costs at many levels from air and water pollution to the destruction of wetlands, wildlife habitat, open space, and fertile agricultural lands. Newman and Kenworthy (1989) and Owens (1986) have raised the issue of increased emission of greenhouse gases due to

low-density settlement patterns. Energy efficient modes of transportation such as public transit, bike and pedestrian travel are typically not feasible in spread-out suburban areas. While environmental costs are borne by society at large, there are spatial differences. Some geographic areas have higher pollution levels than others. The environmental justice literature suggests that certain social groups, e.g., the urban poor, suffer more than others do from environmental pollution. Sometimes economically disadvantaged communities trade environmental protection for economic growth by agreeing to house polluting industries.

Economically, low-density development imposes great fiscal strains on its host communities. Several studies report that infrastructure costs increase as densities decline (Ewing 1997). In many cases low-density suburban jurisdictions fall short in paying their share for road maintenance, water, sewer and emergency services. Middle-class low-density suburbs without commercial tax base have difficulties generating sufficient taxes to provide adequate school funding (Orfield 1997). In addition, the building of new schools, infrastructure, and utilities that may make those already in place in existing neighborhoods redundant (Kelbaugh 1997) represents a waste of physical and fiscal resources.

Socially, we are facing increased spatial inequities and loss of diversity as Americans retreat into the sprawling low-density communities of the rich or are left behind in the ethnic ghettos of the inner city. This kind of separation breeds ignorance and misunderstanding. The resulting tensions can ultimately lead to the kind of violent confrontation we have seen in the riots of Los Angeles or Detroit in the past (Kelbaugh 1997). As for psychological costs, Ewing (1997) points to access and environmental deprivation. Access deprivation affects the elderly and poor who experience severe isolation in the car dependent suburbs. Environmental deprivation refers to the lack of activity and stimuli in the physical uniformity of sprawl, such as the lack of cultural centers and diversity in physical space, which is sometimes also categorized as an aesthetic cost.

Despite the increasing concern over sprawling land use patterns, the trend of low-density urban development holds steady. The current rate of land consumption is alarming; in many US cities it outpaces population growth. The city of Los Angeles, for example, experienced a 45% increase in population that resulted in a 300% urban land expansion; Chicago's 4% population increase led to a 46% urban land expansion (Diamond & Noonan 1996). Many different aspects contribute and encourage sprawling development, which confounds scientific reasoning. The list of contributing factors provided in the literature commonly include:

- Inadequate legislation and lack of land use planning and appropriate zoning

- Existence of the automobile and availability of cheap energy
- Population segregation by class and race
- Population growth and demographic changes to smaller households
- Wealth (allowing for larger and second homes)

Yet, some factors which are less often discussed may be of value to the continuing debate. For one, it has been proposed to view land as a common pool resource. Hardin (1968) and others developed the theory of the "dilemma of the commons." It states that commonly owned resources are prone to over-exploitation because people are unlikely to restrain their own behavior when the immediate benefits of their actions are their own but costs are externalized. While land in the US is often privately owned - the dynamics change little from that of the commons. Land is cheap and can be used repeatedly. As long as acquisition costs are low in relation to the benefits of exploitation of the associated resources (minerals, crops), land is likely to be undervalued and thus not well protected. Furthermore, concepts of public management such as protection of open space, growth control, and land use regulation are in direct conflict with the traditional American patterns of exploitation of the resource base. This leads to a rather ambivalent attitude toward land use planning.

Second, nature matters a great deal to people (Kaplan & Kaplan 1982); the green area immediately surrounding one's home holds a special status (Jackson in Kaplan & Kaplan 1982). Humans try to avoid crowding, confusion, and noise (Kaplan & Kaplan 1982). Jung (1965) believes that property ownership is psychologically important in satisfying the human need for roots and a sense of belonging. Moreover, as Low and Heinen (1993) note, in a variety of cultures, resource accumulation (e.g., land) has been a means to further human's economic, familial and social self-interests. The desire of humans to satisfy these self-interests (psychological and other) may enhance the desire for private homes in an arcadian setting which if multiplied often leads to sprawl.

The above list of sprawl catalysts is far from complete, but a more detailed discussion exceeds the scope of this paper. Moreover, the catalysts for sprawl are not true alternative hypotheses, but likely to be simultaneously true. Some catalysts may have a greater impact than others and impact may change over time and space. At this point, legislation and policies, technology, and human behavior and preferences are probably the more potent catalysts. Further, these catalysts may and probably do interact. For example, the human struggle for survival leads to a competition for resources and to the general failure of common pool resource management. The development of policies in a democratic setting will always reflect the desires and preferences of constituents. If the expressed preference of many is to

own a single-family detached home then subsidies to that effect will be supported in the political arena. Policies that impose restrictions on majorities are likely to be opposed.

3. Review of Environmentally Sound Land Use Strategies

As the driving forces of low-density urbanization are diverse, it is essential that strategies from different fields are evaluated with regard to their potential contributions to reduce wasteful land use. In particular, the questions pursued are what strategies from which discipline address what cost or driving force of low-density urban development? What is the scale at which a certain strategy is applied? These questions address the remaining dimensions of the framework: land use strategies and scale. While many disciplines are involved in shaping the urban realm, including policy science, administrative studies, sociology, engineering and others, this article focuses on the strategies from three disciplines that traditionally are associated with urban/environmental understanding and design: architecture, urban planning, and ecology.

Over the past decades, architects, urban planners and ecologists developed strategies and guidelines for environmentally sensitive land and resource use, each providing different views of the problem based on their professional focus. Architects typically focused on physical artifacts, while planners focused on legislation, administration, and policy. Ecology provides a philosophical and scientific background on the human-nature interaction. It is, therefore, hypothesized that these disciplines can provide complementary insights in the quest to formulate environmentally sound land use strategies.

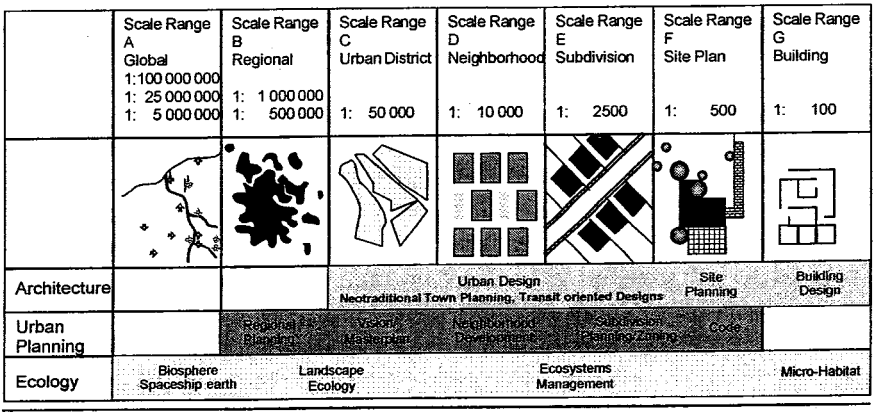

Figure 1: Scale Range and Professional Focus of Urbanization Issues (adapted from Humpert, et al. "Natürliche Prozesse – Haus ane Stadt". 1998).

Using spatial scale as an organizing principle facilitates the evaluation of the different strategies. For the purpose of this paper, the scale division developed by Humpert et. al. (1988) is adopted. Seven scale levels are distinguished (Figure 1) ranging from global to local. Different strategies and processes are used for designing an urban district as opposed to the design of a building. Figure 1 shows also that the primary foci of the disciplines, except for ecology, do not cover the entire scale range. The second step then toward building an interdisciplinary framework for environmentally sound land use is to evaluate and categorize the individual strategies from the three disciplines by cost/implication and scale.

Architecture & Urban Design Strategies

Architectural strategies toward sustainable land use are inherently physical and object oriented. The profession responds to the physical need of humans for shelter. However, architecture also addresses less tangible needs such as the provision of meaning and a sense of belonging. Increasing environmental awareness as well as the growing aesthetic dullness of suburbs motivated architects to develop new building forms and urban typologies (Crowther 1992). Architecturally inspired strategies entail the application of *technology* and *design* that contribute to the reduction of land consumption and preservation of open space, as well as the reduction of impact of land use on ecological functions (pollution, erosion, etc.).

Individual strategies of architects and urban designers pursue quite diverse goals. More detailed evaluation is necessary in order to categorize architectural strategies into dimensions of scale and cost/implication for use in the framework. A sample of architectural ideas and strategies, relevant to land use, has been selected to demonstrate the mechanics of the framework. These strategies are: (1) building design (size/type, performance and material), (2) site planning, (3) Neotraditional Town Planning and transit-oriented designs, (4) regionalism/ Genius Loci, (5) (alternative) community design.

(1) Building Design. Architects address three aspects of buildings, size/type, performance, and materials, in the effort to contribute to environmentally sensitive land use. Since reducing space consumption per person is rarely an option as people tend to buy or build larger homes with more appliances as their income increases (Kim 1996), green architecture targets the reduction of resource flows into and out of buildings. Both high-tech/active (solar panels, water separation and grey water use, heat-pumps, etc.) and low-tech/passive approaches (building shape and orientation, insulation) have been used with significant success. As it is not environmentally sensible to haul materials across continents, environmental buildings tend to reflect local material resources. Other means to reduce environmental impact are the

use of non-toxic materials as well as re-use and recycling of building materials and buildings. As a caveat, Kim (1996) points out that environmentalism in architecture today is largely driven by ethics rather than science, and that the understanding of environmental ramifications of architectural interventions is incomplete.[1] To summarize, architectural strategies promoting sustainability at the building scale (Figure 1, level G) focus mainly on pollution prevention and resource conservation, i.e., economic and environmental implications of urban development. Some aesthetic concerns are addressed by material choice.

(2) Site Planning. After decades of relying on technology to control climatic and geologic impacts, site planning with nature is experiencing a revival. Two ideas prevail: a) landscape and building units can work together to reduce energy/water consumption of the building in using vegetation as a secondary building envelope blocking sun or cold winds, and b) sensible site treatment and building placement can protect fragile soils, wetlands, and local ecosystems. A number of designers (McHarg 1969, Spirn 1984, Hough 1995) suggest that urban areas be designed in concert with natural processes perceiving nature as a resource rather than a plague. Site planning addresses both economic and environmental costs as problems incurred by inadequate development on swelling soils, in flood plains, on steep slopes, and near earthquake faults could be avoided by adherence to proper codes and construction techniques (Spirn 1984). Further, integrating natural processes into urban areas as parks, for example, can satisfy social, aesthetic or spiritual needs of citizens as well as serve as storm water retention systems and wildlife habitat. Site planning addresses scale levels B through G (Figure 1).

(3) Neotraditional Town Planning (NTP) (Duany & Plater-Zyberk 1994), *Pedestrian Pockets and Transit Oriented Designs* (TOD) represent design alternatives to conventional suburban land planning. To overcome aesthetic blight, traffic congestion and land consumption, neotraditional town planners suggest a return to the scale and spatial organization of the traditional town as the basic building block of human settlement (Krieger 1992). The approach has an aura of 'back to the good old days' and is not without controversy. In neglecting the need to improve, reuse, and revitalize existing urban landscapes, the belief is perpetuated that in starting over it can be done better (Krieger 1992). Likewise, the goal of the Pedestrian Pocket and Transit Oriented Development (TOD) (Calthorpe 1993) is the design of mixed-use moderate to high-density communities placed along regional transit lines. At the neighborhood level, the concept addresses the need to reduce the many non-work related trips of suburbanites to curb the use

[1] Energy conservation through insulation may be offset by the energy required to produce the insulating material. The resulting net energy balance may be negative and despite good intentions matters are worse (Kusgen (1970).

of fossil fuel. At the regional level, the concept provides an organizational structure for urban expansion along public transit corridors. The long-term, regional scheme furthers proactive planning for open space preservation, growth, and infill zones. Reduction of land consumption, traffic congestion and pollution prevention are the main goals of these urban design initiatives, yet NTP has also a social/aesthetic component. The affected scales are Region through Building (Figure 1).

(4) Regionalism/Genius Loci. Creating a sense of place is expressed by a regional style with a focus on local culture (building styles and materials), vegetation, history, local craftsmanship and clear boundaries of influence (Kelbaugh 1997). These boundaries may be the extent of the metropolitan area (scale levels B through G). Norberg-Schulz (1980) contends that identification and a sense of belonging are key elements in forming a human-place relationship that fosters a behavior that protects the environment based on the logic that you care for what you love. In contrast to the previous strategies, this style/design-oriented approach addresses aesthetic impacts and psychological costs in supporting humans' need for identification and sense of belonging.

(5) Alternative Community Design. Collaborative housing is one example of alternative community design. Collaborative housing developments started in Sweden, Denmark and the Netherlands as a response to the increasing pressures of combining work, raising children, or aging in a modern society without the support of the social network of extended families. The concept allows a group of like-minded people to form a "community/family" that lives in co-located private households, while sharing extensive common facilities and tasks like cooking and childcare. Retirement communities and assisted housing fall also into this category. Community design addresses mostly social ills of modern urban development at scale levels E through G (Figure 1).

In summary, we can state that architectural strategies seek to overcome the aesthetic as well as environmental, economic and social costs of sprawl, although to varying degrees. At the building level, land use issues are addressed indirectly through the reduction of resources and energy. Yet, buildings are just one element of the urban structure. Arrangements of buildings and settlement patterns are important factors in the ecological equation. The energy savings of a highly energy efficient building may be crushed by the fact that its owner is forced to use the automobile not only to commute to work but for every errand that arises. As pointed out earlier, environmental architecture is mainly based on ethics, lacking scientific grounding. This can lead to a false sense of environmental protection.

Fortunately, architectural strategies are, for the most part, not mutually exclusive and could be implemented in a simultaneous and complementary fashion. Neotraditional town planning can be improved

by green building designs and ecological site planning, for example. Still, innovative ideas are often stopped as a consequence of restrictive building codes and regulation. Duany and Plater-Zyberg (1994) identify zoning ordinances and planning codes as the means to restructure urban development. Most architectural strategies need the supportive legislative framework and the cooperation of urban planners to be implemented successfully.

Urban and Regional Planning

Environmentally-sensitive land use planning poses a challenge to planners who are to seek a working balance between the productive use of land (e.g., urbanization) and natural resources, maintenance of ecological functions and protection of people and property from environmental hazards (Kaiser et al. 1995). Similarly, Campbell (1996) states that "green" cities need to reconcile three divergent interests: economic development, environmental protection, and equity. Effective spatial planning using the traditional tools of land use design and control are identified as possible strategies to aid in the reconciliation (ibid. 1996). The following urban planning strategies are evaluated and categorized in terms of their impact on land use and applicable scale: (1) concepts, (2) regulatory tools, i.e., zoning and taxes, and (3) conservation and prevention measures.

(1) Concepts. Ideas for environmental planning (in the sense of creating healthy, sanitary, and socially vital urban settings) date back to the late 19th century. Some early ideas are worth revisiting in light of the current urbanization trends. Relevant concepts are the "Neighborhood Unit" intended to provide a physical form for neighborly life (Guttenberg 1993, So et al. 1979) and Ebenezer Howard's "Garden City," which was to halt urban expansion and eliminate speculative land costs (Gerckens in So 1979). Both concepts are geared toward social and aesthetic problems of urbanization. The concepts operate at the scale levels B through F in Figure 1.

Bioregionalism advocates biologically and culturally defined spatial units (e.g., watersheds) as basis for planning, local governance and a self-reliant economy (Aberley 1994). This is in contrast to traditional regional planning which respects existing administrative units such as counties, townships and municipalities. Under this paradigm the state of California, for example, would be divided into six units defined by different landscape types, i.e. desert, rainforest etc. (Aberley 1994). The premise of Bioregionalism is that energy and resource flows within an ecoregion are closer linked than across and between regions. Sustainable living and resource management must be adapted to the ecoregion's unique climatic, topological and biological characteristics. The concept seeks to address environmental as well as economic issues.

However, while the concept is laudable, full implementation would require an overhaul of the administrative structure of the nation, which is not very likely to occur. Regional planning in the traditional sense can be a powerful tool in itself. Depending on the focus chosen by the leadership, regional planning may provide the tools and resources to preserve open space or guide development patterns via financial incentives. The effectiveness of regional planning to control growth and sprawl has been demonstrated for Portland, Oregon (e.g., Lewis 1996). Regional planning is per definition applicable to scales Region (B) through Cadastral (E) (Figure 1).

(2) Regulatory Tools. Regulatory land use planning tools, i.e. zoning, and subdivision regulation, are too numerous and diverse, varying from state to state in availability and terminology, to allow a detailed account in this paper. Regulations apply to different geographic scales from federal and state to local levels. However, most land use regulation such as zoning is drafted, implemented, and enforced at the local, municipal or county level (Marx 1992). Zoning allows municipalities to establish areas in which certain land uses are permitted, usually by governing such features as minimum lot size, setbacks, and building types. Subdivision regulations control the conversion of tracts of open space to buildable lots. Those regulations can manage growth or regulate how and where construction and development occurs as one step toward environmentally sensitive land use. Regulations, in terms of their impact on land use management, can be categorized into three classes: intensity of use regulation (I), performance-oriented regulation (II), and permit control (III). A subset of existing regulation is compiled in Table 1.

Intensity of use regulations try to minimize environmental impact by changing the patterns of development. Except for large zoning[2], which seeks to reduce overall density, "intensity of use regulations" are intended to increase the density of the development in exchange for open space conservation or other public benefits. In contrast, performance-oriented regulation, such as "carrying capacity zoning," are concerned with adapting use to site characteristics. The caveat with performance-oriented zones is that the determination of the physical capacity for development of a land parcel is subject to value judgment. Carrying capacity as a concept is time-dependent (Cohen 1995). Ecological insight is a prerequisite to establish this type of regulation. Finally, there are moratoria, regulations that curb the number of building permits issued in a certain time period. The effectiveness of such measures to protect open space and resources depends on the size of the jurisdiction and the strategies of adjacent communities. Development may just move to unregulated areas leading to leapfrog development. Zoning and

[2] Critics believe that large lot zoning destroys rather thanprotects open space; it often adds to segregation by excluding lower income families from wealthy communities (see Marx 1992).

subdivision regulation address social and environmental issues at various scale ranges (up to the urban district).

Other measures for open space protection and land use management include taxes, exaction, acquisition tools, land transaction regulation, and management regulations (Marx 1992). A very popular approach to preserve agricultural land is the "Purchase of Development Rights" (PDR) program. However, Marx (1992) states that despite their popularity, PDRs have contributed little to the preservation of agricultural lands and open space. Again, these regulatory measures address social, environmental and economic costs at various scale levels.

(3) Conservation and Preservation Measures. Water conservation and environmentally sensitive land use are closely linked. Overexploitation of ground water aquifers can lead to significant ground subsidence and related building damage. Tax incentives for the installation of water conserving appliances are effective policy instruments that indirectly further environmentally- sensitive land use. Also, shifting travelers from cars onto public transit can reduce air pollution and emissions. The relationship between transportation modes, resource use and settlement pattern has been established by past research (e.g., Owens 1986, Newman & Kenworthy 1989). The proximity of work and residence can reduce travel demands and thus travel related resource use significantly. Yet, Kaiser et. al. (1995) criticize the separate operation of land use and transportation planning in many planning departments, which has the effect that "land use planning . . . often merely accepts much of the proposed transportation system as an input determined by others rather than a plan element to be coordinated jointly with land use." Economic, social and environmental costs are addressed. The scale levels affected by conservation measures reach from Region (B) to Cadastral (E) (see Figure 1).

In summary, urban planning provides a set of strategies to promote environmentally sensitive land use. Strategies exist at varying levels mostly in the range from Regional (B) to Site Planning (F). There is, however, a problem of implementation. Planners often have difficulties in garnering the political support necessary to implement land use control measures. Land use planning is based on balancing market, social and environmental needs, and values (Campbell 1996, Kaiser et al. 1995) at the local level.

To complicate matters further, two competing philosophies in land use planning exist: spatial planning and environmental planning. Spatial planning is concerned with *where* to best locate an activity often promoting higher densities and mixed uses. Environmental planning is concerned with *which* activity *not* to locate at a certain location. The goal of environmental planning is to improve or protect environmental quality for residents by controlling pollution and segregating activities

that are deemed environmentally incompatible like waste incinerators next to childcare centers (Miller & Roo 1997).

Environmental planning also includes the protection of people and property from natural disasters. Mixed uses and higher densities promoted by spatial planning aimed at reducing car travel may be in conflict with environmentally motivated strategies to separate activities. Site planning with nature in mind as described in the architecture strategy above may help to mitigate potential conflicts between spatial and environmental planning.

Weaknesses of urban planning strategies exist mainly in respect to physical design and the associated problem issues of lack of stimuli, sense of place. A sense of belonging and identification is to a large part supported by physical artifacts and a certain (regional) architectural style (as manifest through forms or material choices and building typology). In addition, as indicated above, some innovative legislation as in the "carrying capacity zoning" (see Table 1) requires deep ecological insight. The definition of "carrying capacity" is dependent on parameters of time, location and quality of the environment. This argument is non-trivial and is laid out in greater detail in the following section on ecological strategies.

Ecology

What strategies has Ecology to offer in terms of environmentally sensitive land use? On one hand, humans are dependent on natural resources for their survival. On the other hand, the way we as humans define and understand this human-nature relationship shapes our behavior towards resource use. The two main streams in ecology, human ecology (concerned with humans as individuals and/or as a species), and system ecology (focusing on material flows and functions), are complementary in exploring human land use. For developing land use strategies, ecology offers not only general theorems on natural processes, interactions, energy and resource flows, but also clues about human behavior and traits. In particular, four ideas are used to explore and evaluate the issue of environmentally sensitive land use from an ecological perspective: (1) spaceship earth and carrying capacity, (2) landscape ecology, (3) ecosystems management, and (4) human behavioral ecology.

(1) Spaceship Earth and Carrying Capacity. The idea of a finite world was put forth (e.g. Asimov 1974, Boulding 1966) as a model to develop sustainable economics, land use, and management practices based on a conservation ethic. While the Earth is comprised of a set of bioregenerative life support systems in which many of the resources are constantly recreated, renewed, and recycled (Miller 1994), clear limits to such systems exist. Attempts to determine the finite quantities and time frames for exhaustion of certain resources have not been successful

(Cohen 1995, Meadows et al. 1972, 1992). Equally unsuccessful have been attempts to determine the human carrying capacity[3], that is the maximum population that planet Earth can sustain. Generally, estimates lie between 5 and 16 billion for a sustainable population size. One reason for the dramatically different estimates is that there are many "carrying capacities" dependent on life-style (i.e. fuel consumption, technology use), diet (vegetarian or meat-based), location (tropics vs. polar region), and the time horizon (5 years vs. 200 years) (Cohen 1995).

The application of the carrying capacity concept to human populations has been widely criticized. Opponents argue that humankind can increase the Earth's carrying capacity through the use of technology (more efficient resource use) and trade (optimization of resource distribution). In response, Wackernagel and Rees (1995) redefined carrying capacity not as maximum population but as maximum human "load." In their ecological footprint analysis, human carrying capacity is expressed in per capita consumption, linking consumption to technology. Through this transformation, human consumption becomes measurable and can be added into a natural resource/energy flow balance to evaluate human impact and demand on nature. Flow of energy and matter to and from a defined community is converted into the corresponding area of land and water that would be required to support these flows. The greater the spatial extent of land and water surface, the larger the ecological footprint of a certain community and the greater the pressure on the environment. Planners and educators can quickly assess a community's footprint and devise strategies to reduce the environmental impact of a community's activities. Mainly economic and environmental costs of urban development are addressed; however, the concepts of "Spaceship Earth" and "Carrying Capacity" can be used at any level of detail and scale.

(2) Landscape Ecology. Landscape Ecology is concerned with human landscape modifications and the constraints those modifications impose on the development of its components (plant and animal species). The specific mosaic of landscape components (ecosystems, patches, and corridors) has a profound impact on energy and nutrient flows.

Knowledge about which patch sizes, shape and grain of landscape components support species habitats may be helpful in configuring urban development so that the habitats of species are protected effectively (Westman 1985). Grant et al. (1996) presented a framework to apply this approach to the design of residential areas. The strategy is somewhat narrow in that is addresses almost solely environmental costs.

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[3] One definition of carrying capacity is that of the maximum population of a given species that can be supported indefinitely in a specified habitat without permanently impairing the productivity of that habitat (Cohen 1995; Gotelli 1995, Wackernagel & Rees 1995, Miller 1994). Typically, the concept of carrying capacity has been used to determine the optimal population for a given size of land in range and game management.

Table 1: Overview of Zoning and other Land Use Regulations (Adapted from Marx 1992 - modified and extended).

Category	Regulation	Explanation
(I) Intensity of Use Regulation	Large Lot Zoning	Large minimum lot sizes keep residential density low by spreading units over a wide area.
	Cluster Zoning, PUD	Clustered development concentrates buildings in specific areas on the site to allow the remaining land to be used for recreation or preservation of environmentally sensitive land. A traditional zoning ratio of units/acre is maintained.
	Density Bonuses	Density bonuses allow greater building densities or development capacities in exchange for the developer providing a public benefit or amenity, which could include open space. These are often used in conjunction with transfer-of-development-rights programs.
	Conservation Density Subdivisions	Towns allow developers to build smaller, less expensive roads in exchange for reducing the number of units constructed.
	Transfer of Development Rights	Development rights from one property are transferred to another property, permanently conserving the first and increasing the density of the second.
(II) Performance Oriented Regulation	Performance Standards	Zones are based on permissible impact rather than permissible uses. These often overlay and occasionally replace Use Based Zones. Factors considered may include local growth rate, infrastructure, municipal services, design and natural resources.
	Carrying Capacity Zoning	Zones are based on the physical capacity of an area to accommodate growth by determining the limit beyond which development will endanger natural resource, overburden infrastructure and overwhelm municipal services.
	Special Districts, Overlay Districts	Areas with special attributes or features are identified and protected by stricter development standards. These districts may include agriculture, open space, historic, coastal and watershed areas, sloped land, earthquake zones. These overlays are usually created by local governments; occasionally states have created special districts as well.
	Local Environ-mental Ordinance	Localities may regulate development in environmentally sensitive areas such as floodplains, wetlands, and watersheds.
	Critical Environ-mental Areas (CEAs)	Land use in dedicated CEAs requires environmental assessment or environmental impact assessment before approval.
	Integrated Environ-mental Zoning	Tool to allow assessment of use compatibility in industrial areas. Sectoral environmental loads (noise, air pollution, and odor) are aggregated into one load. Areas are zoned from severely polluted to clean.
	Adequate Facility Rules	The ability of public utilities and agencies to provide for the needs of the proposed development is assessed. Facilities considered may include water supply, sewerage, roads, schools, fire and police, etc. Assessment may be based on capital improvement plans.
	Service Limits	Infrastructure extension is limited to a specified geographic region. Development beyond that region needs to pay for private services.
	Curb Cuts	State and municipal government controls access to highways/roads.
	Viewshed Protection	Regulations require that special views remain unobstructed.
	Set Backs and Buffers	Setback regulations specify the distance required between buildings and streets. Buffer requirements dictate the amount of open space or type of landscape treatment between structures and different land uses.
(III) Permit Control	Phased Growth	Phasing controls growth rates in a community by limiting the number of construction permits granted per year. Phased growth is justified on the basis of current or projected facility capacity.
	Moratorium	A moratorium temporarily halts land development. Under a variant "Interim Development Controls", most development is curtailed, but a small number of projects are allowed to proceed.

It is applicable at scale levels from the Region (B) to the Cadastral/Plot level (E) (Figure 1).

(3) Ecosystem Management. This strategy is a relatively new approach for natural resource management. As numerous authors perceive urban areas as ecosystems (Spirn 1984) or "techno-ecosystems" (Neveh in Odum 1993), it potentially provides valuable insight for the management of urban dynamics as well. In contrast to older views, ecosystems under this paradigm are defined as a community of different species (including humans) interacting with one another and with the chemical and physical factors making up the nonliving environment at different levels of scale. The approach recognizes variability, randomness, surprise events and change as integral properties of ecosystems that guarantee the adaptability to changing conditions (Pahl-Wostl 1995, Botkin 1990, Allen, Bandurski & King 1993, Allen & Hoekstra 1992). There is a notion that ecosystems are self-organizing and "self-correcting" (Regier 1993) in the sense that the system can respond to disturbances (e.g. fire, drought) and restore itself (resilience). However, extreme changes in the system can lead to the loss of the capability for restoration and the permanent change of the system into a different, often less desirable state. Anything that grows rapidly and haphazardly is endangered and may outstrip the infrastructure necessary to maintain its growth (Odum 1993). Ecologists believe that interactions with ecosystems need to take advantage of the system's self-organizing energies, so as to not overexploit and risk total systems change. The approach by definition addresses social, environmental, and economic aspects and covers regional (B) to site planning (F) scales.

(4) Human Behavioral Ecology. The premise of human behavioral ecology is that natural selection has shaped all living organisms to exploit resources effectively in competition with each other to ensure survival. Low and Heinen (1993) argue that this is true for humans as well. Evolved behavior in humans displays a distinct genetic selfishness with a bias toward individual and familial well being as well as resource accumulation and control. In addition, humans have evolved to maximize short-term rewards since such behavior was (at least in the past) correlated with reproductive success. Possession and control of land can be interpreted as a resource. Hence, some human behavioral ecologists have started to argue that we might interpret the desire of many Americans (and non-Americans) for a private home and property as a behavioral strategy that has been proven beneficial in the past.

Conservation strategies requiring individuals to constrain resource use for the greater (global) good in the long range stand in stark contrast to evolved traits that condition humans to favor short-term individual advantages over long-term group benefits. This conflict of interest is viewed by some ecologists as the source for the failure of conventional

conservation strategies (Low & Heinen 1993). In this line of argument, environmentally sensitive, (self-constraint) land use is seen as an evolutionary novel behavioral requirement. Behavioral Ecologists therefore suggest building environmental policies on legislation and economic incentives (that appeal to human's short-term calculations) rather than appealing to human conscience. This is especially true for national and global policies that exert little immediate impact at the personal scale. Only under special circumstances can social incentives to cooperate, manage, and share (common) resources be exploited. Human cost-benefits analysis is partly derived from cultural values (Heinen & Low 1992). Compliance with conservation strategies, such as recycling, is therefore predicted for tightly knit communities, i.e. whenever an individual feels that his/her reputation as a "good" neighbor is at stake (Ostrom 1995). In other words, if the cost of bad behavior (e.g. loss of status) far exceed the individual short-term benefits, then, and only then can conservation behavior be enforced socially.

The human behavioral ecological perspective provides an understanding of the motivations of (individual) human resource use, behavior, and adaptation at the micro scale. It is not a strategy in itself. However, by providing an understanding of human motivation, it can help to shape more effective environmental policy.

In summary, strategies inspired by ecology tend to focus narrowly on environmental issues, while generally ignoring social and economic issues. Sometimes they ignore humans altogether. Ecological thought is often not immediately applicable to urban problems. It seems, however, that ecological knowledge may be useful in improving strategies from other fields. In terms of land policy, the carrying capacity approach (and footprint analysis) may be used as a management tool devising zoning and land use intensity. The systematic approach afforded by ecological methods may help planners and architects to set priorities, thematically and geographically, to maximize resource conservation and pollution prevention.

Both landscape ecology and ecosystem management are governed by an ethic that seeks to maintain the integrity and health of natural systems. However, ecosystems are under the joint influence of natural and cultural processes and both types of processes are in essence not fully predictable within a contemporary mindset of open self-organizing systems (Regier 1993). The goal is to avoid irreversible damage to ecological functions. Ecologists must establish a dialog with planners and others to shape flexible and adaptive plans for environmentally sensitive land use.

Although conservation and 'wise use' of resources may be prudent, human ecology predicts that conventional conservation strategies are in conflict with learned and evolved human behaviors. Humans today continue to maximize resource use and exploitation; they seem ill

equipped to think and act globally (Pahl-Wostl 1995). Low (1996) also rejects the notion of the noble savage who protected and preserved natural resources as a myth. Resource use in traditional societies is often low only due to the lack of technology, markets, or both. This means that strategies promoting "traditional settlement structures" and "life-styles," e.g., as in Neotraditional town planning and Bioregionalism may be misguided attempts in reaching environmentally sensitive land use. Land use planning, legislation and economic incentives may be able to help curb human resource use more effectively.

4. Across Scale and Between Disciplines: Strategy Integration

Current patterns of low-density urban land use and the associated life-styles are based on a level of resource consumption that is deemed unsustainable. Strategies to change behavior and urbanization patterns have been put forth by scientists and professionals alike. The approach proposed here is to integrate strategies for environmentally-sensitive urban land use across disciplines using scale as an organizational structure. In doing so, it may be possible to overcome the impeding issues that are inherent in the single disciplinary strategies for environmentally-sensitive land use. For the strategies and disciplines discussed in this paper, three impeding issues can be identified:

- Disciplinary strengths and foci that address (only) subsets of the problem
- Discrepancy in problem interpretations and environment definitions
- Scale

The first two issues are related, since the focus of a discipline predetermines to a certain extent the definition of what constitutes environmentally-sensitive land use. The issue of scale adds to the complexity and seems to be ignored in most of the literature reviewed.

Disciplinary Strength and Foci. Most of the popular models and strategies for urban development, such as Transit Oriented Developments or Neotraditional Town Planning "do not directly confront the realities of deteriorating local and global environments" (Grant et al 1996). My review of the different disciplinary strengths revealed that each discipline addresses particular issues and costs related to urban sprawl, but fails to address the whole range of costs.

Discrepancy in Problem Interpretation and Environment Definition. Environmentally-sensitive land use is defined quite differently for each of the disciplines. Is environmentally sound land use planning "environmental planning" in the sense of protecting humans from environmental hazards? Are we attempting to reduce the metabolic rate of the urban techno-ecosystem by reducing input (resources, energy) and

output (waste, pollution) of urban areas? Or, are we trying to protect the integrity of the biophysical environment with its vital ecological processes? These questions have no simple answers. There is no going back to a pristine landscape in a constantly changing world (Regier 1993, Botkin 1990). It is up to us to define how an environment that is favorable to human development and survival should look.

Scale. Figure 1 illustrates that architecture and urban planning as professions have different foci regarding the scale of intervention. There is significant overlap but architectural strategies typically stop at the subregional level, and planning strategies at the regional level. Ecology spans the whole scale range from microhabitats to global systems. Hence, ecological strategies based on ecosystem dynamics and landscape ecology may yield useful guidance for urban land use planning, although they have not been widely applied in this area to date.[4] For example, the notion of self-organization and randomness which today is understood as an integral part of evolution is useful for the understanding of urban patterns as well. Urban patterns are formed through the interplay of deterministic planning and stochastic self-organization. Depending on the scale, one or the other may dominate. Human intervention and planning is visible in simple Euclidean geometric patterns and order at the building scale. However, at the regional and global scales the importance of self-organizing processes in respect to urban shape seems to prevail (Humpert et. al. 1988).

The Framework and Its Use

"Disciplinary focus" and "scale" are visualized in the matrix of Table 2. Selected (single) strategies from the three disciplines are listed top to bottom in the second column. The columns of the matrix depict the seven scale ranges from the global to the building level. Cells in white indicate at which scale range a certain strategy is most effective and applicable. For example, "building size and type" (row 3 from top in the architecture category) addresses the scale ranges *Site Plan* and *Building* (scale levels F and G). Shaded cells indicate that a strategy generally does not operate on that scale level. Icons in the cells give an indication of the disciplinary focus and what types of costs regarding sprawl a particular strategy addresses. For reasons of clarity, costs and issues were limited to four: environmental, economic, social (and psychological), and aesthetic. The flower icon, for example, indicates that the strategy focuses primarily on the environmental aspects of sprawl. While the most prominent aspects are depicted, strategies may also address other issues indirectly.

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[4] Carrying capacity based management and landscape ecology has been typically used for game and forest management. A notable exception may be Ian McHarg's overlay planning to determine suitable land uses (Estman 1995).

Most of the strategies currently listed in Table 2 address two or three of the selected issues. The "regionalism/genius loci" approach (last row, architecture), for example, addresses social and psychological issues of belonging and sense of place as well as aesthetic ones by creating a localized style. Some strategies, however, are very narrow such as "landscape ecology" (second row, ecology). This strategy focuses almost exclusively on environmental issues, without much regard for economic or social aspects.

The matrix of Table 2 can be used in several ways to formulate new, integrated strategies. Strategies can be combined within and across disciplines. Integrative strategies can be derived from:

1) Combining rows of cells with complementary icons, i.e. rows that only address environmental and economic issues with ones that focus on social and aesthetic ones.
2) Analyzing a given strategy for its shortcomings and improving it; e.g., creating new strategies that address previously lacking issues.
3) Adding several strategies to cover multiple scales, i.e. implementing strategies that work at scale levels A-E *and* strategies that work at scale levels F and G.

Integrative Scenarios

Three example scenarios for integrated strategies are developed following the method outlined above. They are termed 1) complementary foci, 2) improving existing strategies, and 3) considering scale.

(1) Complementary Foci. An integrative scenario that capitalizes on various disciplinary strengths may be the merger of the largely ecocentric landscape ecology with the anthropocentric-oriented Neotraditional Town Planning. Neotraditional Town Planning addresses the issues of access and stimuli deprivation, and aesthetic and social costs of sprawl. Community building and creating a sense of place is one of the main goals pursued by this strategy.

However, the strategy fails to give attention to ecosystems processes and issues of open space protection. The proposed urban layouts follow generally grand geometric schemes, rather than natural, geological, and topographical patterns. While indirect environmental benefits derive from a design that encourages development of neighborhood stores and local community service centers reachable by foot, there is great potential in pursuing complementary ecologically focused strategies. The layout of the urban scheme could be modified to enhance or preserve landscape features. Urban gardening may be encouraged and supported by local codes. Building designs that focus on performance may be unified by guidelines. However, these guidelines should not focus simply on replicating some historic time period. A local environmental style based on climate conditions and materials may be developed. Urban planning will be needed to transform this utopian vision into reality. The

community will need to be educated and gradually guided toward this vision using participatory and adaptive planning techniques.

(2) Improving Existing Strategies. The ideas of bioregionalism, i.e. having regional planning using watersheds or other natural entities to define the planning unit is a good concept, but difficult to implement. It would require the complete reorganization of existing administration and governance. The establishment of regional entities (similar to traditional regional planning agencies) on the basis of ideal units as sort of a special district may be an intermediate step that is easier to implement. These new entities could gradually gain more power and responsibility whereas traditional unit boundaries such as county and town divisions diminish in importance. Of course, this requires strong collaboration of state and local decision-makers.

(3) Considering Scale. Scale can be used in an additive way. The Garden city model could be perceived as a "pedestrian pocket" within a transit-oriented design. There is no provision for interventions at the building level. Interplay between strategies at the building level (water and energy conservation) and urban level is potentially fruitful (i.e. district heating). The garden city as a whole will be a less consumptive place if the individual buildings perform better in terms of their energy and material throughput.

For implementation of strategies, scale also must be considered as a separating factor. In close-knit communities, conservation strategies may be developed and implemented without economic incentives. Local social norms may suffice as control instrument. In larger heterogeneous communities, however, social norms have a lesser significance. People will most likely only adopt conservation behaviors when they derive individual economic benefits that outweigh costs.

5. Conclusion

Sustainable and "green city" concepts strongly suggest that land development in urban areas be changed toward a more environmentally sound and efficient land use pattern. Depending on the viewpoint, social, economic or environmental costs need to be addressed. Yet, changing land use and development patterns is a slow and difficult process. The fact, that multiple factors, including population growth, technology, evolved preferences, government subsidies for mortgages and road construction and lack of land use planning contribute simultaneously to the proliferation of spread out, low-density urbanization adds to the complexity of the problem.

Table 2: Strategy foci regarding Scale and Codes

	STRATEGIES	SCALE CATEGORIES						
		A Global	B Regional	C Urban District	D Neighborhood	E Cadastral Plan	F Site Plan	G Building
ARCHITECTURE	Building material and style							⊛ ■ ☺ ✕
	Building Performance							⊛ ■
	Building size and type						⊛ ■	⊛ ■ ⌖
	Social Community Design					■ ☺ ✕	■ ☺	■ ☺
	Neotraditional Town Planning				■ ☺ ✕	☺ ✕		☺ ✕
	Transit Oriented Design		⊛ ☺		⊛ ☺	⊛ ☺	⊛ ☺	
	Site Planning with Nature		⊛ ■	⊛ ■	⊛ ■	⊛ ■	⊛ ■	⊛ ■
	Regionalism Genius Loci		☺ ✕	☺ ✕	☺ ✕	☺ ✕	☺ ✕	⊛ ☺ ✕
URBAN PLANNING	Codes						⊛ ✕	⊛ ✕
	Zoning, Subdivision			⊛ ☺	⊛ ☺	⊛ ☺	⊛ ☺	⊛
	Neighborhood Unit				☺ ✕	☺ ✕	☺ ✕	
	Utilities, etc.			⊛ ■	⊛ ■	⊛ ■	⊛ ■	
	Garden City		⊛ ☺ ✕	⊛ ☺ ✕	⊛ ☺ ✕			
	Taxes, Incentives, Acquisitions, etc.		⊛ ☺	⊛ ☺	⊛ ☺	⊛ ■ ☺	⊛ ■ ☺	
	Transportation		⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺		
	Bioregionalism		⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺		
	Regional Cooperation		⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺		
ECOLOGY	Ecosystems Management		⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺	⊛ ■ ☺	
	Landscape Ecology		⊛	⊛	⊛	⊛		
	Human Behavioral Ecology	☺	☺	☺	☺			
	Footprint Analysis Carrying Capacity	⊛ ■	⊛ ■	⊛ ■	⊛ ■	⊛ ■	⊛ ■	⊛ ■

Issues Addressed: ⊛ Environmental Issues ■ Economic Issues
☺ Social/Psych. Issues ✕ Aesthetic Issues

Many of today's strategies geared toward curbing sprawl and reducing environmental impacts associated with urbanization and development can only address single aspects of urban environmental problems. The evaluation of individual strategies from three different disciplines (architecture, urban planning, and ecology) illustrates that shortcomings exist at all levels. One strategy, e.g., alternative community designs (co-housing), attempts to counteract the isolation often faced by suburban residents in providing an environment that stimulates shared tasks and responsibilities as well as interaction and neighborly care. The denser living arrangement in co-housing communities also preserves open space. Yet, this community-oriented strategy hardly impacts resource consumption at the regional scale. Other strategies, such a regional planning and ecosystems management may be more effective at these scales.

In conclusion, to implement environmentally-sensitive land use in a comprehensive fashion, one needs to draw on different disciplines that consider several problem aspects as well as scale levels. Environmentally- sensitive land use requires cross-scale and cross-disciplinary integration of (existing) land use strategies. The framework, developed here, presents a first step toward the development of a tool to help optimize the integration of strategies by complementing scales and primary goals and foci of strategies from various disciplines. Examples of integrated strategies from three different disciplines demonstrate how the framework can be used to create new packages of comprehensive land use strategies.

At this point, only a small subset of disciplines involved in urban development and their strategies have been explored. This leads to a somewhat limited perspective. A significant drawback of the framework is the lack of economic and political science viewpoints. However, due to the framework's open structure this shortcoming can be easily remedied. Future research entails the incorporation of such strategies into the framework. Furthermore, there is a notion that human intervention at certain scales (i.e. global) requires too much energy in implementation and monitoring to warrant it. This is in part because self-organizing system forces dominate at the levels of greater scales. Pahl-Wostl (1995) and Low and Heinen (1993) suggest that it may be most effective to intervene at local and regional scales working towards making land use practices at each locale as environmentally sound as possible. Investigations into these issues must be conducted. Insights in this area may be used to further improve the framework.

Contrasting the thought processes and ideas from architecture, urban planning and ecology raises some interesting points. If we adopt ecological perceptions of the world being an intertwined, evolving human-environment system, predictions of future development become impossible. The problem is, "being part of an evolving system and the

ability to control and predict a system's behavior are mutually exclusive properties" (Pahl-Wostl 1995). However, being part of the system means we are also partly responsible for its development path. It is useful to perceive human actions as proactive innovative disturbances to the human-environment system. Adopting a responsible attitude toward resource use will increase our flexibility to adapt to change, increase life-style choices, and enhance our quality of life.

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