ENVIRONMENTAL PERFORMANCE OF URBAN PATTERNS IN TERMS OF THEIR ECOLOGICAL FOOTPRINT

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Approval of the thesis

ENVIRONMENTAL PERFORMANCE OF URBAN PATTERNS IN TERMS OF THEIR ECOLOGICAL FOOTPRINT

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ABSTRACT

ENVIRONMENTAL PERFORMANCE OF URBAN PATTERNS
IN TERMS OF THEIR ECOLOGICAL FOOTPRINT

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Within the twenty–first century, nearly three billion people, half of total population of the world, live in cities. It is estimated that in the forthcoming twenty–five years, two billion more people will settle in urban lands. Essentially most of these devastating changes will occur in developing countries, both in terms of the total global urban population as well as increased percentage of the individual country's population living in urban areas. For many developing countries, the urban population is already large. Further increases in size and rates of growth will no doubt stress already impacted environments and living quality. All cities, however, are not impacting the ecology of the world similarly. On the one hand, developed cities have mostly cope with their environmental problems regarded as traditional; concern has focused to their impacts on ecosystems as well as those larger in scale. Cities in the developing world are more concerned with other issues. However, it is not only the development level of countries but the urban planning and development tendencies of their cities impacting the environment differently should be considered, which comprehensively shows us environmental performance of urban patterns. Environmental performance basically refers to the abilities and capabilities of urban patterns to mitigate their impacts on environment and ecology of the world and to cope with the negative of all. As an indicator of environmental performance of urban patterns, ecological footprints, its reasons and long term effects should be specified as inseparable part of urban development and inevitably ecological footprints of different urban patterns and their effects on climate change should be concerned while taking planning and development decisions for urban areas.

The basic purpose of the thesis is to specify the environmental performance of different urban patterns in terms of their ecological footprints through defining the relationship between implications of urban patterns and their contributions to the ecological footprint.

Key Words: Climate Change, Environmental Performance, Ecological Footprint, Urban Carbon, Urban (Ecosystem) Design, Eco-Compact Cities

ÖZ

KENTSEL DOKULARIN EKOLOJİK AYAKİZİ AÇISINDAN
ÇEVRESEL PERFORMANSLARI

Tanrıkulu, Melda
Yüksek Lisans, Şehir ve Bölge Planlama Bölümü, Kentsel Tasarım
Tez Yöneticisi: Doç. Dr. Adnan Barlas

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İçinde bulunduğumuz 21. yüzyılda, dünya nüfusunun yarısı, yaklaşık 3 trilyon insan, kentlerde yaşamaktadır. Önümüzdeki 25 yıl içerisinde yaklaşık 2 trilyon insanın daha kentsel alanlarda yer seçeceği tahmin edilmektedir. Bu eğilim göz önünde bulundurulduğunda toplam küresel kentsel nüfusta beklenen bu değişikliklerin büyük bir kısmı gelişmekte olan ülkelerde görülecektir. Çoğu gelişmekte olan ülke için, kentsel nüfus oldukça fazladır. Nüfus büyüklüğündeki ve nüfusun gelişme oranında beklenen artış, şüphesiz çevresel koşullarının ve yaşam kalitesinin daha da bozulmasına neden olacaktır. Ancak kentler doğayı farklı şekillerde etkilemektedir. Gelişmiş dünya kentleri geleneksel çevresel problemlerin (atıksu dönüşümü, sağlık koruma, su arzı, hava kirliliği, vb) üstesinden büyük ölçüde gelebilmişken, dikkatler bu problemlerin ekosistem üzerindeki yaygın etkisine dönmüştür. Gelişmekte olan dünya kentleri, diğer konulara daha fazla odaklanmıştır. Diğer bir yandan, ülkelerin gelişmişlik düzeylerinin yanı sıra kentlerin çevreye olan etkilerinde dikkate alınması gereken bir başka nokta ise kentsel dokuların çevresel performanslarının temelini oluşturan kentsel planlama ve gelişme eğilimleridir. Çevresel performans temel olarak, kentsel modellerin çevre ve dünya ekolojisi üzerindeki etkilerini azaltma ve tüm olumsuzluklarıyla baş edebilme yeteneklerini ve kabiliyetlerini anlatır. Çevresel performansın bir göstergesi olarak, ekolojik izler, sebepleri ve uzun dönem etkileri kentsel gelişmenin ayrılmaz bir parçası olarak belirtilmelidir.

Tezin temel amacı, kentsel modellerin çıkarımları ile ekolojik ayak izlerine katkıları arasındaki ilişkinin belirlenmesi yoluyla farklı kentsel modellerin çevresel performansının ekolojik ayak izi açısından belirlenmesidir.

Anahtar Kelimeler: İklim Değişikliği, Çevresel Performans, Ekolojik Ayakizi, Kentsel Karbon, Kentsel (Ekosistem) Tasarımı, Eko-Derişik Kent

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CHAPTER 1

INTRODUCTION

This chapter makes an introduction to the study through defining structure of the study, study limitations, research focus, research questions and hypothesis, research approach, research relevance and significance for urban planning and design theories and practices, orientation to the document and gives the background information of the purpose of the study.

1.1. Structure of the Study

This thesis, with the purpose of specifying the environmental performance of different urban patterns in terms of ecological footprint, introduces a new way of looking to urban pattern and its implications.

In most studies of urban design, urban pattern is seen as a matter including physical, psychological, spatial hints. However, there is another point of view for the pattern problematic; that is ecological. Although management and control of urban pattern is being discussed as a crucial problem of urban design platforms, its ecological leg is not clearly situated yet.

An urban designer, as the expert of urban pattern specification, is not only responsible for finding the best solution for problems of existing urban patterns of cities. He also should consider the consequences and multiplier effects of taken decisions. Most of these effects occur on environment and ecologically valuable lands. While urban land consuming resources and producing human-based wastes, it makes short and long terms effects on natural resources.

This thesis, therefore, makes an introduction to unclear matter of urban pattern through trying to define the close relationship between the decisions on urban pattern and impacts of urban lands on environment, called environmental performance.

As this issue is brand new and become important recently, this study aimed to clarify the relationship in a speculative way. Structure of the thesis introduces

Chapter 1 defines the structure of the study, study limitations, research focus, hypothesis and research questions and research approach and finally its relevance and significance for urban design theory and practice.

Chapter 2 gives a brief summary of background information about the *City as an Ecosystem, Kyoto Protocol and Global Issues on Climate Change and Climate Change Facts.*

Chapter 3 defines the theoretical framework by presenting *a new tool for environmental performance that is ecological footprint.* This framework will be redefined under the sub headings of estimating environmental performance of cities to clarify their impacts on climate change, definition of ecological footprint, use of ecological footprint as the main indicator for sustaining the world, countries and "cities", ecological footprint calculation methods and tools, ecological footprint minimization strategies.

Chapter 4 defines the urban design approach of the study as *urban ecosystem design: a multidimensional process.* Indeed, this chapter specifies urban patterns, their implications and eco-compact urban pattern as the pattern with the highest environmental performance.

Chapter 5 comprehensively describes the research *methodology and relation matrix* of indicators of ecological footprint and implications of urban patterns. Starting with research design and method, determines the relation as decreasing, increasing and no defined relation. Discussion on Urban Patterns and Ecological Footprints of World Cities clarified the outcomes of the theoretical framework the study focuses.

Chapter 6 provides *discussions* in terms of study limitations and focal points for planners and architects and clarifies the *concluding remarks by representing recommendations* for urban design theory and for further research and implementations.

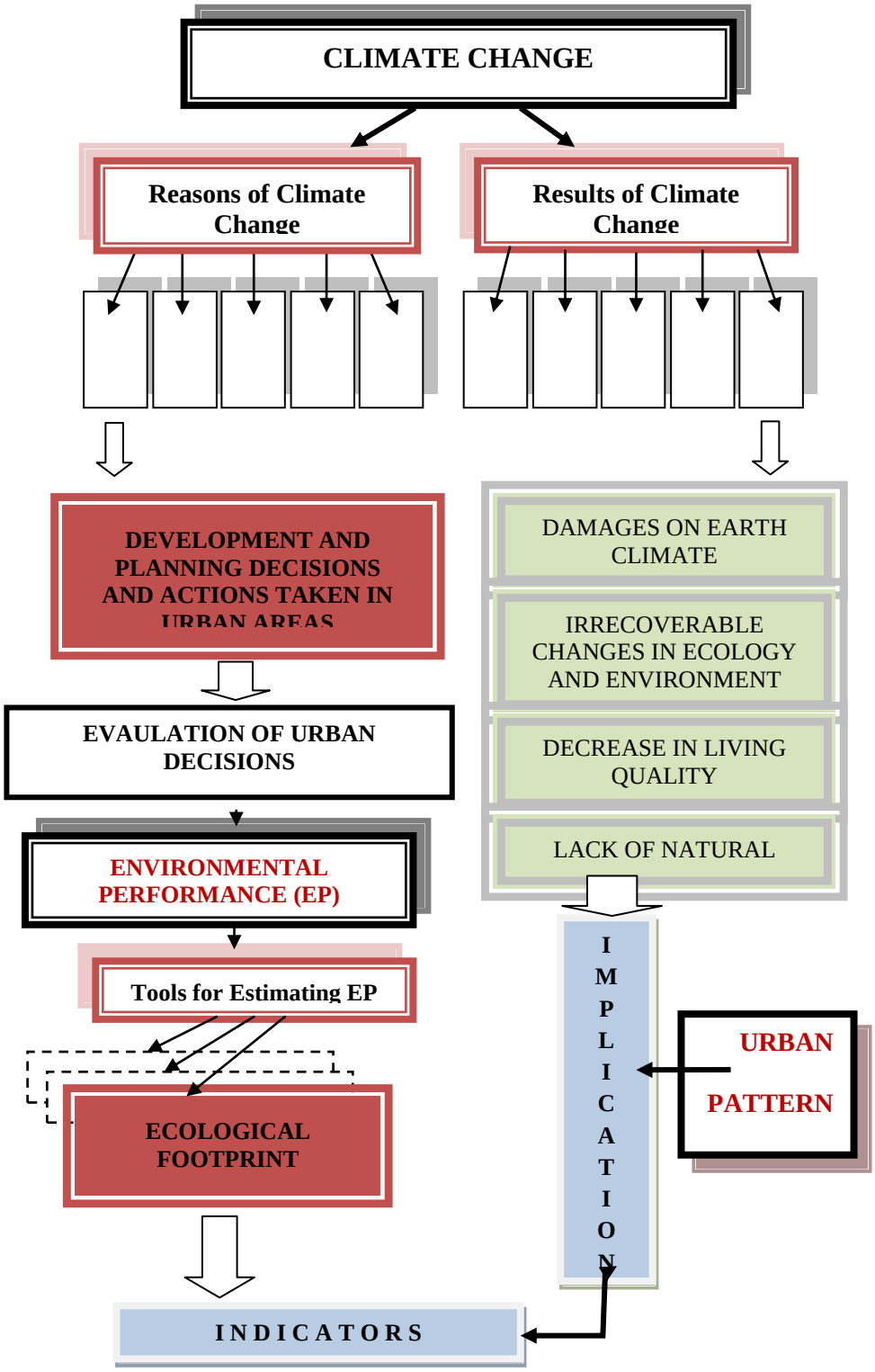

Figure 1-1 Structure of the Study

1.2. Study Limitations

Investigating the environmental performances of urban patterns in terms of their ecological footprints through developing a framework for the relationship between the implications of urban patterns and indicators of ecological footprint, this research involves a number of limitations. These limitations are explained as country based information and data constraints, different tendencies and technologies used for calculation of ecological footprint, imperfect assumptions and unclear analysis below:

- *Country based information and data constraints*:

  In most developed and developing countries of the world, researches has already started about the short and long term effects of urban decisions on ecological footprints of different urban patterns. However, it is hard to find similar comprehensive discussions in Turkey. This is also reasoned by lack of systematic and detailed data constraints of cities in Turkey. Unfortunately, it is still hard to find all data and information, such as annual production and consumption rates of resources about any of cities in Turkey. There is no research and calculation in Turkey do determine the ecological footprint of any selected city, which limited this study focus on using data of other world cities implications. On the other hand, there is also no certain researches on the relationship of urban patterns and their ecological footprints. Most studies basically explain the citizen behaviors and living attitudes and their impacts on ecological footprint of the cities they live in. On the other hand, to make such calculation for any city of Turkey, the data of indicators of ecological footprint is needed, similarly. Therefore, this study developed a speculative relation matrix, however could not test this matrix.

- *Different tendencies and technologies used for calculation of ecological footprint*:

  There are many different tendencies and technologies (most are web-based) used for calculation of ecological footprint. However, similarly most of these methods are based on calculation of person-based ecological footprints, *called citizen footprint*. Tools used for calculation of urban ecological footprint are dealing with territory based ecological footprints, and try to make a clear calculation through

this. It might be more useful and may produce more meaningful results to develop a tool to define the ecological footprint of urban areas through their development tendencies, patterns. As the method used for calculation of territorial footprint, which fits for the purpose of this study, is being used more recently and based on the basis of data of indicators used for calculation, it is hard to evaluate and calculate this footprint at short notice. Most studies of world cities such as Paris, London, New York had taken a span of years. In case that methods used for the calculation may be simplified and data necessary for calculation will be available for most cities, the relation matrix developed in this thesis may be tested in any city selected and the discussed relations may take place in urban design literature perceptibly.

- *Imperfect assumptions and unclear analysis*:

It would be hard to make assumptions of this thesis perfectly and to determine the results of this analysis clearly. Therefore, this thesis begged to answer the questions, on the contrary, try to define a discussion on the outcomes of developed relation matrix. However, it is still hard to say which urban pattern is the best eco-friendly one. Therefore, this thesis does not point at any of urban patterns as the pattern having least ecological footprint. Instead, it discusses different variables of patterns in terms of pattern implications to clarify the advantages and disadvantages of patterns from different point of views.

1.3. Research Focus

The main purpose of this thesis is to specify the environmental performance of different urban patterns in terms of their ecological footprint.

As half of the world's population live in urban areas, cities would become the focus of most researches on how to sustain the existing life quality and even increase. However, conversely, there is still lack of information on the environmental effects of urban changes and development. Research on how urban patterns and dynamics of urban development affect the ecosystem of the earth is still limited. As global warming, and accordingly climate

change, became the most crucial problematic of the world in recent years, attention is given to close relationship of urban patterns (and the way how we plan the urban development) with their effects on environment.

Concerns about the quality of the environment, and impact on the global environment have generated a new interest in cities' environmental quality and performance. Today, virtually all cities share concerns for the future of their environment. Although the impacts of urban pattern and development tendencies are often perceived as local and regional, the urban footprint on the landscape generates environmental changes at larger scales. Cities appropriate Earth's natural resources from distant regions to support urban activities. On the other hand, the urban setting provides major opportunities to achieve economies of scale and conserve natural resources. The management and organization, basically form of urban settings determines the level of pressure that urban dwellers place on the local and global environment. This is the thing called as environmental performance. Cities may be the places of higher environmental performance and lesser impacts on ecology, accordingly less contribution to climate change, in case we consider the relationship between the ways we shape our urban lands (urban forms) and the impacts they have on environment.

Within a century that would be a period of concerns for sustaining the ecology of the world and mitigating the risks of climate change, considerable evidences exist that most of this warming has been caused by unplanned, underestimated and uncontrolled rapid development of urban areas and the actions of main actors, human beings live there. This multidimensional issue, resulting in effortful solutions for urban macroforms has brought about new approaches for eco-friendly urban patterns.

Decisions about controlling urban carbon emissions and correspondingly other “greenhouse effects” through ecological footprint minimization strategies standing alone cannot mean a complete solution for the wide spreading problems of this long-term attitudes and flows of urban areas. By favor of many previous attempts of ecologists and other environmentally global sustainability researches, it was approved that this comprehensive change can only reach a happy-ending in case that those strategies have been integrated into long and short term urban (ecosystem) design processes. To achieve this, we should be aware of environmental performance of different urban patterns.

The evaluation of urban pattern and their ecological footprint (in this study mostly defined as the main indicator of environmental performance) will be done in terms of pattern implications redefined as:

**Centrality*

**Density (also Extent)*

**Connectivity (and also Modularity)*

**Grain (also Edges and Transitions)*

To state the roles of urban pattern on ecological footprint, as one of the main indicator of environmental performance, the logical framework has been developed as seen in Figure 1-2, as a multi-directional chain between “Climate Change” and “Urban Pattern”.

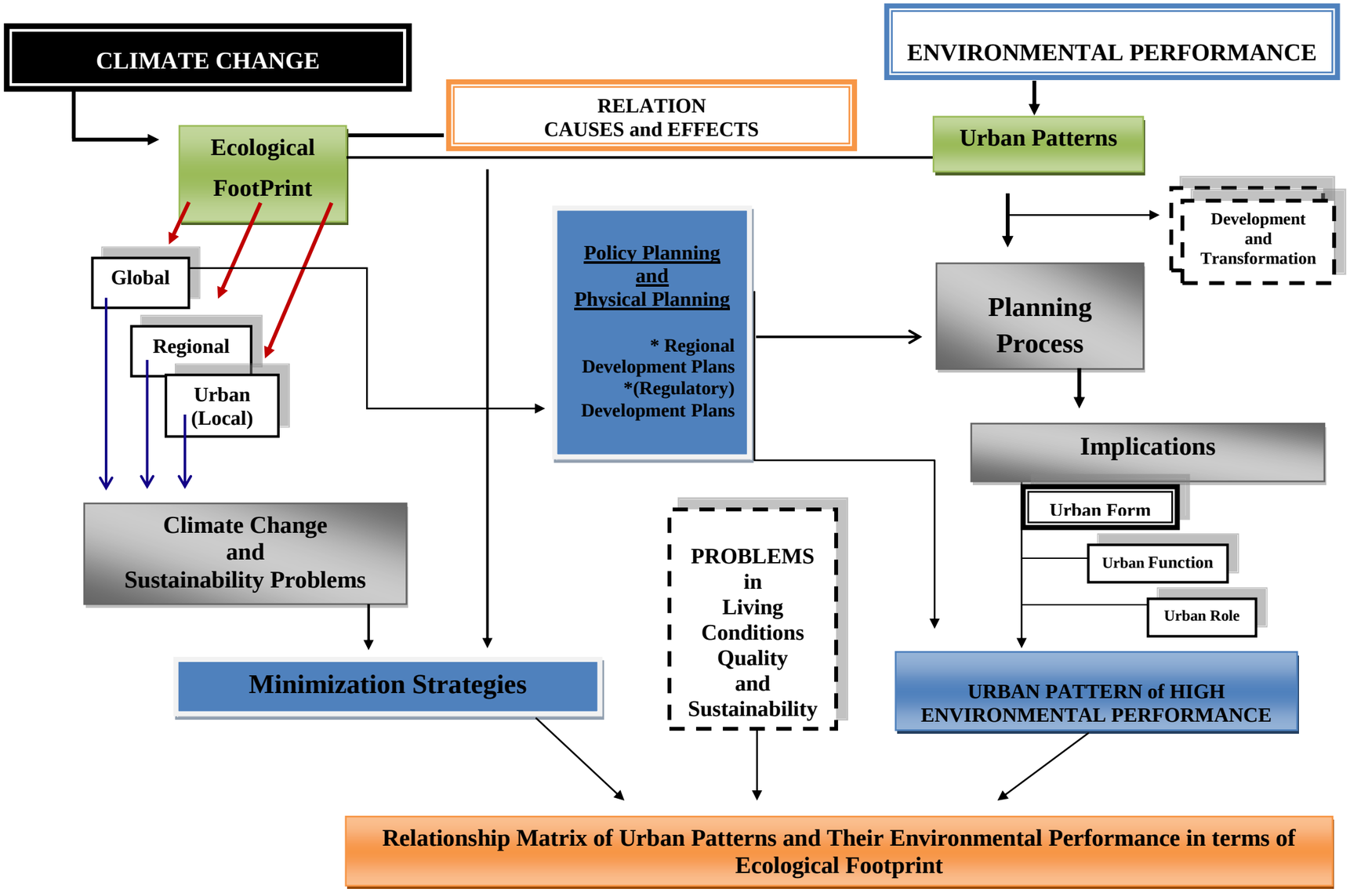

Figure 1-2 Logical Framework

1.4. Research Questions and Hypothesis

As mentioned in the research focus part, the thesis aims to determine the environmental performance of different urban patterns in terms of ecological footprint. The logical framework will mainly aim to give contributions to urban design literature for testing the hypothesis of "**Although to cope with ecological footprints, as a tool for estimating environmental performance of cities and clarifying climate change, strategies are mostly considered and determined per person, this comprehensive and multi-dimensional issue results from a broader basis of urban design through implications of urban pattern.**" This hypothesis of the thesis was tested through answering the following question:

- What kind of a relationship can be defined between implications of urban patterns, and its indicators of ecological footprint?

So as to answer this main question, some sub-questions, each of which is answered in previous and following sections are specified:

- How environmental performance of cities can be calculated?
- What are the indicators of ecological footprint?
- What are the ways to estimate urban ecological footprint (by using the calculations of territorial footprints)
- What implications does urban pattern have?
- How can ecological footprint indicators be related with urban patterns?
- Which urban pattern is the best eco-friendly in terms of ecological footprint it creates?

1.5. Research Approach

Considering the "Research Process" in Figure 1-3 below, research approach is defined. Firstly, the theoretical framework of the thesis was developed considering the literature review, which includes assessment of information under the headings of *Climate Change Efforts, Ecological Footprint Minimization Strategies, Urban (Ecosystem) Design Processes, Archetypal Urban Forms and Their Implications, Eco-Compact Urban Form as a New*

Approach for Urban Design in detail. While problem definition has been rationalized, argument was done about the hypothesis of: *"Although to cope with ecological footprints, as a tool for estimating environmental performance of cities and clarifying climate change, strategies are mostly considered and determined per person, this comprehensive and multi-dimensional issue results from a broader basis of urban design through implications of urban pattern."*

Then, under the light of background information, causes and effects of this hypothesis were assessed and the following main question was asked as the research question: *"What kind of a relationship can be defined between implications of urban patterns, and its indicators of ecological footprint?"* this question was supported by sub-questions clarified in research focus section:

Considering the questions asked in the study, necessary data was collected through literature review and collecting information from developed cities of the world, whose footprint has already calculated and mitigation measures were developed. The data collected was analyzed and restructured from the thesis point of view.

Finally; to answer the questions, a methodology was developed and a model was determined as the outcome of this study. Although this thesis does not include a case area, a relationship matrix will be developed between implications of urban patterns and indicators of ecological footprint. Additionally, outcomes of eco-compact urban form will be discussed as the urban pattern with least ecological footprint. At the end, the study limitations of the research and its contributions to literature were defined in the conclusion part. Also some recommendations were provided for planners and further studies.

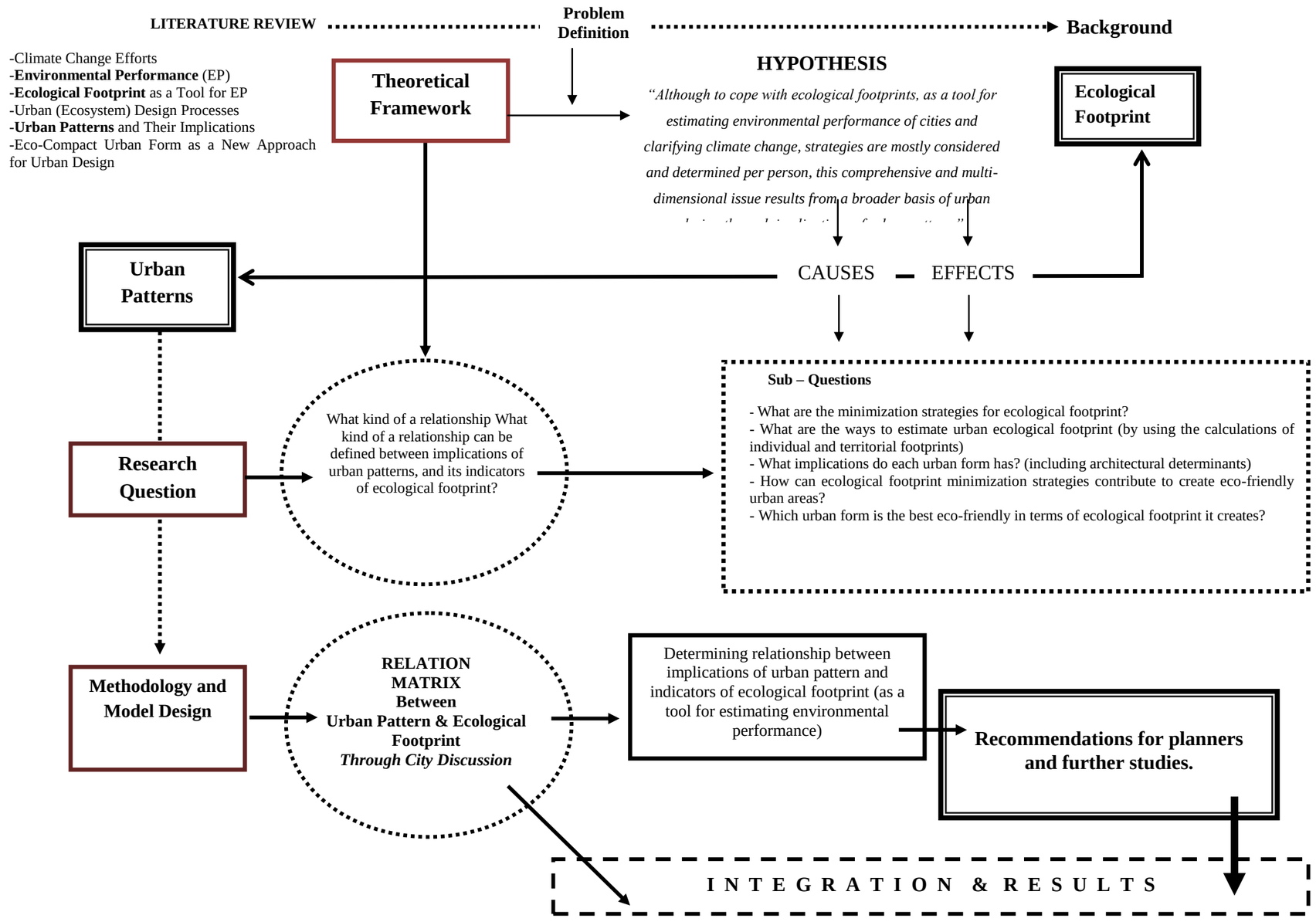

Figure 1-3 Research Process

1.6. Research Relevance and Significance for Urban Planning Theory and Practice

This thesis, with the purpose of determining the environmental performance of different urban patterns in terms of ecological footprint, aims to make a crucial contribution to urban design literature. As planners, urban designers and architects are the actors of decision making processes in urban issues; this study is relevant to these practices.

The world is more complex now than at any other time in history. In many parts of the world, and notably in the Turkey, rapid economic growth, decentralization, privatization, and related socio–cultural changes are leading to the emergence of a complex decision making environment. New concepts and approaches are needed to find constructive solutions to environmental issues in urban areas. (UNU/IAS Report, Urban Ecosystem Analysis, 2009) Thereby, ecological footprint is one of the most commonly used indicators for evaluating the environmental performance of an urban pattern and it substantially shows the contribution of that pattern to changing climate. While ecologists and other researches experienced on environmental issues develop new tools and strategies for decreasing the effects of climate change, planners, designers and architects should adapt those clues into development, regeneration or transformation processes of urban areas and should consider the environmental performance of that pattern while decision making.

In the whole world, a new urbanization approach would occur (United Nations Centre for Human Settlement, 1996). For urban planning, the density level of settlements and urban development along transport networks is reasoning crucial concern in industrialized countries. It is unfortunately expected that these processes conduce to urban patterns which are environmentally incompetent and have harmful impacts on the surrounding environment (Antrop, 2000; Swenson and Franklin, 2000) and have the least environmental performance.

Thus, achieving the satisfying level of urban efficiency and environmental performance, strategies of considering ecological footprint of every urban development should be integrated into urban design process. So as to make contributions to this process, the thesis will try to determine the environmental performance of different urban patterns in terms of their ecological footprint, and aim to make a crucial contribution to urban design literature.

CHAPTER 2

BACKGROUND OF THE ECOLOGICAL FOOTPRINT APPROACH

Environmental or 'ecological' footprints' have been widely used in recent years as a partial indicator of environmental performance; specifically of resource consumption and waste absorption transformed on the basis of the biologically productive land area required by a defined population. In the present chapter, background supporting the hypothesis of the thesis will be summarized and each definition will be done from this thesis's point of view.

2.1. The City as an Ecosystem

> "A pond, a forest, a meadow, a terrarium, a fish tank: all of these are ecosystems. Each includes a community of living things (plants, animals, microbial organisms) interacting with nonliving things (sunlight, nutrients, soil, water, wind). An urban ecosystem includes people among the living things, and the structures they build among the nonliving things. In an urban ecosystem, humans influence ecological factors (plants, air, soil, animals), and human decisions (where to build houses, parks, highways, schools) are influenced by ecological factors. Ecologists study interactions among living organisms as well as interactions of organisms and their physical environment."
> (http://caplter.asu.edu/explorers/about/urban.htm)

Defining the city as an ecosystem supports the idea of estimating environmental performance of urban patterns. The fact that cities with different patterns have changing environmental performance, comes from the approach of that those cities with different patterns becomes different ecosystems as their inputs and outputs vary.

Cities with different urban patterns create a different ecosystem within itself. Cities as the creation of people have mostly become *the centers of expectation and inspiration*: they are the places where resources of nature are consumed to create higher qualities of life, and to

ease cultural and intellectual achievements. Their cultural diversity is part of their liveliness and enthusiasm. It comes out of from many sources and is emerged in many ways in urban lands, fundamentally specifying people's privileges and values for the environment and ecological resources. This cultural diversity must always be taken into account when analyzing urban ecosystems. (UNU/IAS Report, 2009)

The biggest world cities have a equilibrium of urban development, architecture and public space (basically open) that in ecological provisions offer not only a high-quality human habitat, but also potentialities for biodiversity. This vigorous role of human being in the urban land continues to create habitat enhancements and to helpfully handle ecosystems, as the best urban wildlife reserves designate. Nevertheless, enormous challenges are created by most cities, with higher concentrations of poverty found put adjacent to wealth in most urban lands. (UNU/IAS Report, 2009)

Regarding the city as an ecosystem started with two different, but connected types of studies. *Urban metabolism* studies produced a holistic city view as a consumer and digester of resources and a creator of waste products. This viewpoint began as *presenting the city as an organism* with its own metabolic processes. (Douglas, 1983). Abe Wolman (1965) offered that so as to cope with the shortages of water and pollution of water and air, the city should be seen as an organic body with metabolic processes. As such, inputs and outputs could be calculated, and this information could be used to form public economic policies (UNU/IAS Report, 2009). (See Figure 2-1)

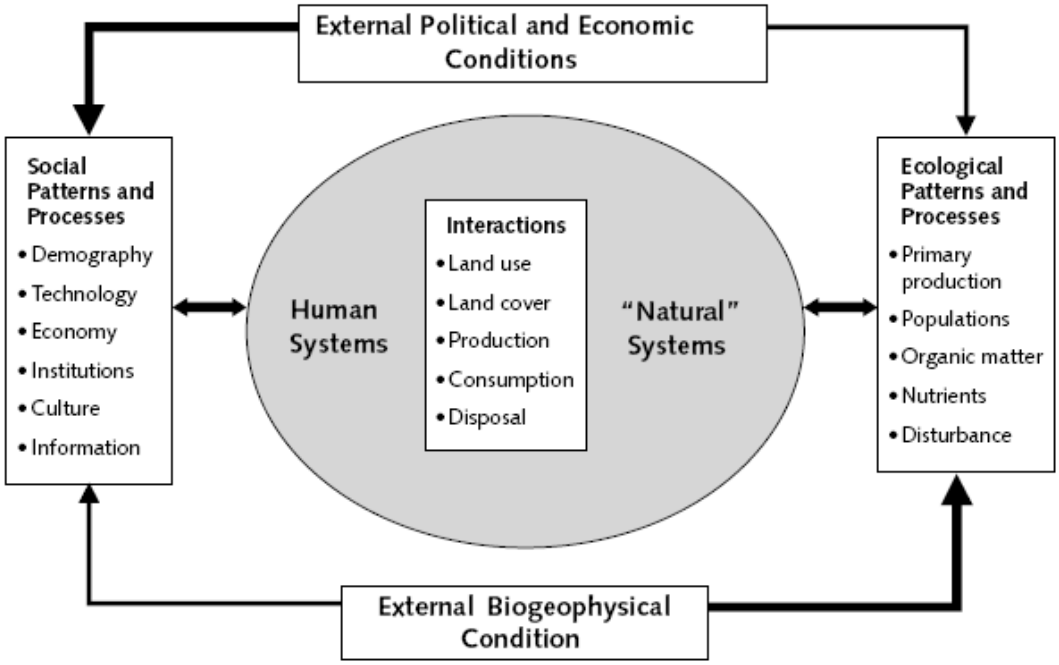

Figure 2-1 Conceptual Framework for investigating the integrated human ecosystem (The U.S. Long-Term Ecological Research Network, 2000)

Urban ecosystems implement the ecosystem approach in urban areas. Urban ecosystems are dynamic ecosystems that have similar interfaces and behaviors as natural ecosystems. Different from natural ecosystems, urban ecosystems are a mixture of natural and man-made component whose interactions are impacted not only by the natural environment, but also culture, human-beings' behavior, politics, economics and social organization.

The urban ecosystem approach promotes the arrangement of cities to that of natural ecosystems where resources, process and products are used more efficiently, producing less waste, consuming less input and viewing by-products as resources. (http://www.gdrc.org/sustdev/concepts/23-u-eco.html)

Ian Douglas, a physical geographer, proposed that *the city itself can be seen as an ecosystem with inputs of energy and water and outputs of noise, climate change, sewage, and garbage and air pollutants.* Another way to regard the city-nature dialectical then is to see the city as an ecological system with a measurable amount of environmental inputs and outputs. To conceive the city as an *ecological unit* is to specify new possibilities for accepting the

environmental inputs crucial for urban development and the environmental impacts of urban development. (Short, L.B. & Short J. R., 2008, pp:5-8)

2.1.1. Kyoto Protocol and Global Issues on Climate Change

"Climate change is happening, and its impact on all of us is growing…"

EU, 2009

Until the day we start to see that the earth's climate is in a process of rapid and unexpected change, the process of efforts for determining its reasons has started. Apart from the global attempts for stopping and mitigating our footprints on the earth, and correspondingly on climate change, some local steps have also been taken especially in developed countries. However, although from the localized point of view, it seems easier to do something for a better world, when we look at the same point globally; it becomes clear that these localized steps should cherish some global hopes, too. Therefore, it is the most crucial step to understand the going on and its approach globally, and then adapt these visions locally, to urban processes.

> "In response to growing consensus in the international scientific community (Hempel 2003; Hoffmann 2005), in 1988 the World Meteorological Organization and the UN formed the Intergovernmental Panel on Climate Change (IPCC) to objectively study and assess "climate change, its potential impacts and options for adaptation and mitigation" (IPCC 2006). The IPCC's first report, released in 1990, concluded that GHG emissions from human activity were enhancing the natural greenhouse effect and warned of the need to reduce significantly certain emissions to, at the very least, stabilize concentrations at current levels. Based on these conclusions, the International Negotiating Committee (INC) was formed in 1990 and charged with preparing what would become the United Nations". (Below, A.M., 2008).

The Kyoto Protocol concentrated on industrialized countries because they are responsible for most of the past and current greenhouse gas emissions and have the knowledge and money to decrease them. For instance, the amount of greenhouse gases produce in the EU is nearly 11 tons per citizen each year, while developing countries produce nearly 1 tons per citizen each year.

The Kyoto Protocol came into force in 2005. Up to now, 183 governments in addition to the European Community have officially adopted it. (See Appendix B) The Protocol specifies emissions targets for 37 industrialized countries. Most of these targets require greenhouse gas emissions reductions of 5-8% from 1990 levels by 2012. Among industrialized nations, only the US has decided not to participate in the Kyoto Protocol. The Protocol also introduced various economic mechanisms under which countries cooperate in reducing emissions (See Figure 2-2). These help to lower the cost of achieving such cuts. The Clean Development Mechanism allows industrialized countries to meet their emission targets partly by investing in emission-saving projects in developing countries.

This, in turn, is helping to transfer new technologies to poorer countries, enabling them to develop in a cleaner way. It is the first global environmental investment and credit scheme of its kind. A parallel mechanism, known as Joint Implementation, enables industrialized countries to invest in such projects on each other's territory. (European Commission, 2009)

EU countries sharing an 8% reduction target under the Kyoto Protocol		EU countries with individual targets under the Kyoto Protocol	
Austria	-13%	Czech Republic	-8%
Belgium	-7.5%	Cyprus	-
Denmark	-21%	Estonia	-8%
Finland	0%	Hungary	-6%
France	0%	Latvia	-8%
Germany	-21%	Lithuania	-8%
Greece	+25%	Malta	-
Ireland	+13%	Poland	-6%
Italy	-6.5%	Slovak Republic	-8%
Luxembourg	-28%	Slovenia	-8%
The Netherlands	-6%	Bulgaria	-8%
Portugal	+27%	Romania	-8%
Spain	+15%		
Sweden	+4%		
United Kingdom	-12.5%		

Figure 2-2 Kyoto targets of EU member countries

Kyoto Protocol is a global conformity connected to the United Nations Framework Convention on Climate Change. The basic aspect of the Kyoto Protocol is that it defines compulsory targets for 37 industrialized countries and the European community for decreasing the level of greenhouse gas (GHG) emissions.

The most important feature between the Protocol and the Convention is that while the Convention supported industrialized countries to steady GHG emissions, the Protocol commits them to do so. (http://unfccc.int/kyoto_protocol/items/2830.php)

2.1.2. Climate Change Facts

Climate change has become an interest of scientific studies, and is no longer one of many concerns of environmental and regulatory issues. As it is said by the United Nations Secretary General, it is the fundamental, prevailing environmental issue of this time, and the single furthermost challenge facing environmental regulators. It is an increasing crisis including economic, health and safety, food production, security, and other dimensions. (UNEP, 2009)

> "1) The term "climate change" encompasses all forms of climatic inconstancy (that is, any differences between long-term statistics of the meteorological elements calculated for different periods but relating to the same area) regardless of their statistical nature or physical causes. Climate change may result from such factors as changes in solar activity, long-period changes in the Earth's orbital elements (eccentricity, obliquity of the ecliptic, precession of equinoxes), natural internal processes of the climate system, or anthropogenic forcing (for example, increasing atmospheric concentrations of carbon dioxide and other greenhouse gases) (See Table 2-1).

Table 2-1 World Carbon Dioxide Emissions: 1990-2025 (Billion Metric Tons Per Year, *Adapted from EIA, 2005*)

	1990	*2002*	*2010*	*2015*	*2020*	*2025*	*Annual % Change 2002–2025*
Total World	21.4	24.4	30.0	33.0	35.6	38.4	2.0
United States	5.0	5.7	6.4	6.7	7.1	7.6	1.2
China	2.3	3.3	5.5	6.5	7.4	8.1	4.0
Former Soviet Union	3.8	2.4	2.8	3.0	3.2	3.4	1.5
India	0.6	1.0	1.4	1.6	1.8	2.0	2.9
Japan	1.0	1.2	1.2	1.2	1.2	1.2	0.2

2) The term "climate change" is often used in a more restricted sense, to denote a significant change (such as a change having important economic, environmental and social effects) in the mean values of a meteorological element (in particular temperature or amount of precipitation) in the course of a certain period of time, where the means are taken over periods of the order of a decade or longer." (homepage, http://www-nsidc.colorado.edu/arcticmet/glossary/, last accessed at May 2009).

Climate change is commonly seen as the basic environmental problem facing the world. Hint is shaping that impacts are being felt in the form of melting icecaps in the polar areas and increased variability of temperature, rainfall and storms in practically all regions. The scientific agreement supporting the increasing political and public acknowledgment of the climate problem has been detained in the newly developed reports of the Intergovernmental Panel on Climate Change (IPCC). The IPCC Fourth Assessment Report (AR4) basically specifies that it is no longer relevant to concern whether the climate is changing but rather how much change we are responsible for and how fast this will come into force. Additionally, the IPCC highlighted that climate change, as a long-term matter, and requires to be regarded as a medium-term problem needing short-term acts. The IPCC also figures out that the necessary action to anticipate crucial climate change is achievable with strong policies, technology improvement and technology transfers using a wide range of policy and technical options. The total costs of restricting concentrations of greenhouse gas emissions (GHGs) to controllable levels will be noteworthy. Thus, compared with the foreseen economic impacts of climate change if mitigation does not take place and the size of the world economy and its supposed growth over the last decades, the costs of mitigation will amount to a small portion of that growth. (UNEP, Climate Change Strategy, 2009)

2.1.2.1. Inputs of Climate Change

> *"Since 1956 and the publication of Thomas' Man's role in changing the face of the earth, the human John Thornes population has almost doubled, half the world's tropical forests have been lost, the processes of overgrazing and desertification have increased, over-fishing, pollution and the conversion of estuarine habitats have altered the world's marine habitats, chemical pollution has become all pervasive, new hazardous wastes have become wide- spread, global warming is occurring – probably due, in part at least, to human activities - and the economy has been globalized through debt- financing and international corporate activity" (Talbot, 1989).*

Climate change is considered as the change in the distribution of weather statistically over time periods that differ from decades to millions of years. It can be a change in the average weather or a change in the allocation of weather events around an average (for instance, more or fewer tremendous weather events). Climate change may be bounded to a defined region, or may ne seen across the whole Earth (www.wikipedia.org).

This change becoming more crucial time after time resulted in decisions taken at global, country and city level. In this thesis, we fundamentally focus on decisions taken in city level. Urban development tendencies, efficiency approaches of urban plans modify the inputs of climate change. Basically, every urban process resulting in carbon emissions, distorting ecology of the world comprises change in climate issues.

As Zengin defines in her study (2009), the cause for concern of present and future climate change is believed due in part to anthropogenic (human-induced) build-up of increased atmospheric trace gas. The major greenhouse gases (GHGs) are carbon dioxide, methane, nitrous oxides, etc… Carbon dioxide is the major contributor to climate change, with most CO2 emissions coming from the combustion of fossil fuels. Records show a clear correlation between CO2 and temperature (Figure 2-3). It is erroneous to conclude from this that changes in CO2 concentration were responsible for the large temperature changes (Dornbusch R. & Poterba J. M., 1993, p: 18).

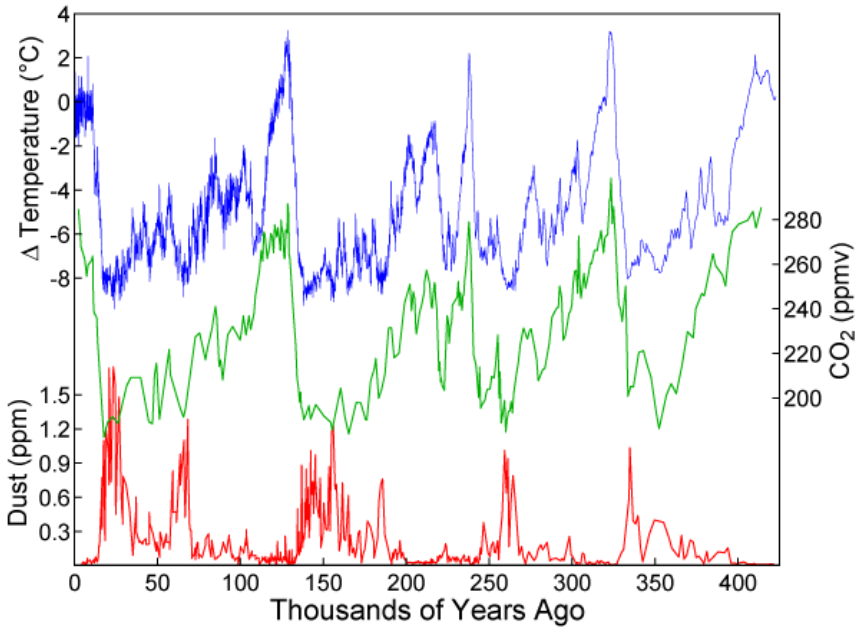

Figure 2-3 Graph of CO_2 (Green graph), temperature (Blue graph), and dust concentration (Red graph) measured from the Vostok, Antarctica ice core as reported by Petit et al., 1999. Higher dust levels are believed to be caused by cold, dry periods.

About one-half the carbon released by fossil fuel burning ends up in the atmosphere. Deforestation also releases carbon and recently this activity contributes about one third of the annual human caused additions to atmospheric CO2. (Caldeira, K. & Kasting, J., 1993) (See Figure 2-4).

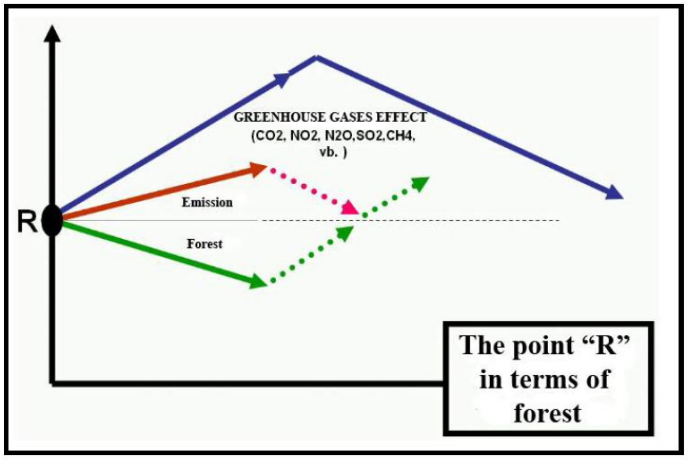

Figure 2-4 Change in Greenhouse Effects (*adapted from Kayhan, M., Küresel İklim Değişikliği ve Türkiye)*

2.1.2.2. Outputs of Climate Change

It is doubtful that outputs, and accordingly, results of change in the world's climate will create other unexpected and underestimated results in the future of the world. Although researches on these outputs show us the changes will be seen considering the climate change, there is still uncertainty of more.

Studies show that even if greenhouse gas emissions were fixed to today's levels, the climate would still carry on changing as it adapts to the increased emissions of last decades. More changes in climate are, for that reason, inevitable, and nations must be ready for them (See Figure 2-5). The declaration results in influencing all nations to take quick actions to decrease the results of climate change, adapt to its impacts and get sure that the issue is covered in all related national and international strategies (Becken, S., 2002a). What we have to ensure is that this change called "*climate change*" refers to the change effecting ecology of the earth and accordingly all types of ecosystems.

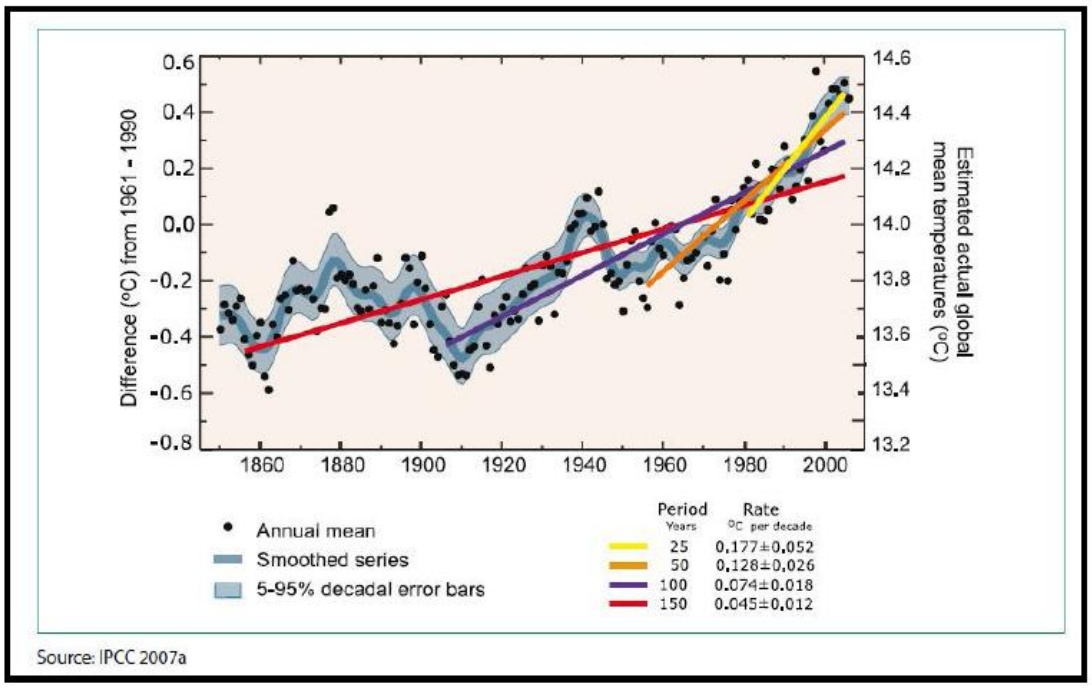

Figure 2-5 Recorded Changes in Global Average Temperature of the World Since 1850

2.1.2.3. Recent Developments in the World

During the efforts of climate change, seen as a global problem of the world and all countries, many conferences were organized and conventions and protocols were signed by countries. The most important and effective of all was the establishment of the Intergovernmental Panel on Climate Change (IPCC). IPCC was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). This panel basically focused on assessing the scientific basis of risks based on human-induced climate change, their potential impacts and ways for adaptation and mitigation.

Another important development was the sign of United Nations Framework Convention on Climate Change (UNFCCC) on the 24th of March, 1994, which was adopted at the Earth Summit in Rio de Janeiro in 1992.

The though behind this convention was that expected results of climate change would be the basis of environmental problems. Apart from these, many conferences were also organized to discuss about climate change and evaluation reports were introduced about the outcomes of these conferences.

During the first years, focus of the world, concerning climate change, was on the green house gases and the other causes of the climate change. Following this, CO2 emissions and human contributions to the climate change and their effects and mitigation measures to decrease the emissions have been discussed in the agenda. Then, the focus was given to the impacts of climate change in the world.

In the agenda of 2000s, both causes and impacts of the climate change were discussed in detail. In addition to this, measurements should be taken for mitigating the impacts of climate change were discussed. Through all these efforts, mitigation measures providing decrease in accumulation of green house gases in the atmosphere have been supported. Common but differentiated responsibilities of the countries, national and regional development priorities, targets and unique conditions, common responsibilities for

decreasing human-based green house gases emissions, preventing the climate change and decreasing the impacts of the climate change have been determined. (Türkeş, M., 2001, pp: 2-3)

In the IPCC's Third Assessment Report (TAR) scientists created an image to represent possible risks related with increase in global mean temperature (GMT) and explained estimated reasons. An updated image was not presented in the AR4 Synthesis Report, but the researchers who updated it published their findings in peer-reviewed literature (Smith et al. 2009). As stated in Climate Change Science Compendium Report and adapted in the Figure 2-6, climate anomalies from 2007 to 2009 are significant in most countries of the world. Most countries faced with the problems of underestimated changes in temperature, sandstorms, droughts and even flooding. This report is one of the evidences of that the *climate change* become visible in the whole world with different forms of changes.

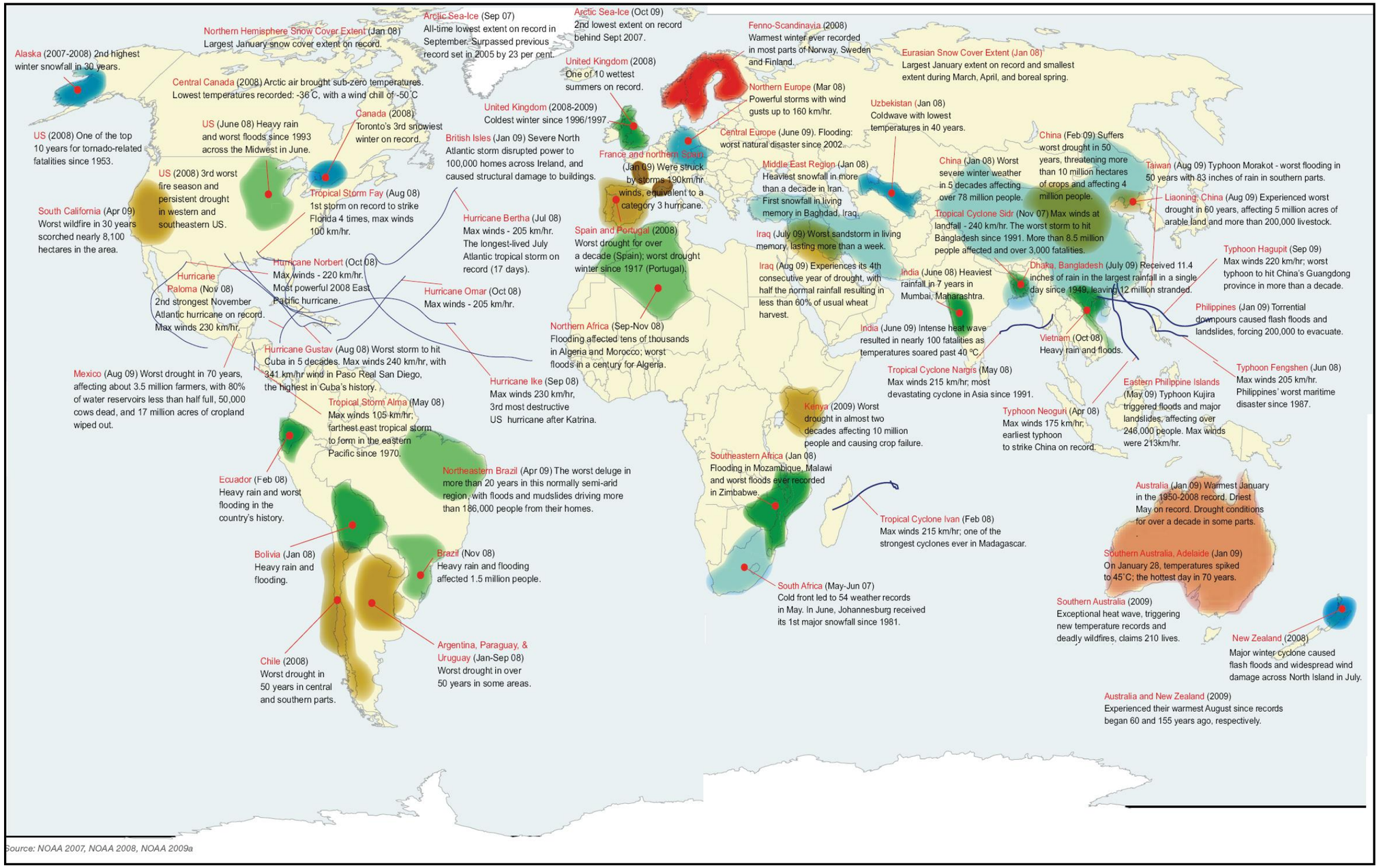

Figure 2-6 Significant Climate Anomalies from 2007 to 2009 ***(Adapted from Climate Change Science Compendium, 200)***

CHAPTER 3

A NEW TOOL FOR ENVIRONMENTAL PERFORMANCE: ECOLOGICAL FOOTPRINT

This chapter specifies the term "ecological footprint" in detail as a new tool for estimating environmental performance of urban patterns. It also determines the common trend of use of ecological footprint as the main indicator for sustaining the world, countries and "cities", ecological footprint calculation methods and tools (human-based and city (territory)-based) and ecological footprint minimization strategies (city (territory)-based) to give a comprehensive looking to the main focus of this thesis.

3.1. Definition of Environmental Performance

While examining a city's environmental performance, both the quality of the local environment and its impacts on the regional and global environments should be considered. Cities are in close relationship based on two-sided interaction, with natural systems beyond their physical boundaries through (a) *the conversion of land and transformation of habitats*; (b) *the extraction and depletion of natural resources;* and (c) *the release of emissions and wastes*. As the ecosystems of the world provides (d) *important goods and services to urban systems*, environmental changes occurring at the regional and global scale such as the contamination of watersheds, loss of biodiversity, and change in climate-affect (e) *the quality of the urban environment* in the long term and ultimately human health and well-being (Figure 3-1). (Downloaded from http://jpe.sagepub.com at Middle East Technical Univ. on February 25, 2010)

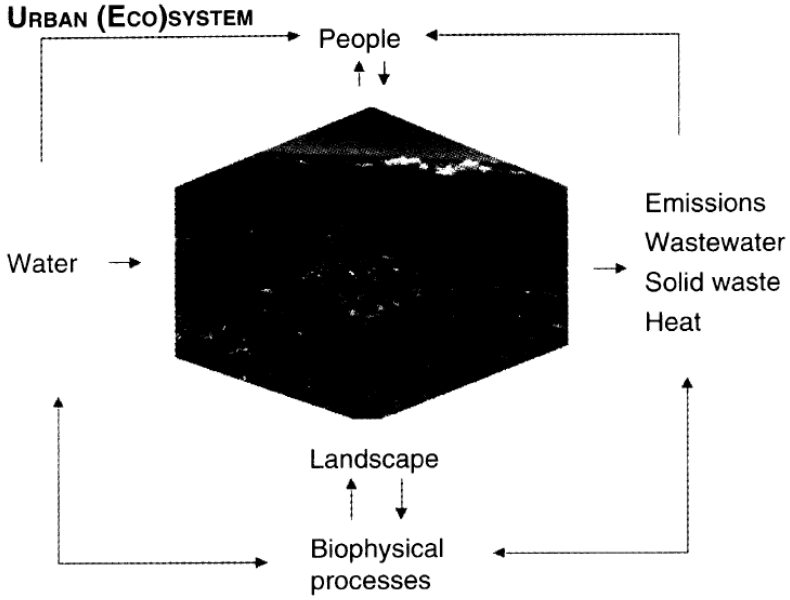

Figure 3-1 Urban Ecosystems

Figure 3-1 shows the relationship of urban and ecological systems. Considering the theoretical model developed by the World Resources Institute (Hammond et al. 1995) and the World Bank (1995) for monitoring environmental performance, four dimensions should be taken into consideration while evaluating the implications between the urban land and ecosystem functions were specified (Figure 3-2): (1) *sources*, (2) *sinks*, (3) *support systems*; and (4) *human well-being*. Human activities based on nature, the source of minerals, energy, food, fibers, and other resources, are crucial for productivity. They also depend on the ability of the nature to serve as a sink to absorb produced emissions and waste of human-beings. Furthermore, earth' ecosystem presents a wide range of critical services to the urban population: they control climate and flooding, absorb carbon, and provide aesthetic beauty. (Westman 1977, Ehrlich and Mooney 1983, Daily 1997, Costanza 1997) Finally, environmental change has direct effects on the health and well-being of human-beings.

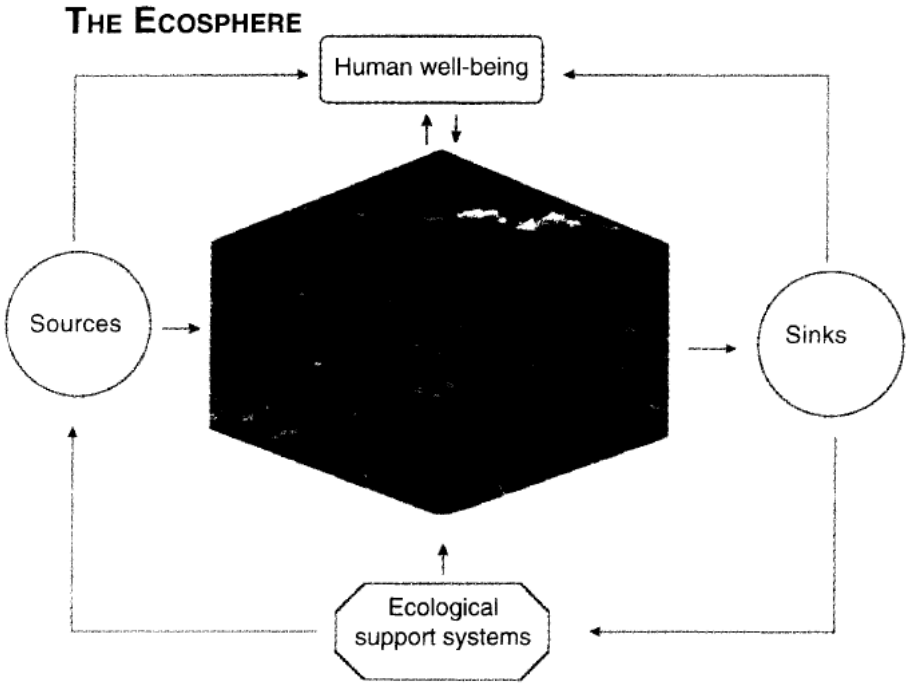

Figure 3-2 Implications (dimensions) of environmental performance

Before exploring the consequences of urban patterns on the implications of environmental performance, it is better to determine what kind of qualitative and quantitative measures are needed to be included. How can our understanding of ecological dynamics facilitate us identify the considerable factors that manage these implications? According to Holling (1978, 25-26), four properties of ecological systems determine how they react to change:

> *"1. Selective connections: The parts in ecological systems are connected to each other in a selective way, which has implications for what should be measured.*
> *2. Spatial heterogeneity: Events are not uniform over space, which has implications for how intense impacts will be and where they will occur.*
> *3. Resilience: Sharp shifts in behaviors are natural for many ecosystems, which may lead to misinterpretation of environmental changes.*
> *4. Dynamic variability: Variability, not constancy, is a feature of ecological systems, which contributes to their persistence and to their self-monitoring and self-correcting capacity." (Holling, 1978)*

These four properties of ecological systems guide the discussions about developing certain scenes of environmental performance of urban patterns.

3.2. Definition of Ecological Footprint

3.2.1.Ecological Footprint

> "The total world ecological footprint is 2.6 global hectares per capita. The ecological reserve, or Biocapacity - the amount of land available for production, is 1.8 global hectares per person, a deficit of 0.8 global hectares per capita." (Living Planet Report, 2006)

Considering the fact that in 5 continents and more than 200 counties, there are 4 billion poor people in the world; 1 billion of them are under hunger threshold. This is not only for the reason that we use existing resources unconsciously. It is also because that we use these resources in an inequivalent way.

Human beings as a part of the nature meet their needs through nature. However we do not recognize that we make pressure on the nature and exceed the ecological carrying capacity of it while we are meeting our needs. Ecological footprint is, therefore, a method to estimate the carrying capacity of the nature. It shows the biological area (global hectare) used to produce the sources people need for living and to dispose wastes they produce. (Ercoşkun Ö.Y, 2007)

Ecological Footprint shows the sustainability indicators (Hammond, 2006). Resources used and wastes produced by a defined population are adapted to a common basis: the area of productive land and aquatic ecosystems seized (in global hectares) from whatever source in worldwide definitions. This footprint is figured out in Figure 3-3, where a variety of essential elements are determined. (See Appendix C)

The term "ecological footprint" was founded by Prof. W. Rees and Dr. M. Wackernagel and calculation methods were determined. Agricultural lands, wetlands, seas, forests constructed lands etc. are considered within bio-productive areas.

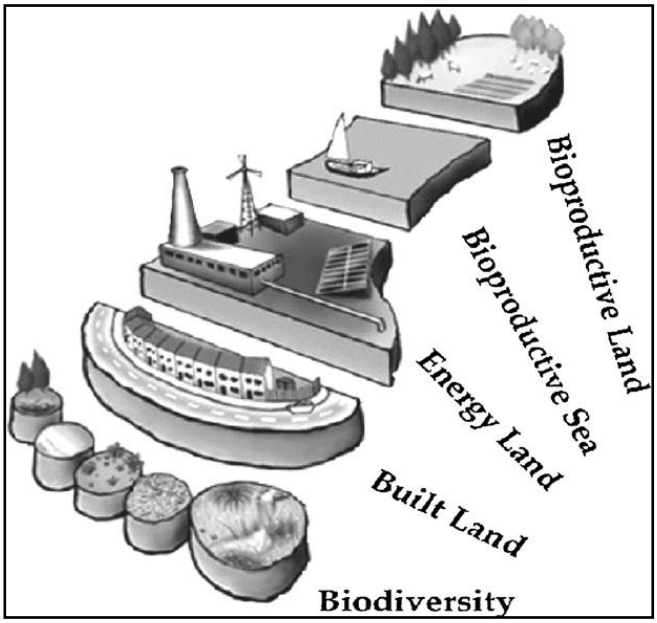

Figure 3-3 Schematic representation of the environmental footprint, and its land types (Adapted from Chambers et al., 1999)

The Ecological (Carbon) Footprint is is an artificial indicator used to evaluate sustainability of *anthropic units*[1]. Its use has been obstructed by some troubles, especially at a local scale. Being envisaged as a measure of the biologically productive area used to sustain individual consumptions in a human community, it leaves out the impacts linked to economic activities. (Scotti M., Bondavalli C., Bodini A., 2008)

The Ecological Footprint has occurred as the world's leading measure of humanity's request from nature. It estimates how much land and water area a human population needs to supply the resource it consumes and to absorb its wastes, using existing technology. (www.footprintnetwork.org)

Until 1970s, humanity has faced with ecological overruns with annual demand on resources more than what Earth can restore every year. It now takes the Earth one year and five months

[1] In contrast to natural units, the term "*anthropic units*" (a neologism meaning human units) describes measurement units which explicitly arise from human physiology or behavior, or which are primarily a construct of human culture. Some were derived directly from the dimensions of the human body, and as such, are commonly referred to as anthropomorphic (meaning human shaped). Other anthropic units evolved indirectly from human activities such as walking or farming, or were invented by humans to support human endeavors. (www.en.wikipedia.org) (Also See Appendix 1, page 7)

to renew what human-beings consume in a year. We sustain this overruns through clearing up the Earth's resources. Overshoot is an underestimated danger to the well-being of people and the health of the planet, and one that is not sufficiently tackled. (See Appendix C)

Through evaluating the Footprint of a certain population, we can review our pressure on the planet, which encourages us monitor our ecological assets more judiciously and take personal and shared action in support of a world where humanity lives within the Earth's bounds. Envisaged in 1990 by Mathis Wackernagel and William Rees at the University of British Columbia, the Ecological Footprint is now mostly used by scientists, businesses, governments, agencies, individuals, and institutions working to monitor ecological resource use and advance sustainable development. (http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_basics_overview/)

An ecological footprint is a measure of the impact our activities have on the environment, and in significant climate change. It pertains to the amount of greenhouse gases produced in our daily lives via wasting fossil fuels for electricity, heating and transportation etc. The ecological footprint is a measure for all greenhouse gases people produce and has units of tonnes (or kg) of carbon dioxide equivalent.

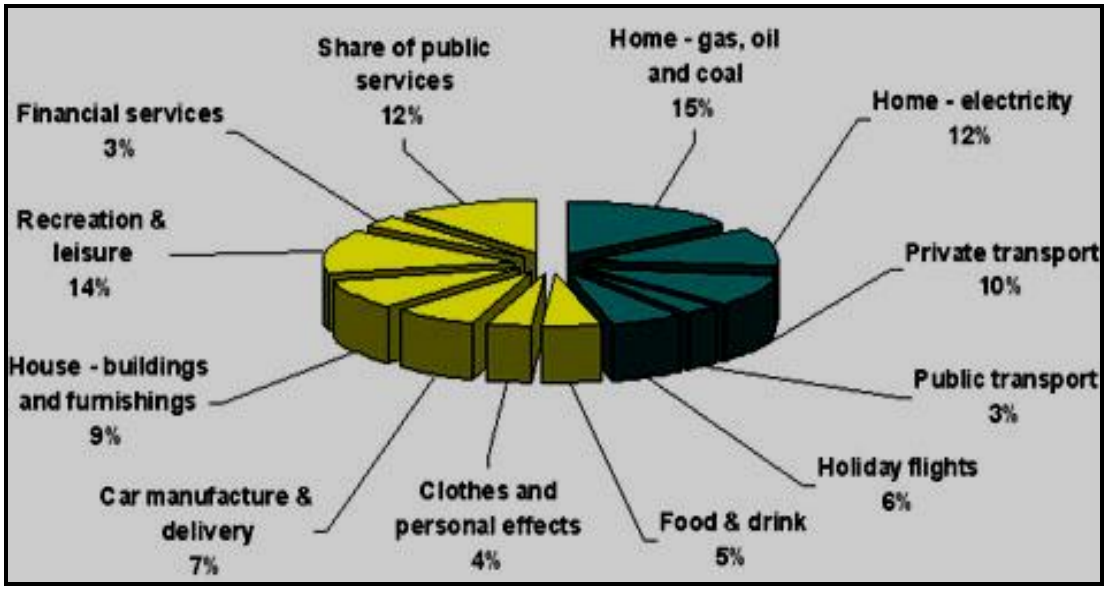

Figure 3-4 Main Elements of a Person's Ecological Footprint (http://www.footprintnetwork.org)

The Figure 3-4 shows the main components which structure the total of an individual person's ecological footprint in the world. An ecological footprint is composed of the total of two parts, the primary footprint (shown by the green slices of the pie chart) and the secondary footprint (shown as the yellow slices):

The primary footprint is a measure of direct emissions of CO2 from the burning of fossil fuels that includes domestic energy consumption and transportation (e.g. car and plane). We have full control on these footprints directly. The secondary footprint is a measure of the CO2 emissions that are indirect from the complete lifecycle of products we consume – which are linked with their manufacture and ultimate break. To put it very cleanly – the more we consume, the more emissions will be produces (Also See Figure 3-5). (http://www.carbonfootprint.com/ carbonfootprint.html)

Ecological footprint itself is based on several assumptions, the most important ones are:

- It is probable to clarify the resources needed during an activity and calculate the wastes produced by it.
- These resources and wastes can then be translated into land area values that are selected as the representatives of exact bio-productive lands necessary for producing the resources and restore the wastes. (Knausa, M., Lo¨hr b, D., O'Reganc, B., 2005)

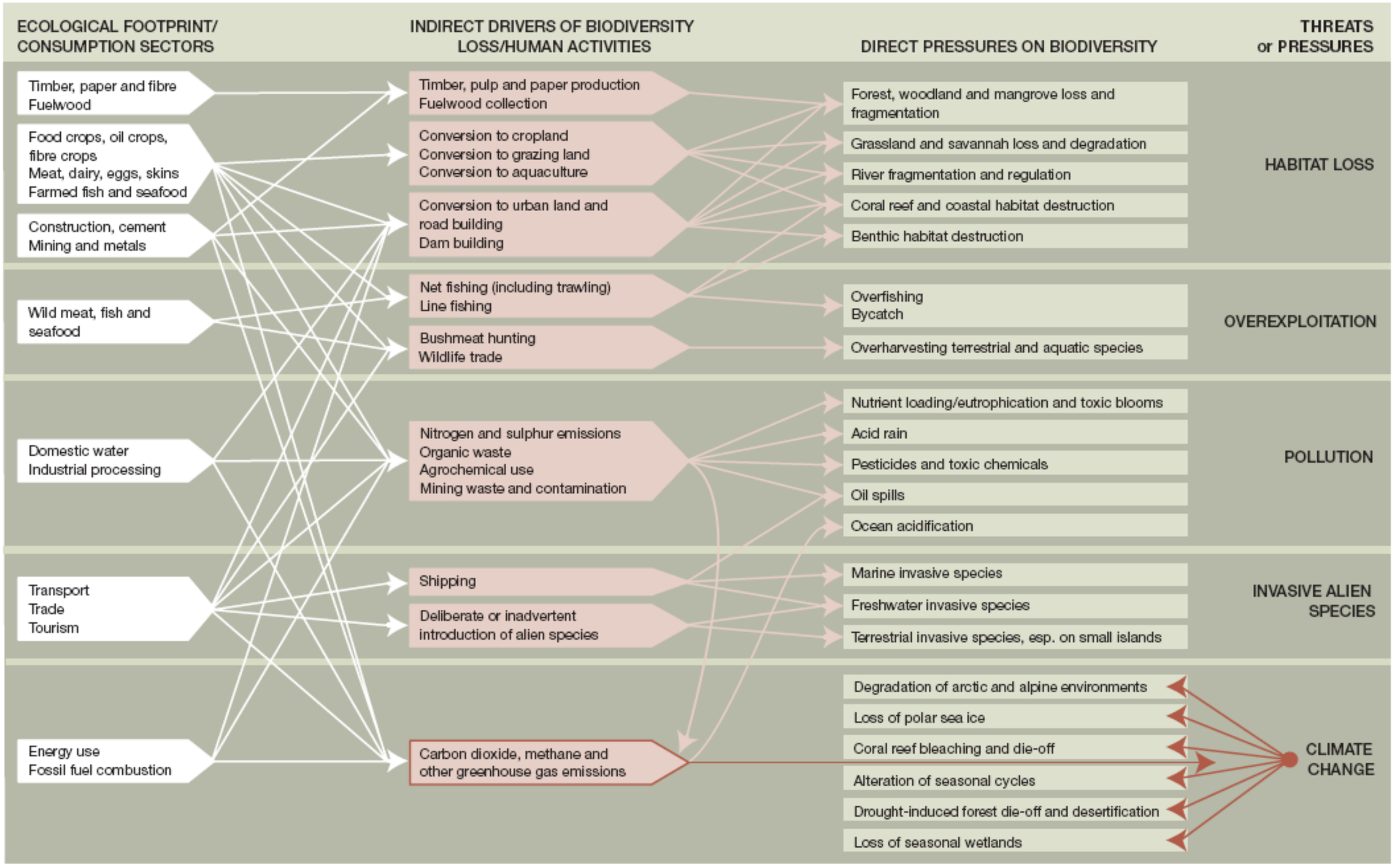

Figure 3-5 Biodiversity Loss, Human Pressure and The Ecological Footprint, cause-and-effect relationships ***(adapted from WWF Living Planet Report, 2008)***

3.2.2. Urban Carbon

Sustainable development is pleasing and, expectantly, achievable globally. But, unfortunately, it is less apparently applicable on the urban scale (Doughty and Hammond, 2004), where the saying 'sustainable cities' is occasionally used with the same meaning with concepts such as *urban autonomy*, *self-reliance* or *self-sufficiency*. For this reason, Doughty and Hammond (1997, 2004) used the method of ecological footprint analysis to discuss the sustainability of cities by evaluating them in a broader geographic context comprehensively. (Eaton, R. L., Hammond G. P., Laurie J., 2007)

Ecological footprint is defined in 5 groups by *Global Footprint Network* as: world footprint, footprint for nations, footprint for cities, footprint for business and personal footprint. In this section what "urban carbon" basically means is the footprint for cities and in somehow personal footprint of people living in urban areas.

Urban carbon that is carbon emissions produced and consumed in urban areas reasoned by human activities and urban development decisions taken physically can be categorized under four groups in terms of the place they consumed and produced.

As seen in the Figure 3-6; carbon emissions can be consumed locally or anywhere out of the urban boundaries and likewise can be produced locally and anywhere out of the urban boundaries. Depending on the type, the emission can occur locally or globally. This typology may be based on the emission types produced and consumed and its total effects on the sustainability in the short term and the long term (www.carbonfootprint.com).

Considering this production and consumption typology, on the other hand, there are two different methods for considering Urban Carbon effects:

- *Territorial Footprint (TF)*
- *Citizen Footprint (CF) (*Scotti M. , Bondavalli C., Bodini A., 2008)

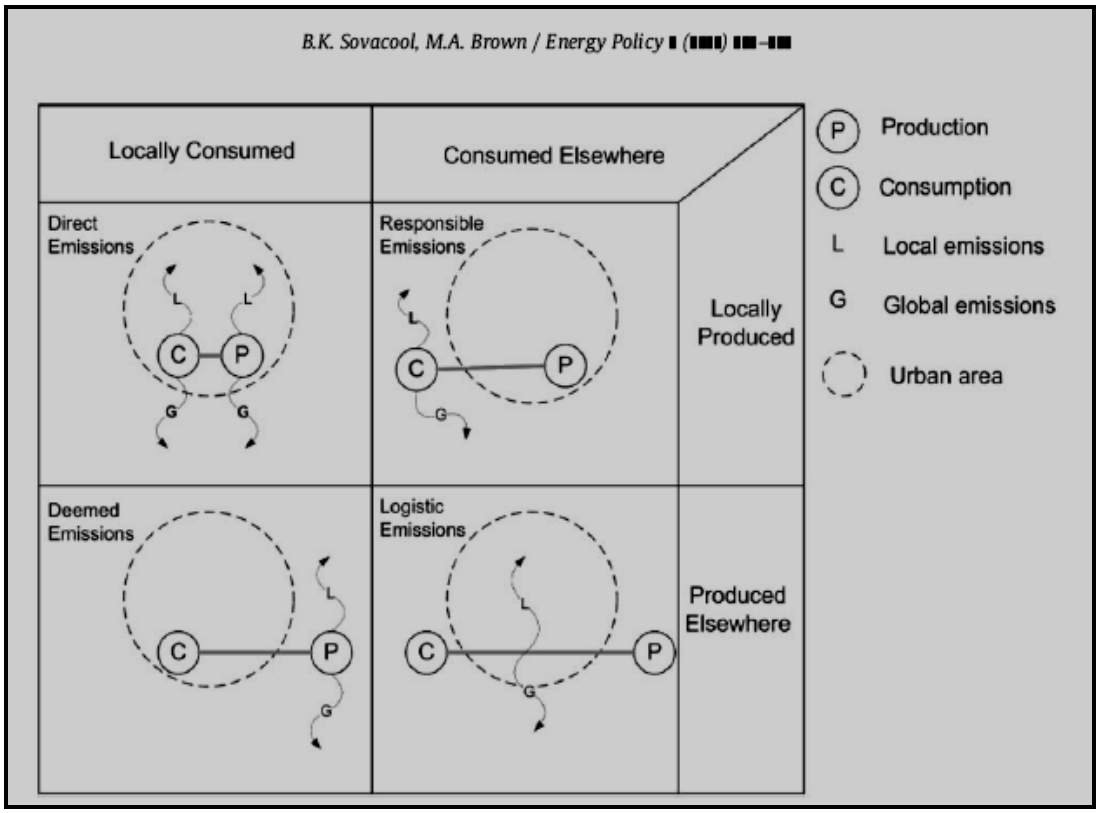

Figure 3-6 Four typologies of carbon emissions

3.2.2.1. Territorial Footprint

Four main categories were considered under territorial footprint:

(a) Productive activities,

(b) Transportation,

(c) Waste disposal and management

(d) Water management.

Productions were further divided by sectors -e.g. industry, agriculture, and tertiary sector. Energy land, area for infrastructures, cropland and grazing land share this EF. Energy consumption for this category comprises electricity and fossil fuel utilization. *Transportation* distributes its impact over two area types: energy land needed to absorb emissions and built-up land for road development. Data to calculate the former contribution include fuel consumptions by cars, buses and trains, trucks and lorries. Cross-border impacts may be taken into account assuming the compensatory effect of vehicles fuelling outside the

urban edges, but consuming inside, and vehicles fuelling within the urban area and travelling outside. Energy land and built-up land were the two categories by which *waste management* contributes to EF. Energy used by the sewer system, for water purification and the management of water distribution make up EF of the *water management system*. Figure 3-7 summarizes all the categories that contribute to Territorial Footprint. TF is expressed as total global hectares (gha), because production cannot be intended in terms of individual contributions. *(*Scotti M. , Bondavalli C., Bodini A., 2008)

Categories in Territorial Footprint
1. Productive activities
• Industry
–Electricity consumption
–Fossil fuels (methane; diesel oil; combustible oil)
–Industrial area
• Agriculture
–Electricity consumption
–Soil use (built-up area; cropland area; pasture area; embodied energy in fertilizers, pesticides and herbicides)
• Tertiary
–Electricity consumption
–Fossil fuels (methane; heating oil)
–Built-up area
2. Transportation
• Cars, buses and trains
–Petrol consumption
–Diesel oil consumption
–Propane liquid gas consumption
–Methane consumption
• Trucks and lorries
–Petrol consumption
–Diesel oil consumption
–Propane liquid gas consumption
–Methane consumption
• Agricultural fuel
–Diesel oil consumption for nursery gardening
–Diesel oil consumption for transportation
• Roads and facilities (highways, railway, bus and train stations, etc.)
3. Waste disposal and management
• Special wastes (dangerous and not dangerous)
• Household wastes (wastes, and fossil fuel consumption for waste transportation)
• Truck diesel fuel
• Built-up areas (dumps, incinerator, etc.)
4. Water management
• Sewerage system
• Purification water plant
• Aqueduct

Figure 3-7 List of Categories included into the Territorial Footprint Calculations

3.2.2.2. Citizen Footprint

Individual consumptions were allocated into five categories:

(a) Food,
(b) Shelter,
(c) Mobility,
(d) Goods
(e) Services (Global Footprint Network, 2005a; Lewan and Simmons, 2001).

As for *food* consumption (annual per-capita kilograms), data may be calculated from per-capita cost (€) and average market prices (€ kg−1). Change to global hectares of impacted land cares energy land, in addition to cropland, grazing land and fishing ground, based on the specific source. *Shelter* category comprises, mostly, domestic energy use. That may be, household consumption of electricity (kWh), methane (m3) and heating oil. This category contributes to EF as energy land and built-up area (in global square meter, henceforth gm2). *Mobility* distributes its impact upon two area types: energy land, needed to absorb fossil fuel emissions by private cars or public means of transport (e.g. bus and train energy consumption), and built-up land (roads and infrastructures). *Good consumptions* (annual per-capita kg), alike food category, are mostly estimated from average per-capita expense (€) and average market prices (€ kg−1). Items in this category build up EF as energy land plus cropland, grazing land and forest productivity. *Services* mostly impact on energy land (electricity and fossil fuel) and built-up land (gm2) for buildings. Details related to the consumption categories are reported in Figure 3-8. *(*Scotti M. , Bondavalli C., Bodini A., 2008)

Categories in Citizen Footprint
1. Food
• Bread and cereals (bread, bread sticks and crackers; biscuits; pasta and rice; cakes; other)
• Meat (beef; pork; chicken, turkey and rabbits; sausages; others)
• Fish
• Milk, cheese and eggs (milk; cheese; eggs; other)
• Oils and fats (olive oil; other oils and fats)
• Potatoes, fruit and vegetable (fruits; potatoes and vegetables)
• Sugar, coffee and spices (sugar; coffee, tea and cacao; ice creams; other)
• Beverages (wine; beer; other)
2. Shelter
• Electricity consumption
• Heating (methane; heating oil)
• Built-up area (houses and apartments)
3. Mobility
• Fuels (petrol; diesel oil; propane liquid gas; methane)
• Built-up area (roads, highways, parkings, railways and other travel facilities)
4. Goods
• Tobacco
• Clothes and shoes
• Furnitures
• Household appliance
• Detersives and detergents
• Linen and kitchenware
• Medicines
• Means of transportations
• Books and newspaper
• Personal computer, TV, radio and Hi-Fi
• Others
5. Services
• Electricity consumption
• Heating (methane; diesel oil)
• Built-up area (hospitals, barracks, cinemas, theaters, etc.)

Figure 3-8 List of Categories included into the Citizen Footprint Calculations

3.3. Ecological Footprint Calculation Methods and Tools

The ecological footprint (EF) provides a quantitative basis for estimating environmental impact of a population living in a defined area and a means of raising awareness on the consequences and crucial effects of human activities. It is a valuable technique that makes it possible to review the sustainability level of development. However, it should not be forgotten that ecological footprint analysis should be incremented by the use of other measures to account for these wider aspects of human welfare and environmental performance.

> *"Footprint analysis specifies judgments about the relative weighting of the various consumption categories and their environmental impact. It reduces all such impacts to a common basis in terms of hectares per capita, which may not prove to be a unit that can be readily assimilated by ordinary people. The International Institute for Environment and Development determined the process of analysis, whereby all environmental impacts are aggregated into a simple index as "resource reductionism". They likened it to traditional measures of economic welfare, such as the gross domestic product (GDP). Nevertheless, it also provides a useful basis for contrasting the footprint of urban activities within an available land area. The consequences of human consumption and produced wastes can be graphically viewed against the 'carrying capacity' of a nation, region, or the planet as a whole." (Kitzes et al., 2008)*

The EF has traditionally been defined as an area-based indicator and visualized as the size of the foot. When the EF exceeds the available area of land, statements like "ones footprint is 1.2 planets" (Kitzes et al., 2008) are used. While this view is very effective in clarifying this dramatic situation of the human species, an alternative view was proposed in which the limit to the size of the EF (i.e. BC) is more evident and clear. This is done by giving EF a third dimension (footprint depth) to indicate the overuse of resources. The EF becomes now a space-time model since it highlights both the limits of space as well as the discrepancy between biological regeneration time and human consumption time. Space and time are both key aspects of sustainability theory. For example in 2003, humanity operated in a state of Ecological

Overshoot (EO = 0.45 gha/person): the Earth's regenerative capacity (BC = 1.78 gha/person) was less than the total area harnessed for human consumption (EF = 2.23 gha/person) (GFN, 2006).

Ecological footprint of countries is calculated as (Rees, 1997):

Ecological Footprint = Consumption * Production * Population
Net Consumption = Domestic Production + Import - Export

For example, an automobile produced in Germany would be sold in France; it will be included in the ecological footprint of France, because it will be consumed in France. On the other hand, so as to calculate net consumption, annual product (tons) is divided into production of the world (annual produced tons in per hectare) and then multiplied with the equivalence factor calculated for all countries from by using total production area. That number becomes the production area of that country in terms of global hectare.

According to 2000 Report of WWF, ecological footprint of countries such as The United Arab Emirates, USA, Canada, New Zealand, and Finland is 8-10 global hectares. Ecological footprint of Turkey is nearly 2.1 hectares (See Figure 3-9). Along the Europe, the footprint is nearly 5.5 hectares. However, environmental performances of cities changes when cities are considered. Cities such as Barcelona or Munich are the cities with the least ecological footprint.

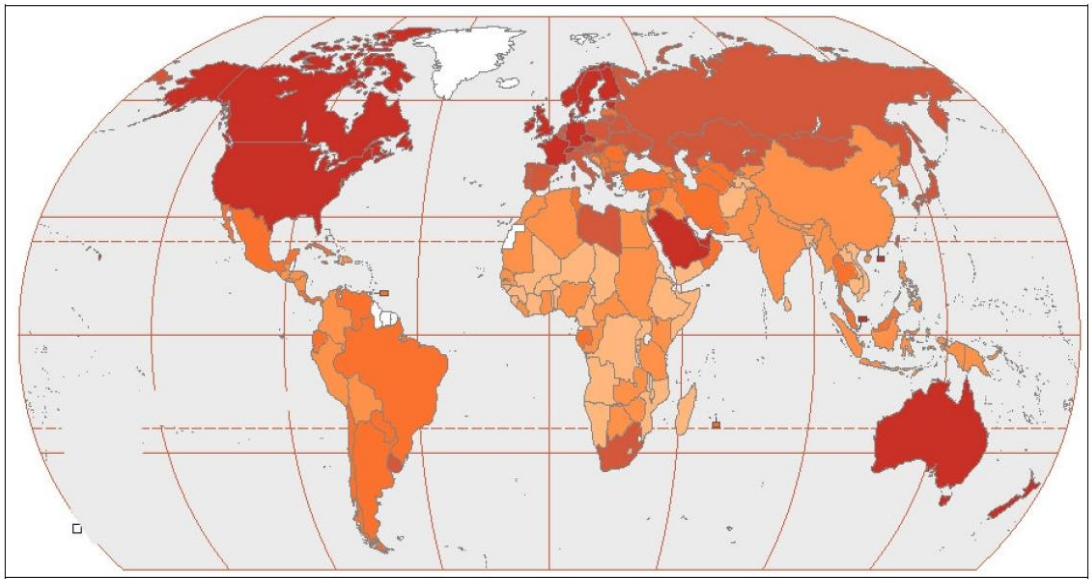

Figure 3-9 Ecological Footprints of Countries (red: 6 and over, orange: 4-6 global hectares)

"According to the conventional model, EF can be shown as a circle in which the white area is the Earth's BC, while the total area enclosed by the dark line is the EF. The difference between the two areas (grey area) is EO. A qualitative difference between BC and EO exists even if they have the same physical unit (gha). While BC represents the annual inflow guaranteed by photosynthesis, EO is an "ecological debt" that, as an "economic debt", accumulates year by year and will continue to increase until humanity reduces its demand. In a certain sense BC and EO can be added to obtain the EF but their difference should be borne in mind: the former is physical, the latter is virtual, indicating the amount of land necessary to sustainably support the human population, but that land may not exist! For example, there may not be enough specific land to absorb CO2. The model here proposed accounts for these differences. The footprint is now shown in three dimensions. The numerical result of the footprint obviously has to be the same, but the representation is different" (See Figure 3-10). (V. Niccolucci et al. / Ecological Modeling 220, 2009)

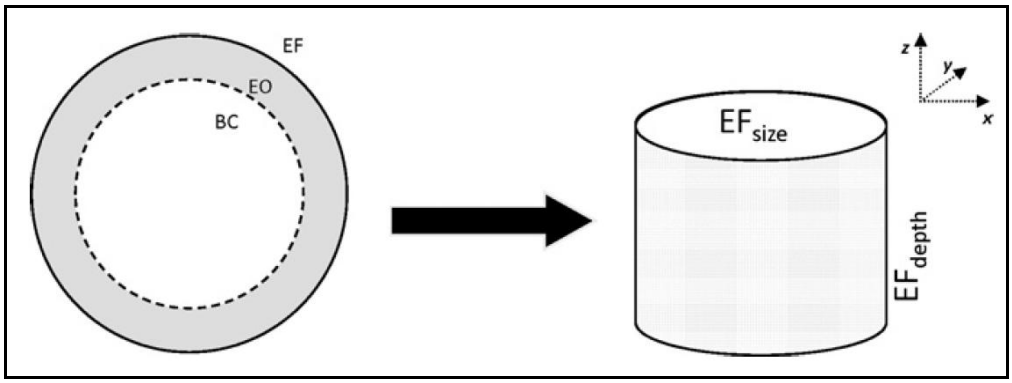

Figure 3-10 The EF models for a world average citizen: the classical (on the left) and the 3D (on the right). Legend: Ecological Footprint (EF), Biocapacity (BC), Ecological Overshoot (EO).

The first Ecological Footprints were estimated through developing a component-based approach. This has developed into a more wide-ranging and vigorous approach: compound footprinting, now used for national footprint calculation (Simmons et al., 2000).

The component-based approach gives the Ecological Footprint of all related components of a population's resource consumption and waste production. This is done through identifying all of the individual items–goods and services–and amounts, that a certain population consumes, and second, evaluating the Ecological Footprint of each component using life-cycle data that follow the resource requirements of a given product from resource withdrawal to waste disposal, or 'cradle to grave'. The total accurateness of the final result depends on the comprehensiveness of the component list as well as on the consistency of the life-cycle

assessment (LCA) of each identified component. This approach gives unexpected results, given LCAs' edge problems, lack of precise and completes information about products' life-cycles, problems of double-counting in the case of composite chains of production with many primary products and by-products, and the large amount of detailed knowledge needed for each analyzed process (Lenzen, 2001).

Additionally, there may be important differences in the resource necessities of products, depending on the way they are produced. It is obvious that, the process of noticing all units and evaluating their individual resource demands has intuitional value, analyzing the hundreds of projects replicating this approach worldwide. Scientific forcefulness and consistency of the component-based Footprinting approach using LCA data, however, may be less due to these limitations (See Table 3-1) www.footprintnetwork.org).

Table 3-1 Trends of EF, BC and EO from 1961 to 2003 ***(Adapted from Global Footprint Network)***

Year	Population ($\times 10^9$ persons)	EF ($\times 10^9$ gha)	BC ($\times 10^9$ gha)	EO ($\times 10^9$ gha)	EF (gha/person)	BC (gha/person)	EO (gha/person)
1961	3,08	5,27	10,57		1,71	3,43	
1962	3,14	5,44	10,59		1,73	3,37	
1963	3,20	5,74	10,60		1,79	3,31	
1964	3,26	5,97	10,61		1,83	3,25	
1965	3,33	6,27	10,62		1,88	3,18	
1966	3,40	6,43	10,63		1,89	3,12	
1967	3,47	6,61	10,64		1,90	3,06	
1968	3,55	6,93	10,66		1,95	3,01	
1969	3,62	7,33	10,68		2,03	2,95	
1970	3,68	7,78	10,69		2,11	2,90	
1971	3,77	8,05	10,71		2,14	2,84	
1972	3,84	8,49	10,72		2,21	2,79	
1973	3,92	8,77	10,74		2,24	2,74	
1974	3,99	8,90	10,76		2,23	2,69	
1975	4,07	8,89	10,77		2,19	2,65	
1976	4,14	9,23	10,77		2,23	2,60	
1977	4,21	9,55	10,78		2,27	2,56	
1978	4,29	9,71	10,79		2,26	2,52	
1979	4,34	10,07	10,80		2,31	2,48	
1980	4,43	10,07	10,82		2,27	2,44	
1981	4,51	9,97	10,83		2,21	2,40	
1982	4,59	9,89	10,84		2,16	2,36	
1983	4,67	10,18	10,87		2,18	2,33	
1984	4,76	10,43	10,89		2,20	2,29	
1985	4,83	10,61	10,93		2,20	2,26	
1986	4,92	10,94	10,96		2,23	2,23	
1987	5,00	11,36	10,98	0,38	2,27	2,19	0,08
1988	5,10	11,75	11,01	0,74	2,31	2,16	0,15
1989	5,18	11,88	11,02	0,85	2,29	2,13	0,16
1990	5,26	11,83	11,04	0,79	2,25	2,10	0,15
1991	5,35	11,88	11,04	0,84	2,22	2,06	0,16
1992	5,43	11,90	11,12	0,78	2,19	2,05	0,14
1993	5,51	12,04	11,15	0,89	2,18	2,02	0,16
1994	5,56	12,19	11,16	1,03	2,18	2,00	0,18
1995	5,67	12,54	11,16	1,38	2,21	1,97	0,24
1996	5,75	12,74	11,16	1,58	2,21	1,94	0,27
1997	5,83	12,86	11,16	1,70	2,20	1,91	0,29
1998	5,91	12,88	11,17	1,71	2,18	1,89	0,29
1999	5,99	13,02	11,18	1,84	2,17	1,87	0,31
2000	6,07	13,35	11,19	2,15	2,20	1,84	0,35
2001	6,15	13,40	11,21	2,19	2,18	1,82	0,36
2002	6,22	13,67	11,20	2,47	2,20	1,80	0,40
2003	6,30	14,07	11,20	2,88	2,23	1,78	0,46

Bioproductive Areas

> "Globally we identify 11.2 billion hectares of distinct bioproductive areas—cropland, forest, pasture, fisheries, and built-up land—that provide economically useful concentrations of renewable resources. These 11.2 billion hectares cover a little less than one quarter of the planet and include 2.3 billion hectares of marine and inland fisheries and 8.8 billion hectares of land. The land area is comprised of 1.5 billion hectares of cropland, 3.5 billion hectares of grazing land, 3.6 billion hectares of forest, and an additional 0.2 billion hectares of built-up land assumed to occupy potential cropland (EEA, 2000; FAO, 2000; SEI, 1998; WRI, 2000). These areas concentrate the bulk of the biosphere's regenerative capacity. We have not yet been able to estimate how much of the total usable annual biomass generation (NBP or Net Biosphere Production) is concentrated on these 11.2 billion hectares, but would be surprised if it were less than 80 to 90 percent. While the remaining areas of the planet are also biologically active, such as the deep oceans or deserts, their renewable resources are not concentrated enough to be a significant addition to the overall Biocapacity" (Monfreda, C., Wackernagel, M., Deumling, D., 2003).

The Common Unit: Global Hectare

> "Ecological Footprint accounts express the use of built-up areas, and the consumption of energy and renewable resources—crops, animal products, timber, and fish—in standardized units of biologically productive area, termed global hectares (gha). Each global hectare represents an equal amount of biological productivity. One global hectare is equal to one hectare with productivity equal to the average productivity of the 11.2 billion bioproductive hectares on Earth. Here productivity does not refer to a rate of biomass production, such as net primary production (NPP). Rather productivity is the potential to achieve maximum agricultural production at a specific level of inputs (see next section). Thus one hectare of highly productive land is equal to more global hectares than one hectare of less productive land. Global hectares are normalized so that the number of actual hectares of bioproductive land and sea on this planet is equal to the number of global hectares on this planet (see Figure 3-11). Global hectares allow for the meaningful comparison of the Ecological Footprints and the Biocapacities of different countries, which use and have different qualities and mixes of cropland, grazing land, and forest. Two conversion factors—equivalence factors (constant for all countries for a given year) and yield factors (specific for each country and each year)—translate each of the biologically productive areas from hectares into global hectares" (Monfreda, C., Wackernagel, M., Deumling, D., 2003). (See Appendix C)

In this study territorial footprint is used as the selected method. As stated in the previous chapter, four main categories were considered under territorial footprint:

(a) Productive activities,

(b) Transportation,

(c) Waste disposal and management

(d) Water management.

Footprint of each of these categories is calculated in terms of global hectares.

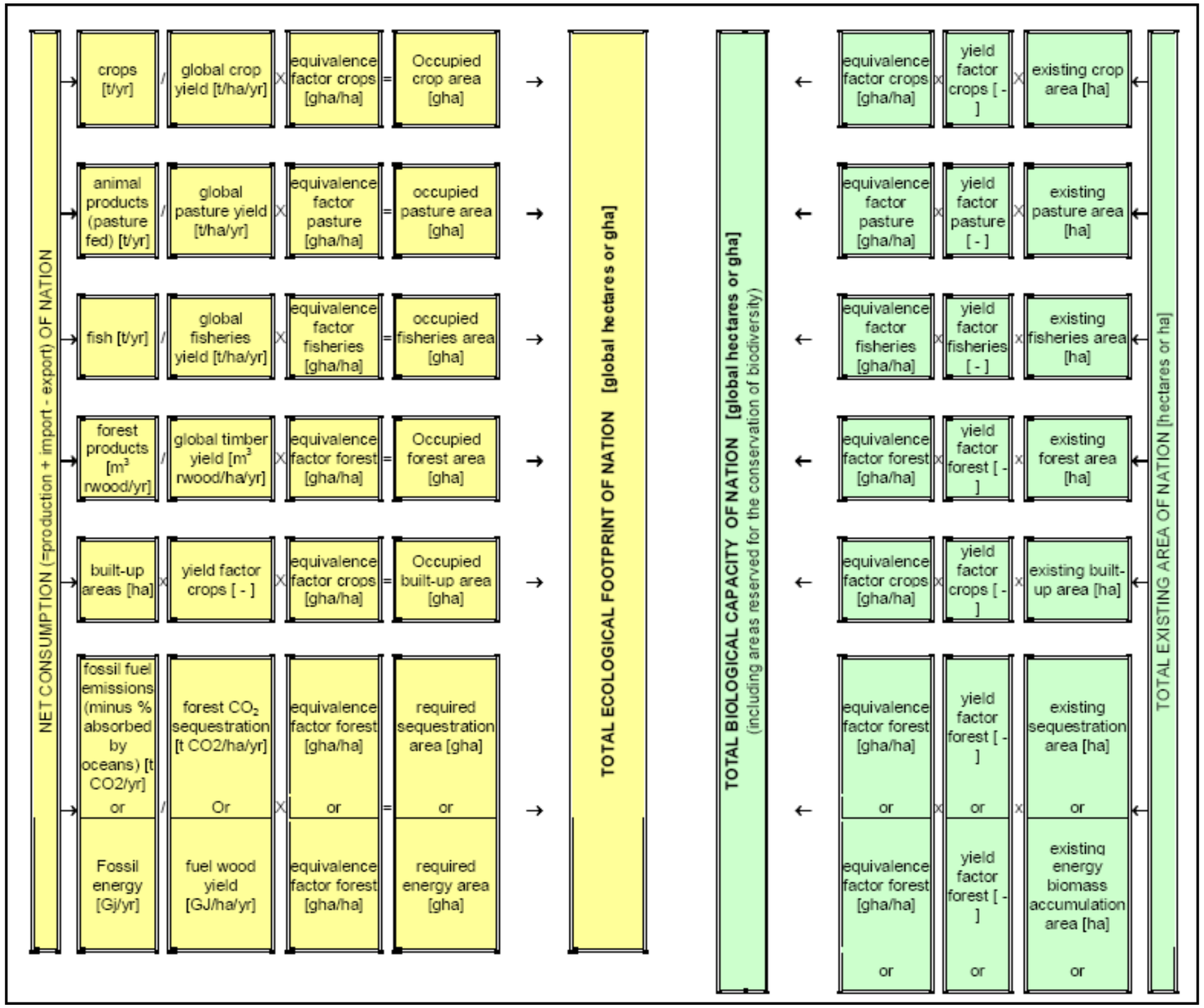

Figure 3-11 Structure of Footprint and Biocapacity Calculations. This figure summarizes how the Ecological Footprint translates net consumption and bioproductive areas into areas of global average productivity. For simplification, this figure excludes secondary products and nuclear power.

CHAPTER 4

URBAN ECOSYSTEM DESIGN: A MULTIDIMENSIONAL PROCESS

Urban ecosystem design is multidimensional process that results in different classification of urban patterns. Urban pattern shows the way an urban area arranges its sub-units and shapes its development. To discuss design of urban ecosystem, therefore, we should firstly determine the ways how the patterns of urban areas are classified with different implications during this multidimensional process. Then evaluation of all determined urban patterns will give us the clues of implication of urban patterns, which will help us to develop a methodology of effect of these implications on their environmental performance in terms of their ecological footprints.

4.1. Definition of Urban Pattern

> "The pattern of the city is the way how different functions and elements of the settlement form are distributed and mixed together spatially. It can be measured by the size of its grain. Grain is fine when similar elements or functions are widely dispersed throughout the district without forming any large clusters. On the other hand, grain is coarse if different elements and functions are segregated from each other in a way that extensive areas of one thing are separated from extensive areas of other things." (Lynch 1981: 265)

Urban patterns of various types may be described and classified in many ways. (See Appendix E) There is no only one way of classification; but some ways are better than others to meet different purposes. For example, any typological set should usefully hold clearly distinct, mutually exclusive types.

Different patterns such as linear, radial, grid, oil-stain or nucleated not only shapes the physical form of the city but also the life quality and aesthetical value of the urban land (Figure 4-1). Therefore, it is crucial to define the ways how we specify the urban patterns and their implications.

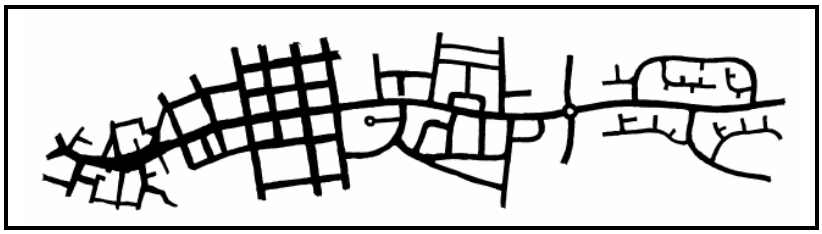

Figure 4-1 Differentiated Urban Pattern Examples (Adapted from Marshall, 2005)

4.2. Urban Pattern Specification

Urban planning is focused on providing a physical formation for urban activities – providing physical places such as streets, parks, district centers and so on, where different kinds of activity are allowed or encouraged. Urban planners have been concerned with proposing ideal or optimal physical forms for urban areas. This typically includes envisioning certain combinations of size, density, and structure and built form, related with explicitly or implicitly diverse urban functions –currently also eco-friendly. (Marshall, S., 2005)

> "Much of twentieth century urban planning was concerned with reducing the overcrowding of the nineteenth century industrial city, in the quest for better living and housing standards. This implied dispersion and reducing density, and often entailed the provision of gardens (e.g. garden cities or suburbs) or landscaped open spaces. However, the late twentieth century rise to prominence of the environmental movement and concern for sustainable development" (Marshall, S., 2005).

Which takes environmental performance of cities into account for urban planning and policies.

Environmental performance research mostly requires the testing of pattern-based variables for their effects on, for instance, travel or resources (Banister *et al*., 1997). While there is an excellent resolution of the indicators (e.g., CO2), or travel variables (e.g., veh km, pass km, etc.), there is not a correspondingly high-resolution, frequently agreed understanding of urban spatial patterns (Stead and Marshall, 2001).

It is obvious to define different urban patterns in many ways. Qualitative methods include morphological and morphographic description. Quantitative methods include "*network component analysis, graph theory, space syntax and fractal dimension"* (Conzen, 1969).

However, the purpose of pattern specification is not basically to define or evaluate urban patterns for their own sakes, but to take out conveniently discerning information about them – to get a new way of looking at environmental performances of different pattern implications in terms of ecological footprint. For the purposes of this evaluation, there is a need to generate a limited number of meaningful *implications to* evaluate.

While considering typologies of urban pattern, the first issue one should deal is identifying what actually it is that is intended to classify. This sets the classification of urban pattern excluding the grouping of cities, streets or buildings. The problem of categorizing buildings, streets and cities can be a whole business, but generally the common 'object of classification' is so clear. On the contrary, it is not necessarily obvious what is meant by an urban pattern. Urban pattern fundamentally refer to the physical pattern of urban areas in three dimensions at a diversity of scales.

"Development pattern involves the arrangement of an urban land in planned forms– in preference to growing buildups. Namely, a development pattern is one that is deliberately envisaged (e.g. a housing layout, or a linear extension to a city), while a settlement pattern may be an aggregation of dwellings without any conception as a creature spontaneously. The term development pattern may also imply the dynamic or chronological development of a settlement, since where an imaginative core acquires a gridded extension and then a suburban fringe. The term **pattern** will be used generally to include any kind of form or structure, or returning feature." (Marshall, S., 2005)

The study of pattern is a continuing discussion. A range of urban patterns is presented in the Appendix E. Within this section, some selected examples are discussed, which will be useful to determine the implications of urban patterns.

In *Good City Form* (1981), Lynch suggests seven types:

A. Star
B. Satellite
C. Linear
D. Rectangular Grid
E. Other Grid
F. Baroque Network
G. Lacework

From the point of view of Lynch's sketches, it is obvious that "*different levels of complexity are implied by the different types, and the different shades of meaning implied by the graphics and the labels"* (Marshall, S., 2005). For example, the 'satellite' form means a simple topological relationship, while the star appears to means different kinds of land use and different kinds of directions (radial and concentric). The 'baroque' case implies by its label some historic association, while the graphic means different kinds of built-up form existing along the main streets compared with 'infill' development (Marshall, S., 2005).

On the other hand, another research developed by Barton (2004) categorized urban pattern into 5 types, which is called as the **local options**.

Type (i) – 'use-segregated dispersal'
Type (ii) – 'closed cell neighborhood'
Type (iii) – 'open cell neighborhood'
Type (iv) – 'interlinked clusters'
Type (v) – 'linear township'

According to Barton, it is also possible to define these five types in terms of seven criterions each having two or three attributes (See Figure 4-2).

Criterion	Attributes	Types				
		(i)	(ii)	(iii)	(iv)	(v)
A. Land use	A1. Different mono A2. Same mixed	A1	A2	A2	A2	A2
B. Nucleation	B1. No nucleus B2. With nucleus	B1	B2	B2	B2	B2
C. Spine type	C1. Solid (segregated) C2. Dashed (all-purpose)	C1	C1	C2	C2	C2
D. On/off-line	D1. Off-line D2. On-line (astride) D3. Edge-on	D1	D1	D2	D3	D3
E. Boundedness	E1. Each area bounded E2. Areas merge – ensemble bounded	E1	E1	E1	E2	E2
F. Central services	F1. Centred on centre of land use area F2. Centred on spine F3. No central services	F3	F1	F1	F1	F2
G. Special status	G1. No special areas G2. Special status area	G1	G1	G1	G2	G1

Figure 4-2 Criterions and attributes of different patterns

It is seen from both Lynch's and Burton's definitions and criterions that urban patterns can be determined and grouped differently with different justifications. Although different approaches of grouping patterns and naming each is the basic step of this process, on the other hand there are some strategic options used to clarify that in addition to the existing form of urban settlement, its development tendency may affect the pattern of the settlement and the form may result in different patterns.

Currently **strategic options** are as follows:

I. Intensification

II. Edge expansion

III. Linear or Corridor expansion

IV. New settlement

V. Free market

VI. *Polycentricity*

Graphical interpretations of the above types are suggested in Figure 4-3. Furthermore, the polycentric type is also suggested as another possibility. Polycentricity implies, "*at the least, a scatter of distinct sub-centers that have an urban significance less than the city centre but greater than the remainder of the inner and outer suburbs. Polycentricity is usually associated with a network of nodal points, and local intensification at those points*." (Marshall, S., 2005).

As seen in Appendix E, there are many ways to define the types of urban patterns and the ways we grouped them. A few were discussed above, to clarify that apart from the types of the pattern we defined, it is more important to determine the reason why we gouped them in that way. In the following parts, while we're discussing the ecological footprints of different cities of the world through analyzing their patterns, the study will try to define examples of different patterns such as linear city, radial city, grid city, oil-stain and nucleated city.

On the other hand, the archetypes (acting as indicators of urban pattern) may be to some extent based on *static forms*, representing a snapshot of a form at any given moment in time, or may be related to the *growth of pattern-(form)*. In this thesis, what we basicly focus is the growth of pattern that is affecting the ecological footprint of it and implications of urban pattern to define the relationship is grouped under four:

- ***Centrality (Land Surface Covers)***
- ***Density (also Extent and Topography)***
- ***Connectivity (and also Continuity and Modularity)***
- ***Grain (Edges and Transitions)***

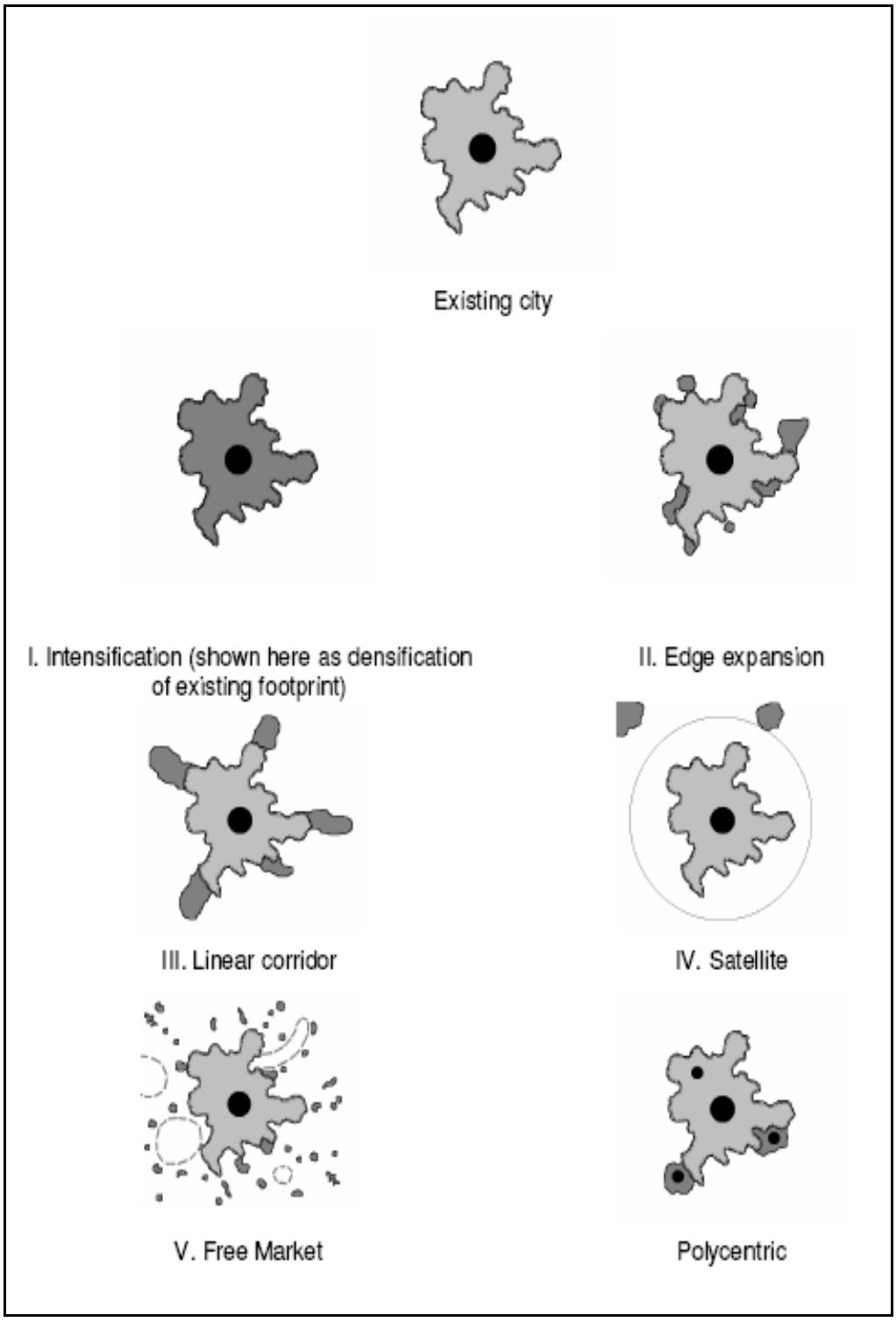

Figure 4-3 Graphical interpretation of strategic options

4.3. Implications of Urban Pattern

4.3.1. Centrality (Land Surface Covers)

Preferably, the centrality dimension of urban pattern defines the level of centralization and decentralization generally and, particularly, to differentiate among monocentric, polycentric and decentralized urban forms as an index of compactness. Galster et al. (2001) evaluates the degree to which development is situated close to the central business district and measures the extent to which an urban area is distinguished by a monocentric form rather than a polycentric form. (Alberti M., 1999)

Centralization affects the number of trips, their length, or the mode of transportation (Handy 1992). When the level of centralization of the urban structure is considered regarding employment, the relationship is even less definite. In fact it becomes visible that it is to be a trade-off between trip length and modal split. (Alberti M., 1999)

4.3.2. Density (also Extent and Topography)

Population, building and job density are the most familiar urban pattern elements stated in urban studies. However, they are also the trickiest ones to understand individually. Instinctively, density is a good indicator of the pressure that urban population and activities will have on the landscape. For instance, urban density on an urban-to-rural gradient parallels a sharp transition from an urban matrix to a forest matrix. However, disturbances associated with urbanization show a complex spatial pattern that cannot be explained by density alone (Medley, McDonnel, and Pickett 1995). It is even more difficult to correlate population density to use of resources or emissions. Density is found to decrease the number of trips and VMT by private vehicles. But the results as regards to total travel and related energy use are contradictory (See Figure 4-4). (Alberti M., 1999)

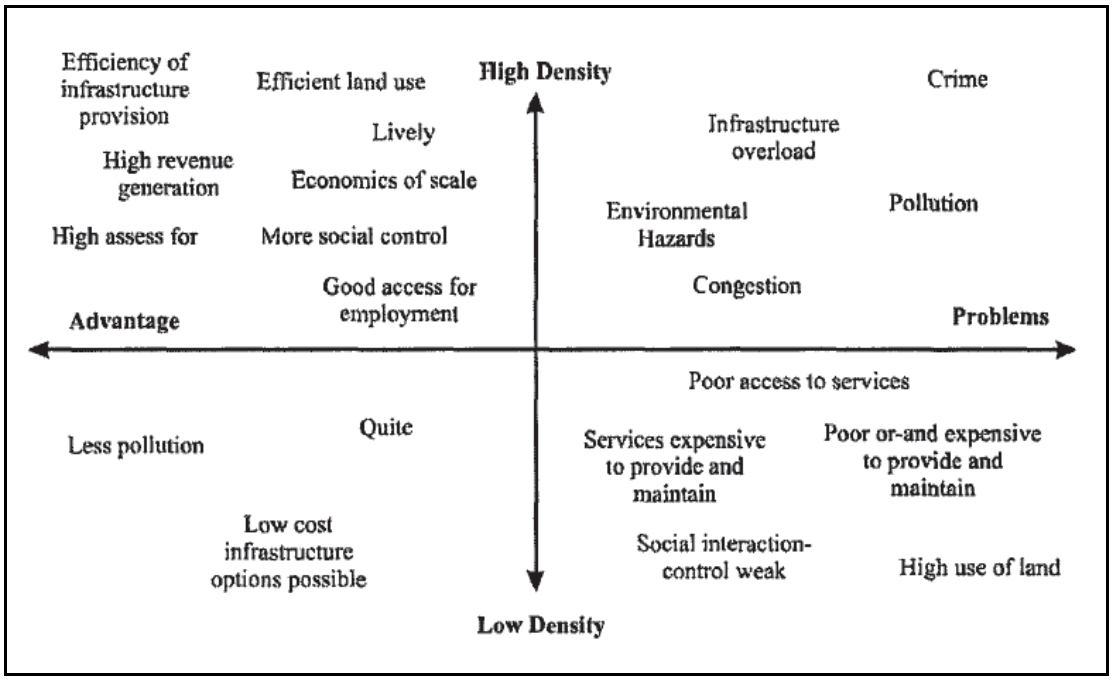

Figure 4-4 Advantages and disadvantages of high and low density (Acioly et al., 1996)

Density, another dimension of urban pattern, can shape density based compactness of patterns by evaluating land consumption per capita (Galster et al., 2001; Malpezzi and Guo, 2001; Hess et al., 2001). Patterns with high density have benefits of efficient land use; economics of scale, better accessibility to employment areas etc. Nevertheless, they have drawbacks of crime, pollution, environmental problems, traffic congestion etc. Quite the opposite, lower density has advantages of less pollution and low cost for infrastructure alternatives appropriate whereas has disadvantages of poor accessibility to public services, high land use, high cost of services to supply and maintain etc. Even though the advantages and disadvantages of tendencies are listed in many researches, no systematic studies exist for their direct relation with environmental problems.

4.3.3. Connectivity (and also Continuity and Modularity)

The transportation infrastructure is, with no doubt, the strongest expressive indicator of travel mode, though the direction of causality of these indicators is unclear. Overall travel demand in sub-regions which have effectively linked with high density and car transit may be lower than in other parts of the city by factors of four (Pushkarev and Zupan 1977), or

even eight (Holtzclaw 1994). The transportation infrastructure is also designated as an indicator that can define atmospheric emissions and concentration patterns across a city, plus other direct impacts such as inhabitants' exposure to various pollutants and their effects on human health, but no systematic study of these relationships is presented yet. Connectivity is an important measure of compactness of urban pattern, but no wide spreading approach has been yet determined for translating transportation infrastructure patterns into a quantitative measure of probable environmental impacts. (Alberti M., 1999)

4.3.4. Grain (Edges and Transitions)

The variety of activities and functions in an urban land has been defined yet to make assessments for the difference generally ascribed to density only in many studies of how urban patterns impact energy consumption derived from transportation modes. Though, a limited number of practical studies have tested an exploration of this divergence. Recent studies do not give definite evidence that land-use mix defines travel patterns. The complexity is in specifying a good measure of land use mix. Using entropy and difference indexes for evaluating land use heterogeneity, Cervero and Kockelman (1997) do explain that mix matters. Through applying a simple behavioral method, Crane (1996) provides that land use mixing and increase in extension may decrease the level of travel demand, although they sometimes do not, attached to a number of other factors together with other urban design elements, decreased level of congestion, and the number of the trips. Grain can be an important element to ascertain different effects of the urban structure on the environment. Particularly, the occurrence, size, and location of open-public, especially, green areas can be important in coping with air pollution and reducing urban heat island effects (Nowak 1994). Nonetheless, excluding the biogeography studies which provide the direct relation between natural patches and biodiversity in an urban land, none of the existing studies provide evidence that grain might be an indicator of urban impacts without considering the impacts of other indicators. (Alberti M., 1999)

CHAPTER 5

RELATION MATRIX: INDICATORS OF ECOLOGICAL FOOTPRINT AND IMPLICATIONS OF URBAN PATTERN

5.1. Research Design

Regarded as centers of culture, education, innovation, knowledge, entertainment, and political power, urban lands are the living places of roughly half of global population. If these urban lands continue to increase their population 67 million people every year, they will be the home for 5 billion people by 2030 (Jo et al., 2008). Although total area of these urban lands accounts for less than one percent of the Earth's surface (Eilperin, 2007), they are unfortunately responsible for approximately 67 percent of the world's energy demand and it is expected that this amount will grow to 73 percent by 2030 (International Energy Agency, 2008, Table 8.2).

Cities are responsible for emitting nearly 80 Percent of the world's total green house gases (Eilperin, 2007). In the United States, nearly 60% of the population and %75 of economic activity finds place in the biggest 100 metropolitan cities, however these same areas consider a smaller percentage of US carbon dioxide emissions (Brown et al., 2008). The proportion of the US population living in urban areas has grown from 40 percent in1900 to over 80 percent today, and it is expected that this percent will reach 87 percent by 2030 (IEA, 2008, p.184). At first glance, this may appear to be unforeseen as urban areas in the US tend to offer more carbon-efficient life styles than rural areas. However, many of the fastest-growing metropolitan areas are also the least compact and most carbon-intensive (Brown et al., 2008). This is evident in the rapid growth and decentralization of many Southern cities, such as Austin, TX, Raleigh, NC, and Nashville, TN. Thus, new development is often occurring in

locations and in patterns that fail to take advantage of energy and location efficiencies (Glaeser and Kahn, 2008).

Designers concentrate on gathering zoning regulations instead of supporting sustainable design and architectural design roads to increase the speed of car flow but ignore the negative social aspects of the spaces created (Friedman, 2007). However, there is a ‘‘widely shared dissatisfaction with the effectiveness of efforts to integrate the dimensions of green communities into the ways we build human settlements’’ (Berke, 2008). A combined effort from urban designers, transport planners, energy providers, and environmentalists is needed to minimize the ecological footprints of cities and urban areas, but such coordinated action seldom occurs (Birch andSilver, 2009). So far, the lack of footprint analysis of cities in terms of urban carbon not through individuals and also comparative analysis between cities, which makes it difficult to confirm best practices and policies of cities with lower ecological footprints. To help provide benchmarks and clarify the discussion of the study, this chapter will compare the footprint indicators with implications of urban patterns through considering the data available for discussion (Mittleman, D., D., 2009).

Environmental Performance / Urban Patterns	Sources	Sinks	Support Systems	Human well-being
Centralization	↔ Solar radiation ↔ Energy use ↓ Energy supply ↓ Number of trips by auto ↔ Trip length	↑ Urban heat island ↔Atmospheric pollution ↔Water pollution	↔Climate & air pollution ↑ Flooding ↑ Pollutants runoff ↓ Habitat fragmentation	*No systematic studies*
Density	↓ Solar radiation ↔Energy use ↓ Energy supply ↓ Number of trips & VMT by auto ↔Total travel	↑ Urban heat island ↔Atmospheric pollution ↑ Water pollution	↑ Climate & air pollution ↑ Flooding ↑ Pollutants runoff ↓ Habitat fragmentation	↑ Population exposure to air pollutants
Grain	↔Travel patterns ↓ Energy supply	↔Urban heat island ↔Atmospheric pollution	*No systematic studies*	*No systematic studies*
Connectivity	↓ Energy use by private transportation	↓ Atmospheric pollution	↑ Habitat fragmentation	*No systematic studies*

Figure 5-1 Relation between Environmental Performance and Urban Patterns

(Adapted from Alberti, M., 1999)

Defined research questions were answered by developing a relationship matrix between the indicators of ecological footprint as most useful tool used for estimating environmental performances of the cities and implications of urban patterns which shows the basic characteristics and development tendencies of an urban area. Analyzing most related studies and international reports, most parts of this relation was defined. As it is still not possible to find the detailed data needed for an analysis of this relationship in any cities of Turkey, this relation matrix was discussed in some selected metropolitan cities of the world through the data collected about them. Research focus was figured out in Figure 5-2. Since the main purpose of this research was to determine the impacts of urban patterns on environmental performances of those cities in terms of their ecological footprint, the research basically focused on clarifying the clues of this relationship. Also, for a better understanding of the dynamics of the urban patterns, estimated relations of each indicator with each implication were tested in the selected cities.

This approach was constitutively developed through the studies of Alberti. Alberti discussed the environmental performances of urban patterns through the indicators *sources, sinks, support systems, human well-being*. During this discussion, developed the framework based on the implications of urban pattern as: *centralization, density, grain and connectivity* (See Figure 5-1).

5.2. Relation Matrix of Indicators of Ecological FootPrint and Implications of Urban Pattern

In the relation matrix of indicators of ecological footprint and implications of urban pattern, relation between each indicator and implication was determined as:

D: Decreasing

I: Increasing

=: No defined relation (Table 5-2)

Table 5-1 Relation Matrix of Indicators of Ecological FootPrint and Implications of Urban Pattern (Developed in the Study)

INDICATORS

IMPLICATIONS

Ecological Footprint **Urban pattern**	**Productive Activities (Industry, Agriculture and Tertiary)**	**Transportation**		**Waste Disposal and Management**				**Water Management**		
		Roads and Facilities	**Energy Consumption and Pollution**	**Special Wastes**	**Household Wastes**	**Built up Areas**	**Transferring and Others**	**Sewerage System**	**Purification**	**Aqueduct**
Centrality	D Electricity Consumption = Energy Use D Energy Supply D Use of Fossil Fuels = Industrial Area D Soil Use D Built-Up Area D Habitat Fragmentation = Atmospheric Pollution I Urban Heat Island	D Highways, railways, D Bus and train stations D Trip Length D Number of Trip by Auto D Total Travel	= Energy Consumption (cars) = Energy Consumption (buses and trains) = Atmospheric Pollution of transportation network	= Dangerous special wastes = Nondangerous special wastes	= Wastes D Fossil fuel consumption for waste transportation	= Dumps Incinerator	= Co2 D Fuel consumption I Pollutants Runoff	D Construction of the system D Energy consumption = Water Use	D Construction of the system D Energy consumption	D Construction of the system D Energy consumption
Density	= Electricity Consumption = Energy Use D Energy Supply = Use of Fossil Fuels = Industrial Area D Soil Use = Built-Up Area I Habitat Fragmentation I Atmospheric Pollution I Urban Heat Island	D Highways, railways, = Bus and train stations D Trip Length D Number of Trip by Auto = Total Travel	D Energy Consumption (cars) = Energy Consumption (buses and trains) = Atmospheric Pollution of transportation network	I Dangerous special wastes I Nondangerous special wastes	I Wastes = Fossil fuel consumption for waste transportation	= Dumps Incinerator	I Co2 = Fuel consumption I Pollutants Runoff	= Construction of the system I Energy consumption I Water Use	= Construction of the system = Energy consumption	= Construction of the system = Energy consumption

Grain	= Electricity Consumption = Energy Use D Energy Supply = Use of Fossil Fuels = Industrial Area D Soil Use = Built-Up Area I Habitat Fragmentation I Atmospheric Pollution I Urban Heat Island	D Highways, railways, = Bus and train stations D Trip Length D Number of Trip by Auto = Total Travel	D Energy Consumption (cars) = Energy Consumption (buses and trains) = Atmospheric Pollution of transportation network	No Systematic Studies	I Wastes = Fossil fuel consumption for waste transportation	= Dumps Incinerator	I Co2 = Fuel consumption I Pollutants Runoff	= Construction of the system I Energy consumption I Water Use	= Construction of the system = Energy consumption	= Construction of the system = Energy consumption
Connectivity	= Electricity Consumption = Energy Use D Energy Supply = Use of Fossil Fuels = Industrial Area D Soil Use = Built-Up Area = Habitat Fragmentation = Atmospheric Pollution = Urban Heat Island	D Highways, railways, = Bus and train stations D Trip Length D & I Number of Trip by Auto D & I Total Travel	D & I Energy Consumption (cars) = Energy Consumption (buses and trains) = Atmospheric Pollution of transportation network	No Systematic Studies	I Wastes = Fossil fuel consumption for waste transportation	= Dumps Incinerator	D & I Co2 = Fuel consumption I Pollutants Runoff	= Construction of the system D & I Energy consumption = Water Use	= Construction of the system = Energy consumption	= Construction of the system = Energy consumption

D- Decreasing **I- Increasing** **= NO Defined Relation**

Decreasing means that implication decreases the ecological footprint of the city through the selected indicator. *Increasing* means that implication increases the ecological footprint of the city through the selected indicator. *No defined relation* means there is not any discussion or clue for the relationship between that implication of urban pattern and that indicator of ecological footprint.

On the other hand, land types used for calculation of ecological footprint can be used for estimation of ecological footprint of that city. Implications of urban pattern may show us some clues of the level of expected ecological footprint through the relationship discussed between them as seen in Table 5-2.

Table 5-2 Ecological Footprints of Different Land Types and Their Relation with Implications of Urban Patterns (Developed in the Study)

Ecological Footprint	**Urban Pattern**			
	Centralization	**Density**	**Grain**	**Connectivity**
Cropland	DR	DR	DR	ND
Grazing Land	DR	DR	DR	ND
Forest Land	DR	DR	DR	ND
Fishing Ground	ND	DR	ND	ND
Builtup Land	DR	DR	DR	DR

DR_Defined Relation / **ND**_No Defined Relation

The relation was determined in two types: *Defined Relation* means that existence of ecological footprint for that type of land relates to the implication. *No Defined Relation* means the opposite. For example as shown in the table, it can be seen that the ecological footprint of one city in terms of its built-up land might be in relation with centralization level, density pattern, grain and connectivity attitudes of that city.

5.3. Results

Summary and results of this chapter are given in below Table 7. As seen in the Table, each city having a different pattern suffers from different disadvantages, including high densities and difficulties in mobility and waste and resource management, and on the opposite, each has different advantages such as energy efficiency etc. Therefore, it is difficult to say which of these patterns is the most eco friendly and which has the least ecological footprint.

Thus, it is crucial to say that, instead, patterns of these cities have impacts on their environmental performances and ecological footprints through the relationships defined between the implications of these patterns and the indicators of their performances.

As given in the Table of ***Relation Matrix of Indicators of Ecological FootPrint and Implications of Urban Pattern***, and each implication (centrality, density, grain and connectivity) of patterns have different shares and impacts on ecological footprint of the cities, accordingly, their environmental performances.

Results of this relation matrix are listed below:

- In terms of productive activities, **centrality decreases** the footprint of electric consumption, energy supply, use of fossil fuels, soil use, built up area and habitat fragmentation while increasing the urban heat island.
- In terms of transportation, **centrality decreases** the footprint of roads and facilities, highways and railways construction, bus and train stations, trip length, number of trip by auto and total travel. However, there are also studies to ascertain the perfect relation between centrality and "trip length, number of trip by auto and total travel". Apart from all, in case a centralized city is designed with a point of view that aims to increase the environmental performance of that city, centrality might be in line with this aim.
- On the contrary there are studies indicating that **centrality increases** pollutants runoff, while **decreasing** the footprint of water management.

- In terms of productive activities, **density decreases** the footprint of energy supply and soil use for existing population and on the other hand, **increases** habitat fragmentation, atmospheric pollution and urban heat island.
- In terms of transportation, **density decreases** footprint of highways and railways, trip length, number of trip by auto and energy consumption for private cars.
- On the contrary, **density increases** footprint of waste, CO2 and pollutants runoff in line with increase in energy consumption and water use.
- **Grain** also affects the footprint of energy supply in terms of productive activities, however, no systematic studies about the relation between grain and wastes.
- In terms of productive activities, **connectivity decreases** the footprint of energy supply and soil use.
- In terms of transportation, **connectivity decreases** the footprint of highways and railways construction, trip length, while may **both increase and decrease** trip length, number of trip by auto and total travel.

CHAPTER 6

CONCLUSIONS

6.1. Discussions

This thesis basically aims to determine the environmental performance of different urban patterns in terms of their ecological footprints through defining the relationship between implications of urban patterns and their contributions to the ecological footprint.

Firstly, the study determined the research focus, hypothesis and research questions and research approach and finally its relevance and significance for urban design theory and practice. Additionally, it gave a brief summary of background information about the *City as an Ecosystem, Kyoto Protocol and Global Issues on Climate Change and Climate Change Facts.*

Secondly, we defined the theoretical framework by presenting *a new tool for environmental performance that is ecological footprint.* This framework would be redefined under the sub headings of estimating environmental performance of cities to clarify their impacts on climate change, definition of ecological footprint, use of ecological footprint as the main indicator for sustaining the world, countries and "cities", ecological footprint calculation methods and tools, ecological footprint minimization strategies.

The, through defining the urban design approach of the study as *urban ecosystem design: a multidimensional process*, we specified urban patterns, their implications and eco-compact urban pattern as one of the patterns with the highest environmental performance.

Finally, we comprehensively described the research *methodology and relation matrix* of indicators of ecological footprint and implications of urban patterns. Starting with research design and method, determined the relation as decreasing, increasing and no defined relation.

Following all these discussion, we specified ecological footprint of different cities with different patterns and development tendencies, which let the study clarify the outcomes of the theoretical framework it creates.

What fundamentally important in the developed matrix, which is the speculative result of this study, is that, it re-defines the basis of urban pattern specification through developing another indicator for the evaluation of urban lands. Until the day urban development has started to be considered as a problematic of urban pattern specification, implications of urban pattern have been used to estimate the results of the pattern. On the other hand, in addition to variables such as population, topography, ecological point of view started to be used as a newly developed indicator used for making decisions in the urban land.
We can discuss the contributions of this thesis under the following sub-topics: contributions to urban design principle theoretically, contribution to architectural approaches, impacts of development level of countries and regions to ecological footprint.

Contributions to urban design principle theoretically:
This study makes a speculative contribution to urban design principle. The common belief in urban literature is that urban design focuses on the *arrangement and design of buildings, public spaces, transport systems, services, and amenities*. Urban design is the process of forming, shaping, and charactering groups of buildings, to complete neighbourhoods, and the city. It is a frame which orders the components into a whole network of streets, squares, and blocks. Urban design harmonize architecture, landscape architecture, and city planning point of view together to make urban areas functional and attractive (http://www.urbandesign.org/).

However, from the looking of concerns of today's cities, urban design should not be seen as a principle regarding only physical, aesthetical or functional performance of the patterns of the cities. Environmental performance of urban patterns should be considered to create better and sustaining cities through considering wastes produced and resources consumed. Urban

pattern implications which show the development tendency of a city's existing form may be used to estimate the short and long term impacts of a decision taken. From this point, the matrix of this study may create a new way of looking to cities through giving new hints intended for urban pattern.

From now on, in the days we discuss un-planned and extensive impacts of climate change, mostly resulted from actions of humans, cities as the basic problematic of the world, should consider their shares in this change and develop measures itself. While taking decisions in the urban land, the impacts of these decisions on the ecology of the world may be calculated through ecological footprint. Ecological footprint created a new and crucial outlook on urban pattern.

Contributions to architectural approaches:

Urban design is in a close relationship with architectural design. Architecture does not mean designing single buildings ignoring its surrounding and environment. It should also regard the impact on its environment not only physically and aesthetically but also ecologically. New trends on creating ecologically successful architectural places do not effectively meet the basis of becoming environmental-friendly.

The relationship between the implications of urban pattern and indicators of ecological footprint should also be reviewed from an architectural perspective. Building musts should be re-shaped to decrease the footprint of each building and their whole footprint within the urban land and be supported with legal regulations.

Impacts of development level of countries and regions to ecological footprint:

Although ecological footprint of different countries and cities differs due to their efforts on using clean energies, decrease transport modes, trip length and numbers, waste production and recycle etc, development level of countries and regions effects their footprint. Africa has the least footprint in the whole world, as the least developed region, because they have fewer resources to consume and low level of living quality.

Although European countries have many measures to mitigate energy, waste, transport and building footprints, they have a higher footprint when compared with the average ecological

footprint of the world. This results from their high level of living quality and consumption habits. Therefore, while discussing on the ecological footprint of a country or a city, we should also consider the development level and take the share of it into consideration.

6.2. Focal Points for Urban Planners

Considering climate change as a global matter can not mean that it should only be mitigated through global policies and decisions. It is accepted by most countries that global agreements and protocols show way to countries to cope with this change and try to decrease their share in this global problem. However, both in developed and developing countries, it is obvious that countries should also develop legal frameworks and start actions to mitigate their own share, through regarding their planning and development tendencies and their environmental performance of their cities. As the most useful and real-like tool for estimating environmental performance of urban lands, ecological footprint is used and it creates a clear picture to researchers and decision makers of where the city is standing.

Urban Planners should start considering that if there is such reality that where people living is damaging the ecology of the world and results in changes irretrievably, it is not arbitrary but must to consider the short and long term effects of our decisions. Therefore, our focus should be given to determine the ecological footprint of our cities we live in and to define the result of them and to develop mitigation measures for it during planning and design processes. In addition to responsibilities of creating livable, healthy, aesthetic cities, we are also responsible for considering the effects of our decisions on ecology and environment and take our decisions through regarding this connection between the urban and natural areas.

In case that we create updated and detailed databases of our cities, including all data we need to consider the ecological footprint of our cities, it becomes easier to make estimations. Although it seems like that it is the humans themselves that damages the ecology of the world, and most calculations of ecological footprint focus that, we should see that it is the urban decisions and the way how we planned our cities, which makes the ecological footprint of citizen living in higher or lower. If you design your city in a way that private car usage is the most comfortable and easy way for transportation in that city, we do not have the right to say that people take actions to decrease their footprint. Therefore, we are

responsible for proposing the effects of our decisions and should start to discuss how implications of urban patterns of the cities we created are closely related with the level of ecological footprint of those cities. We should always keep this in mind while making decisions on urban lives.

6.3. Recommendations for Further Researches and Implementations

This thesis basically aims to determine the environmental performance of different urban patterns in terms of their ecological footprints through defining the relationship between implications of urban patterns and their contributions to the ecological footprint.

As there is lack of data to calculate the urban ecological footprint in Turkey, this study should be limited to develop a theoretical framework but could not testify this framework in any of cities of Turkey. Additionally, it would be difficult to define all relations in the relation matrix as there is no certain research or study to define some of them.

Considering the theoretical framework developed, ecological footprint of any selected city of Turkey could be calculated for more clear results. Through adapting any of the methods developed by researchers in the world, citizen based and territory based ecological footprint of the selected city might be determined.

Avoiding the study limitations, through a more comprehensive and detailed research the total footprint could be calculated for any of patterns specified. The footprint could not be calculated in this study because of time and data constraints. By this way, the theoretical framework developed in this study could be used to contribute to urban studies.

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APPENDIX A

DEFINITIONS

Kyoto Protocol: The protocol setting emission target for industrialized countries that came into force in 2005 and 183 governments plus the European Community have formally adopted.

Climate Change: encompasses all forms of climatic inconstancy (that is, any differences between long-term statistics of the meteorological elements calculated for different periods but relating to the same area) regardless of their statistical nature or physical causes.

Environmental Performance: Environmental performance of a city is its performance considering the level of its impact on the regional and global environments and the local environment's ability of being eco-friendly.

Ecological Footprint: Ecological footprint is the indicator of sustainability and environmental performance of an ecosystem or human-being living in it and calculated on the basis of resources used and wastes produced through measurement unit of productive land and aquatic ecosystems sequestered in global hectares.

Urban Carbon: Urban carbon is carbon emissions produced and consumed in urban areas due to human activities and urban development decisions taken physically can be categorized under four typologies in terms of their place of consumption and production.

Global Hectare: Each global hectare represents an equal amount of biological productivity. One global hectare is equal to one hectare with productivity equal to the average productivity

of the 11.2 billion bioproductive hectares on Earth. Here productivity does not refer to a rate of biomass production, such as net primary production (NPP). Rather productivity is the potential to achieve maximum agricultural production at a specific level of inputs (see next section). Thus one hectare of highly productive land is equal to more global hectares than one hectare of less productive land

Bioproductive Areas: Globally we identify 11.2 billion hectares of distinct bioproductive areas cropland, forest, pasture, fisheries, and built-up land—that provide economically useful concentrations of renewable resources.

APPENDIX B

KYOTO PROTOCOL TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

UNITED NATIONS

1998

The Parties to this Protocol,

Being Parties to the United Nations Framework Convention on Climate Change, hereinafter referred to as "the Convention",

In pursuit of the ultimate objective of the Convention as stated in its Article 2, *Recalling* the provisions of the Convention,

Being guided by Article 3 of the Convention,

Pursuant to the Berlin Mandate adopted by decision 1/CP.1 of the Conference of the Parties to the Convention at its first session,

Have agreed as follows:

Article 1

For the purposes of this Protocol, the definitions contained in Article 1 of the Convention shall apply. In addition:

1. "Conference of the Parties" means the Conference of the Parties to the Convention.

2. “Convention” means the United Nations Framework Convention on Climate Change, adopted in New York on 9 May 1992.

3. “Intergovernmental Panel on Climate Change” means the Intergovernmental Panel on Climate Change established in 1988 jointly by the World Meteorological Organization and the United Nations Environment Programme.

4. “Montreal Protocol” means the Montreal Protocol on Substances that Deplete the Ozone Layer, adopted in Montreal on 16 September 1987 and as subsequently adjusted and amended.

5. “Parties present and voting” means Parties present and casting an affirmative or negative vote.

6. “Party” means, unless the context otherwise indicates, a Party to this Protocol.

7. “Party included in Annex I” means a Party included in Annex I to the Convention, as may be amended, or a Party which has made a notification under Article 4, paragraph 2 (g), of the Convention.

Article 2

1. Each Party included in Annex I, in achieving its quantified emission limitation and reduction commitments under Article 3, in order to promote sustainable development, shall:

(a) Implement and/or further elaborate policies and measures in accordance with its national circumstances, such as:

(i) Enhancement of energy efficiency in relevant sectors of the national economy;

(ii) Protection and enhancement of sinks and reservoirs of greenhouse gases not controlled by the Montreal Protocol, taking into account its commitments under relevant international environmental agreements; promotion of sustainable forest management practices, afforestation and reforestation;

(iii) Promotion of sustainable forms of agriculture in light of climate change considerations;

(iv) Research on, and promotion, development and increased use of, new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies;
(v) Progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors that run counter to the objective of the Convention and application of market instruments;
(vi) Encouragement of appropriate reforms in relevant sectors aimed at promoting policies and measures which limit or reduce emissions of greenhouse gases not controlled by the Montreal Protocol;
(vii) Measures to limit and/or reduce emissions of greenhouse gases not controlled by the Montreal Protocol in the transport sector;
(viii) Limitation and/or reduction of methane emissions through recovery and use in waste management, as well as in the production, transport and distribution of energy;
(b) Cooperate with other such Parties to enhance the individual and combined effectiveness of their policies and measures adopted under this Article, pursuant to Article 4, paragraph 2 (e) (i), of the Convention. To this end, these Parties shall take steps to share their experience and exchange information on such policies and measures, including developing ways of improving their comparability, transparency and effectiveness. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soonas practicable thereafter, consider ways to facilitate such cooperation, taking into account all relevant information.

2. The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively.

3. The Parties included in Annex I shall strive to implement policies and measures under this Article in such a way as to minimize adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties and in particular those identified in Article 4, paragraphs 8 and 9, of the Convention, taking into account Article 3 of the Convention. The Conference of the Parties serving as the meeting of the Parties to this

Protocol may take further action, as appropriate, to promote the implementation of the provisions of this paragraph.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol, if it decides that it would be beneficial to coordinate any of the policies and measures in paragraph 1 (a) above, taking into account different national circumstances and potential effects, shall consider ways and means to elaborate the coordination of such policies and measures.

Article 3

1. The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.

2. Each Party included in Annex I shall, by 2005, have made demonstrable progress in achieving its commitments under this Protocol.

3. The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I. The greenhouse gas emissions by sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8.

4. Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide, for consideration by the Subsidiary Body for Scientific and Technological Advice, data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years. The Conference of the Parties serving as the meeting of the Parties to this

Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to, or subtracted from, the assigned amounts for Parties included in Annex I, taking into account uncertainties, transparency in reporting, verifiability, the methodological work of the Intergovernmental Panel on Climate Change, the advice provided by the Subsidiary Body for Scientific and Technological Advice in accordance with Article 5 and the decisions of the Conference of the Parties. Such a decision shall apply in the second and subsequent commitment periods. A Party may choose to apply such a decision on these additional human-induced activities for its first commitment period, provided that these activities have taken place since 1990.

5. The Parties included in Annex I undergoing the process of transition to a market economy whose base year or period was established pursuant to decision 9/CP.2 of the Conference of the Parties at its second session shall use that base year or period for the implementation of their commitments under this Article. Any other Party included in Annex I undergoing the process of transition to a market economy which has not yet submitted its first national communication under Article 12 of the Convention may also notify the Conference of the Parties serving as the meeting of the Parties to this Protocol that it intends to use an historical base year or period other than 1990 for the implementation of its commitments under this Article. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall decide on the acceptance of such notification.

6. Taking into account Article 4, paragraph 6, of the Convention, in the implementation of their commitments under this Protocol other than those under this Article, a certain degree of flexibility shall be allowed by the Conference of the Parties serving as the meeting of the Parties to this Protocol to the Parties included in Annex I undergoing the process of transition to a market economy.

7. In the first quantified emission limitation and reduction commitment period, from 2008 to 2012, the assigned amount for each Party included in Annex I shall be equal to the percentage inscribed for it in Annex B of its aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A in 1990, or the base year or

period determined in accordance with paragraph 5 above, multiplied by five. Those Parties included in Annex I for whom land-use change and forestry constituted a net source of greenhouse gas emissions in 1990 shall include in their 1990 emissions base year or period the aggregate anthropogenic carbon dioxide equivalent emissions by sources minus removals by sinks in 1990 from land use change for the purposes of calculating their assigned amount.

8. Any Party included in Annex I may use 1995 as its base year for hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride, for the purposes of the calculation referred to in paragraph 7 above.

9. Commitments for subsequent periods for Parties included in Annex I shall be established in amendments to Annex B to this Protocol, which shall be adopted in accordance with the provisions of Article 21, paragraph 7. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall initiate the consideration of such commitments at least seven years before the end of the first commitment period referred to in paragraph 1 above.

10. Any emission reduction units, or any part of an assigned amount, which a Party acquires from another Party in accordance with the provisions of Article 6 or of Article 17 shall be added to the assigned amount for the acquiring Party.

11. Any emission reduction units, or any part of an assigned amount, which a Party transfers to another Party in accordance with the provisions of Article 6 or of Article 17 shall be subtracted from the assigned amount for the transferring Party.

12. Any certified emission reductions which a Party acquires from another Party in accordance with the provisions of Article 12 shall be added to the assigned amount for the acquiring Party.

13. If the emissions of a Party included in Annex I in a commitment period are less than its assigned amount under this Article, this difference shall, on request of that Party, be added to the assigned amount for that Party for subsequent commitment periods.

14. Each Party included in Annex I shall strive to implement the commitments mentioned in paragraph 1 above in such a way as to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention. In line with relevant decisions of the Conference of the Parties on the implementation of those paragraphs, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, consider what actions are necessary to minimize the adverse effects of climate change and/or the impacts of response measures on Parties referred to in those paragraphs. Among the issues to be considered shall be the establishment of funding, insurance and transfer of technology.

Article 4

1. Any Parties included in Annex I that have reached an agreement to fulfil their commitments under Article 3 jointly, shall be deemed to have met those commitments provided that their total combined aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of Article 3. The respective emission level allocated to each of the Parties to the agreement shall be set out in that agreement.

2. The Parties to any such agreement shall notify the secretariat of the terms of the agreement on the date of deposit of their instruments of ratification, acceptance or approval of this Protocol, or accession thereto. The secretariat shall in turn inform the Parties and signatories to the Convention of the terms of the agreement.

3. Any such agreement shall remain in operation for the duration of the commitment period specified in Article 3, paragraph 7.

4. If Parties acting jointly do so in the framework of, and together with, a regional economic integration organization, any alteration in the composition of the organization after adoption of this Protocol shall not affect existing commitments under this Protocol. Any alteration in the composition of the organization shall only apply for the purposes of those commitments under Article 3 that are adopted subsequent to that alteration.

5. In the event of failure by the Parties to such an agreement to achieve their total combined level of emission reductions, each Party to that agreement shall be responsible for its own level of emissions set out in the agreement.

6. If Parties acting jointly do so in the framework of, and together with, a regional economic integration organization which is itself a Party to this Protocol, each member State of that regional economic integration organization individually, and together with the regional economic integration organization acting in accordance with Article 24, shall, in the event of failure to achieve the total combined level of emission reductions, be responsible for its level of emissions as notified in accordance with this Article.

Article 5

1. Each Party included in Annex I shall have in place, no later than one year prior to the start of the first commitment period, a national system for the estimation of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. Guidelines for such national systems, which shall incorporate the methodologies specified in paragraph 2 below, shall be decided upon by the Conference of the Parties serving as the meeting of the Parties to this Protocol at its first session.

2. Methodologies for estimating anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol shall be those accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties at its third session. Where such methodologies are not used, appropriate adjustments shall be applied according to methodologies agreed upon by the Conference of the Parties serving as the meeting of the Parties to this Protocol at its first session. Based on the work of, *inter alia*, the Intergovernmental Panel on Climate Change and advice provided by the Subsidiary Body for Scientific and Technological Advice, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall regularly review and, as appropriate, revise such methodologies and adjustments, taking fully into account any relevant decisions by the Conference of the Parties. Any revision to methodologies or adjustments shall be used only for the purposes of ascertaining compliance with commitments under Article 3 in respect of any commitment period adopted subsequent to that revision.

3. The global warming potentials used to calculate the carbon dioxide equivalence of anthropogenic emissions by sources and removals by sinks of greenhouse gases listed in Annex A shall be those accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties at its third session. Based on the work of, *inter alia*, the Intergovernmental Panel on Climate Change and advice provided by the Subsidiary Body for Scientific and Technological Advice, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall regularly review and, as appropriate, revise the global warming potential of each such greenhouse gas, taking fully into account any relevant decisions by the Conference of the Parties. Any revision to a global warming potential shall apply only to commitments under Article 3 in respect of any commitment period adopted subsequent to that revision.

Article 6

1. For the purpose of meeting its commitments under Article 3, any Party included in Annex I may transfer to, or acquire from, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy, provided that:

(a) Any such project has the approval of the Parties involved;

(b) Any such project provides a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur;

(c) It does not acquire any emission reduction units if it is not in compliance with its obligations under Articles 5 and 7; and

(d) The acquisition of emission reduction units shall be supplemental to domestic actions for the purposes of meeting commitments under Article 3.

2. The Conference of the Parties serving as the meeting of the Parties to this Protocol may, at its first session or as soon as practicable thereafter, further elaborate guidelines for the implementation of this Article, including for verification and reporting.

3. A Party included in Annex I may authorize legal entities to participate, under its responsibility, in actions leading to the generation, transfer or acquisition under this Article of emission reduction units.

4. If a question of implementation by a Party included in Annex I of the requirements referred to in this Article is identified in accordance with the relevant provisions of Article 8, transfers and acquisitions of emission reduction units may continue to be made after the question has been identified, provided that any such units may not be used by a Party to meet its commitments under Article 3 until any issue of compliance is resolved.

Article 7

1. Each Party included in Annex I shall incorporate in its annual inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol, submitted in accordance with the relevant decisions of the Conference of the Parties, the necessary supplementary information for the purposes of ensuring compliance with Article 3, to be determined in accordance with paragraph 4 below.

2. Each Party included in Annex I shall incorporate in its national communication, submitted under Article 12 of the Convention, the supplementary information necessary to demonstrate compliance with its commitments under this Protocol, to be determined in accordance with paragraph 4 below.

3. Each Party included in Annex I shall submit the information required under paragraph 1 above annually, beginning with the first inventory due under the Convention for the first year of the commitment period after this Protocol has entered into force for that Party. Each such Party shall submit the information required under paragraph 2 above as part of the first national communication due under the Convention after this Protocol has entered into force for it and after the adoption of guidelines as provided for in paragraph 4 below. The frequency of subsequent submission of information required under this Article shall be determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol, taking into account any timetable for the submission of national communications decided upon by the Conference of the Parties.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall adopt at its first session, and review periodically thereafter, guidelines for the preparation of the information required under this Article, taking into account guidelines for the preparation ofnational communications by Parties included in Annex I adopted by the Conference of the

Parties. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall also, prior to the first commitment period, decide upon modalities for the accounting of assigned amounts.

Article 8

1. The information submitted under Article 7 by each Party included in Annex I shall be reviewed by expert review teams pursuant to the relevant decisions of the Conference of the Parties and in accordance with guidelines adopted for this purpose by the Conference of the Parties serving as the meeting of the Parties to this Protocol under paragraph 4 below. The information submitted under Article 7, paragraph 1, by each Party included in Annex I shall be reviewed as part of the annual compilation and accounting of emissions inventories and assigned amounts. Additionally, the information submitted under Article 7, paragraph 2, by each Party included in Annex I shall be reviewed as part of the review of communications.

2. Expert review teams shall be coordinated by the secretariat and shall be composed of experts selected from those nominated by Parties to the Convention and, as appropriate, by intergovernmental organizations, in accordance with guidance provided for this purpose by the Conference of the Parties.

3. The review process shall provide a thorough and comprehensive technical assessment of all aspects of the implementation by a Party of this Protocol. The expert review teams shall prepare a report to the Conference of the Parties serving as the meeting of the Parties to this Protocol, assessing the implementation of the commitments of the Party and identifying any potential problems in, and factors influencing, the fulfilment of commitments. Such reports shall be circulated by the secretariat to all Parties to the Convention. The secretariat shall list those questions of implementation indicated in such reports for further consideration by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall adopt at its first session, and review periodically thereafter, guidelines for the review of implementation of this Protocol by expert review teams taking into account the relevant decisions of the Conference of the Parties.

5. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, with the assistance of the Subsidiary Body for Implementation and, as appropriate, the Subsidiary Body for Scientific and Technological Advice, consider:

(a) The information submitted by Parties under Article 7 and the reports of the expert reviews thereon conducted under this Article; and

(b) Those questions of implementation listed by the secretariat under paragraph 3 above, as well as any questions raised by Parties.

6. Pursuant to its consideration of the information referred to in paragraph 5 above, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall take decisions on any matter required for the implementation of this Protocol.

Article 9

1. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall periodically review this Protocol in the light of the best available scientific information and assessments on climate change and its impacts, as well as relevant technical, social and economic information. Such reviews shall be coordinated with pertinent reviews under the Convention, in particular those required by Article 4, paragraph 2 (d), and Article 7, paragraph 2 (a), of the Convention. Based on these reviews, the Conference of the Parties serving as the meeting of the Parties to this Protocol shall take appropriate action.

2. The first review shall take place at the second session of the Conference of the Parties serving as the meeting of the Parties to this Protocol. Further reviews shall take place at regular intervals and in a timely manner.

Article 10

All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, without introducing any new commitments for Parties not included in Annex I, but reaffirming existing commitments under Article 4, paragraph 1, of the Convention, and continuing to advance the implementation of these commitments in order to achieve sustainable development, taking into account Article 4, paragraphs 3, 5 and 7, of the Convention, shall:

(a) Formulate, where relevant and to the extent possible, cost-effective national and, where appropriate, regional programmes to improve the quality of local emission factors, activity data and/or models which reflect the socio-economic conditions of each Party for the preparation and periodic updating of national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties, and consistent with the guidelines for the preparation of national communications adopted by the Conference of the Parties;

(b) Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change and measures to facilitate adequate adaptation to climate change:

(i) Such programmes would, *inter alia*, concern the energy, transport and industry sectors as well as agriculture, forestry and waste management. Furthermore, adaptation technologies and methods for improving spatial planning would improve adaptation to climate change; and

(ii) Parties included in Annex I shall submit information on action under this Protocol, including national programmes, in accordance with Article 7; and other Parties shall seek to include in their national communications, as appropriate, information on programmes which contain measures that the Party believes contribute to addressing climate change and its adverse impacts, including the abatement of increases in greenhouse gas emissions, and enhancement of and removals by sinks, capacity building and adaptation measures;

(c) Cooperate in the promotion of effective modalities for the development, application and diffusion of, and take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies, know-how, practices and processes pertinent to climate change, in particular to developing countries, including the formulation of policies and programmes for the effective transfer of environmentally sound technologies that are publicly owned or in the public domain and the creation of an enabling environment for the private sector, to promote and enhance the transfer of, and access to, environmentally sound technologies;

(d) Cooperate in scientific and technical research and promote the maintenance and the development of systematic observation systems and development of data archives to reduce uncertainties related to the climate system, the adverse impacts of climate change and the economic and social consequences of various response strategies, and promote the

development and strengthening of endogenous capacities and capabilities to participate in international and intergovernmental efforts, programmes and networks on research and systematic observation, taking into account Article 5 of the Convention;

(e) Cooperate in and promote at the international level, and, where appropriate, using existing bodies, the development and implementation of education and training programmes, including the strengthening of national capacity building, in particular human and institutional capacities and the exchange or secondment of personnel to train experts in this field, in particular for developing countries, and facilitate at the national level public awareness of, and public access to information on, climate change. Suitable modalities should be developed to implement these activities through the relevant bodies of the Convention, taking into account Article 6 of the Convention;

(f) Include in their national communications information on programmes and activities undertaken pursuant to this Article in accordance with relevant decisions of the Conference of the Parties; and

(g) Give full consideration, in implementing the commitments under this Article, to Article 4, paragraph 8, of the Convention.

Article 11

1. In the implementation of Article 10, Parties shall take into account the provisions of Article 4, paragraphs 4, 5, 7, 8 and 9, of the Convention.

2. In the context of the implementation of Article 4, paragraph 1, of the Convention, in accordance with the provisions of Article 4, paragraph 3, and Article 11 of the Convention, and through the entity or entities entrusted with the operation of the financial mechanism of the Convention, the developed country Parties and other developed Parties included in Annex II to the Convention shall:

(a) Provide new and additional financial resources to meet the agreed full costs incurred by developing country Parties in advancing the implementation of existing commitments under Article 4, paragraph 1 (a), of the Convention that are covered in Article 10, subparagraph (a); and

(b) Also provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of advancing the

implementation of existing commitments under Article 4, paragraph 1, of the Convention that are covered by Article 10 and that are agreed between a developing country Party and the international entity or entities referred to in Article 11 of the Convention, in accordance with that Article. The implementation of these existing commitments shall take into account the need for adequacy and predictability in the flow of funds and the importance of appropriate burden sharing among developed country Parties. The guidance to the entity or entities entrusted with the operation of the financial mechanism of the Convention in relevant decisions of the Conference of the Parties, including those agreed before the adoption of this Protocol, shall apply *mutatis mutandis* to the provisions of this paragraph.

3. The developed country Parties and other developed Parties in Annex II to the Convention may also provide, and developing country Parties avail themselves of, financial resources for the implementation of Article 10, through bilateral, regional and other multilateral channels.

Article 12

1. A clean development mechanism is hereby defined.

2. The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.

3. Under the clean development mechanism:

(a) Parties not included in Annex I will benefit from project activities resulting in certified emission reductions; and

(b) Parties included in Annex I may use the certified emission reductions accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, as determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

4. The clean development mechanism shall be subject to the authority and guidance of the Conference of the Parties serving as the meeting of the Parties to this Protocol and be supervised by an executive board of the clean development mechanism.

5. Emission reductions resulting from each project activity shall be certified by operational entities to be designated by the Conference of the Parties serving as the meeting of the Parties to this Protocol, on the basis of:

(a) Voluntary participation approved by each Party involved;

(b) Real, measurable, and long-term benefits related to the mitigation of climate change; and

(c) Reductions in emissions that are additional to any that would occur in the absence of the certified project activity.

6. The clean development mechanism shall assist in arranging funding of certified project activities as necessary.

7. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, elaborate modalities and procedures with the objective of ensuring transparency, efficiency and accountability through independent auditing and verification of project activities.

8. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall ensure that a share of the proceeds from certified project activities is used to cover administrative expenses as well as to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation.

9. Participation under the clean development mechanism, including in activities mentioned in paragraph 3 (a) above and in the acquisition of certified emission reductions, may involve private and/or public entities, and is to be subject to whatever guidance may be provided by the executive board of the clean development mechanism.

10. Certified emission reductions obtained during the period from the year 2000 up to the beginning of the first commitment period can be used to assist in achieving compliance in the first commitment period.

Article 13

1. The Conference of the Parties, the supreme body of the Convention, shall serve as the meeting of the Parties to this Protocol.

2. Parties to the Convention that are not Parties to this Protocol may participate as observers in the proceedings of any session of the Conference of the Parties serving as the meeting of the Parties to this Protocol. When the Conference of the Parties serves as the meeting of the Parties to this Protocol, decisions under this Protocol shall be taken only by those that are Parties to this Protocol.

3. When the Conference of the Parties serves as the meeting of the Parties to this Protocol, any member of the Bureau of the Conference of the Parties representing a Party to the Convention but, at that time, not a Party to this Protocol, shall be replaced by an additional member to be elected by and from amongst the Parties to this Protocol.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall keep under regular review the implementation of this Protocol and shall make, within its mandate, the decisions necessary to promote its effective implementation. It shall perform the functions assigned to it by this Protocol and shall:

(a) Assess, on the basis of all information made available to it in accordance with the provisions of this Protocol, the implementation of this Protocol by the Parties, the overall effects of the measures taken pursuant to this Protocol, in particular environmental, economic and social effects as well as their cumulative impacts and the extent to which progress towards the objective of the Convention is being achieved;

(b) Periodically examine the obligations of the Parties under this Protocol, giving due consideration to any reviews required by Article 4, paragraph 2 (d), and Article 7, paragraph 2, of the Convention, in the light of the objective of the Convention, the experience gained in its implementation and the evolution of scientific and technological knowledge, and in this respect consider and adopt regular reports on the implementation of this Protocol;

(c) Promote and facilitate the exchange of information on measures adopted by the Parties to address climate change and its effects, taking into account the differing circumstances, responsibilities and capabilities of the Parties and their respective commitments under this Protocol;

(d) Facilitate, at the request of two or more Parties, the coordination of measures adopted by them to address climate change and its effects, taking into account the differing

circumstances, responsibilities and capabilities of the Parties and their respective commitments under this Protocol;

(e) Promote and guide, in accordance with the objective of the Convention and the provisions of this Protocol, and taking fully into account the relevant decisions by the Conference of the Parties, the development and periodic refinement of comparable methodologies for the effective implementation of this Protocol, to be agreed on by the Conference of the Parties serving as the meeting of the Parties to this Protocol;

(f) Make recommendations on any matters necessary for the implementation of this Protocol;

(g) Seek to mobilize additional financial resources in accordance with Article 11, paragraph 2;

(h) Establish such subsidiary bodies as are deemed necessary for the implementation of this Protocol;

(i) Seek and utilize, where appropriate, the services and cooperation of, and information provided by, competent international organizations and intergovernmental and non-governmental bodies; and

(j) Exercise such other functions as may be required for the implementation of this Protocol, and consider any assignment resulting from a decision by the Conference of the Parties.

5. The rules of procedure of the Conference of the Parties and financial procedures applied under the Convention shall be applied *mutatis mutandis* under this Protocol, except as may be otherwise decided by consensus by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

6. The first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be convened by the secretariat in conjunction with the first session of the Conference of the Parties that is scheduled after the date of the entry into force of this Protocol. Subsequent ordinary sessions of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be held every year and in conjunction with ordinary sessions of the Conference of the Parties, unless otherwise decided by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

7. Extraordinary sessions of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be held at such other times as may be deemed necessary by the

Conference of the Parties serving as the meeting of the Parties to this Protocol, or at the written request of any Party, provided that, within six months of the request being communicated to the Parties by the secretariat, it is supported by at least one third of the Parties.

8. The United Nations, its specialized agencies and the International Atomic Energy Agency, as well as any State member thereof or observers thereto not party to the Convention, may be represented at sessions of the Conference of the Parties serving as the meeting of the Parties to this Protocol as observers. Anybody or agency, whether national or international, governmental or non-governmental, which is qualified in matters covered by this Protocol and which has informed the secretariat of its wish to be represented at a session of the Conference of the Parties serving as the meeting of the Parties to this Protocol as an observer, may be so admitted unless at least one third of the Parties present object. The admission and participation of observers shall be subject to the rules of procedure, as referred to in paragraph 5 above.

Article 14

1. The secretariat established by Article 8 of the Convention shall serve as the secretariat of this Protocol.

2. Article 8, paragraph 2, of the Convention on the functions of the secretariat, and Article 8, paragraph 3, of the Convention on arrangements made for the functioning of the secretariat, shall apply *mutatis mutandis* to this Protocol. The secretariat shall, in addition, exercise the functions assigned to it under this Protocol.

Article 15

1. The Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation established by Articles 9 and 10 of the Convention shall serve as, respectively, the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation of this Protocol. The provisions relating to the functioning of these two bodies under the Convention shall apply *mutatis mutandis* to this Protocol. Sessions of the meetings of the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation of this Protocol shall be held in

conjunction with the meetings of, respectively, the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation of the Convention.

2. Parties to the Convention that are not Parties to this Protocol may participate as observers in the proceedings of any session of the subsidiary bodies. When the subsidiary bodies serve as the subsidiary bodies of this Protocol, decisions under this Protocol shall be taken only by those that are Parties to this Protocol.

3. When the subsidiary bodies established by Articles 9 and 10 of the Convention exercise their functions with regard to matters concerning this Protocol, any member of the Bureaux of those subsidiary bodies representing a Party to the Convention but, at that time, not a party to this Protocol, shall be replaced by an additional member to be elected by and from amongst the Parties to this Protocol.

Article 16

The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, as soon as practicable, consider the application to this Protocol of, and modify as appropriate, the multilateral consultative process referred to in Article 13 of the Convention, in the light of any relevant decisions that may be taken by the Conference of the Parties. Any multilateral consultative process that may be applied to this Protocol shall operate without prejudice to the procedures and mechanisms established in accordance with Article 18.

Article 17

The Conference of the Parties shall define the relevant principles, modalities, rules and guidelines, in particular for verification, reporting and accountability for emissions trading. The Parties included in Annex B may participate in emissions trading for the purposes of fulfilling their commitments under Article 3. Any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments under that Article.

Article 18

The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, approve appropriate and effective procedures and mechanisms to determine

and to address cases of non-compliance with the provisions of this Protocol, including through the development of an indicative list of consequences, taking into account the cause, type, degree and frequency of non-compliance. Any procedures and mechanisms under this Article entailing binding consequences shall be adopted by means of an amendment to this Protocol.

Article 19

The provisions of Article 14 of the Convention on settlement of disputes shall apply *mutatis mutandis* to this Protocol.

Article 20

1. Any Party may propose amendments to this Protocol.

2. Amendments to this Protocol shall be adopted at an ordinary session of the Conference of the Parties serving as the meeting of the Parties to this Protocol. The text of any proposed amendment to this Protocol shall be communicated to the Parties by the secretariat at least six months before the meeting at which it is proposed for adoption. The secretariat shall also communicate the text of any proposed amendments to the Parties and signatories to the Convention and, for information, to the Depositary.

3. The Parties shall make every effort to reach agreement on any proposed amendment to this Protocol by consensus. If all efforts at consensus have been exhausted, and no agreement reached, the amendment shall as a last resort be adopted by a three-fourths majority vote of the Parties present and voting at the meeting. The adopted amendment shall be communicated by the secretariat to the Depositary, who shall circulate it to all Parties for their acceptance.

4. Instruments of acceptance in respect of an amendment shall be deposited with the Depositary. An amendment adopted in accordance with paragraph 3 above shall enter into force for those Parties having accepted it on the ninetieth day after the date of receipt by the Depositary of an instrument of acceptance by at least three fourths of the Parties to this Protocol.

5. The amendment shall enter into force for any other Party on the ninetieth day after the date on which that Party deposits with the Depositary its instrument of acceptance of the said amendment.

Article 21

1. Annexes to this Protocol shall form an integral part thereof and, unless otherwise expressly provided, a reference to this Protocol constitutes at the same time a reference to any annexes thereto. Any annexes adopted after the entry into force of this Protocol shall be restricted to lists, forms and any other material of a descriptive nature that is of a scientific, technical, procedural or administrative character.

2. Any Party may make proposals for an annex to this Protocol and may propose amendments to annexes to this Protocol.

3. Annexes to this Protocol and amendments to annexes to this Protocol shall be adopted at an ordinary session of the Conference of the Parties serving as the meeting of the Parties to this Protocol. The text of any proposed annex or amendment to an annex shall be communicated to the Parties by the secretariat at least six months before the meeting at which it is proposed for adoption. The secretariat shall also communicate the text of any proposed annex or amendment to an annex to the Parties and signatories to the Convention and, for information, to the Depositary.

4. The Parties shall make every effort to reach agreement on any proposed annex or amendment to an annex by consensus. If all efforts at consensus have been exhausted, and no agreement reached, the annex or amendment to an annex shall as a last resort be adopted by a three-fourths majority vote of the Parties present and voting at the meeting. The adopted annex or amendment to an annex shall be communicated by the secretariat to the Depositary, who shall circulate it to all Parties for their acceptance.

5. An annex, or amendment to an annex other than Annex A or B, that has been adopted in accordance with paragraphs 3 and 4 above shall enter into force for all Parties to this Protocol six months after the date of the communication by the Depositary to such Parties of the adoption of the annex or adoption of the amendment to the annex, except for those

Parties that have notified the Depositary, in writing, within that period of their non-acceptance of the annex or amendment to the annex. The annex or amendment to an annex shall enter into force for Parties which withdraw their notification of non-acceptance on the ninetieth day after the date on which withdrawal of such notification has been received by the Depositary.

6. If the adoption of an annex or an amendment to an annex involves an amendment to this Protocol, that annex or amendment to an annex shall not enter into force until such time as the amendment to this Protocol enters into force.

7. Amendments to Annexes A and B to this Protocol shall be adopted and enter into force in accordance with the procedure set out in Article 20, provided that any amendment to Annex B shall be adopted only with the written consent of the Party concerned.

Article 22

1. Each Party shall have one vote, except as provided for in paragraph 2 below.

2. Regional economic integration organizations, in matters within their competence, shall exercise their right to vote with a number of votes equal to the number of their member States that are Parties to this Protocol. Such an organization shall not exercise its right to vote if any of its member States exercises its right, and vice versa.

Article 23

The Secretary-General of the United Nations shall be the Depositary of this Protocol.

Article 24

1. This Protocol shall be open for signature and subject to ratification, acceptance or approval by States and regional economic integration organizations which are Parties to the Convention. It shall be open for signature at United Nations Headquarters in New York from 16 March 1998 to 15 March 1999. This Protocol shall be open for accession from the day after the date on which it is closed for signature. Instruments of ratification, acceptance, approval or accession shall be deposited with the Depositary.

2. Any regional economic integration organization which becomes a Party to this Protocol without any of its member States being a Party shall be bound by all the obligations under this Protocol. In the case of such organizations, one or more of whose member States is a Party to this Protocol, the organization and its member States shall decide on their respective responsibilities for the performance of their obligations under this Protocol. In such cases, the organization and the member States shall not be entitled to exercise rights under this Protocol concurrently.

3. In their instruments of ratification, acceptance, approval or accession, regional economic integration organizations shall declare the extent of their competence with respect to the matters governed by this Protocol. These organizations shall also inform the Depositary, who shall in turn inform the Parties, of any substantial modification in the extent of their competence.

Article 25

1. This Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Parties included in Annex I which accounted in total for at least 55 per cent of the total carbon dioxide emissions for 1990 of the Parties included in Annex I, have deposited their instruments of ratification, acceptance, approval or accession.

2. For the purposes of this Article, "the total carbon dioxide emissions for 1990 of the Parties included in Annex I" means the amount communicated on or before the date of adoption of this Protocol by the Parties included in Annex I in their first national communications submitted in accordance with Article 12 of the Convention.

3. For each State or regional economic integration organization that ratifies, accepts or approves this Protocol or accedes thereto after the conditions set out in paragraph 1 above for entry into force have been fulfilled, this Protocol shall enter into force on the ninetieth day following the date of deposit of its instrument of ratification, acceptance, approval or accession.

4. For the purposes of this Article, any instrument deposited by a regional economic integration organization shall not be counted as additional to those deposited by States members of the organization.

Article 26

No reservations may be made to this Protocol.

Article 27

1. At any time after three years from the date on which this Protocol has entered into force for a Party, that Party may withdraw from this Protocol by giving written notification to the Depositary.

2. Any such withdrawal shall take effect upon expiry of one year from the date of receipt by the Depositary of the notification of withdrawal, or on such later date as may be specified in the notification of withdrawal.

3. Any Party that withdraws from the Convention shall be considered as also having withdrawn from this Protocol.

Article 28

The original of this Protocol, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations.

DONE at Kyoto this eleventh day of December one thousand nine hundred and ninety-seven.

IN WITNESS WHEREOF the undersigned, being duly authorized to that effect, have affixed their signatures to this Protocol on the dates indicated.

Annex A

Greenhouse gases

Carbon dioxide (C02)

Methane (CH4)

Nitrous oxide (N20)

Hydrofluorocarbons (HFCs)

Perfluorocarbons (PFCs)

Sulphur hexafluoride (SF6)

Sectors/source categories

Energy

- Fuel combustion
  - Energy industries
  - Manufacturing industries and construction
  - Transport
  - Other sectors
  - Other
- Fugitive emissions from fuels
  - Solid fuels
  - Oil and natural gas
  - Other

Industrial processes

- Mineral products
- Chemical industry
- Metal production
- Other production
- Production of halocarbons and sulphur hexafluoride
- Consumption of halocarbons and sulphur hexafluoride
- Other

Solvent and other product use

Agriculture

- Enteric fermentation
- Manure management
- Rice cultivation
- Agricultural soils
- Prescribed burning of savannas
- Field burning of agricultural residues

Other

Waste

Solid waste disposal on land

Wastewater handling

Waste incineration

Other

Annex B

Party	Quantified emission limitation or reduction commitment (percentage of base year or period)
Australia	108
Austria	92
Belgium	92
Bulgaria*	92
Canada	94
Croatia*	95
Czech Republic*	92
Denmark	92
Estonia*	92
European Community	92
Finland	92
France	92
Germany	92
Greece	92
Hungary*	94
Iceland	110
Ireland	92
Italy	92
Japan	94
Latvia*	92
Liechtenstein	92
Lithuania*	92
Luxembourg	92
Monaco	92
Netherlands	92
New Zealand	92
Norway	101
Poland*	94
Portugal	92
Romania*	92
Russian Federation*	100
Slovakia*	92
Slovenia*	92
Spain	92
Sweden	92
Switzerland	92
Ukraine*	100

United Kingdom of Great Britain and Northern Ireland	92
United States of America	93

* Countries that are undergoing the process of transition to a market economy.

APPENDIX C

ECOLOGICAL FOOTPRINT OF NATIONS

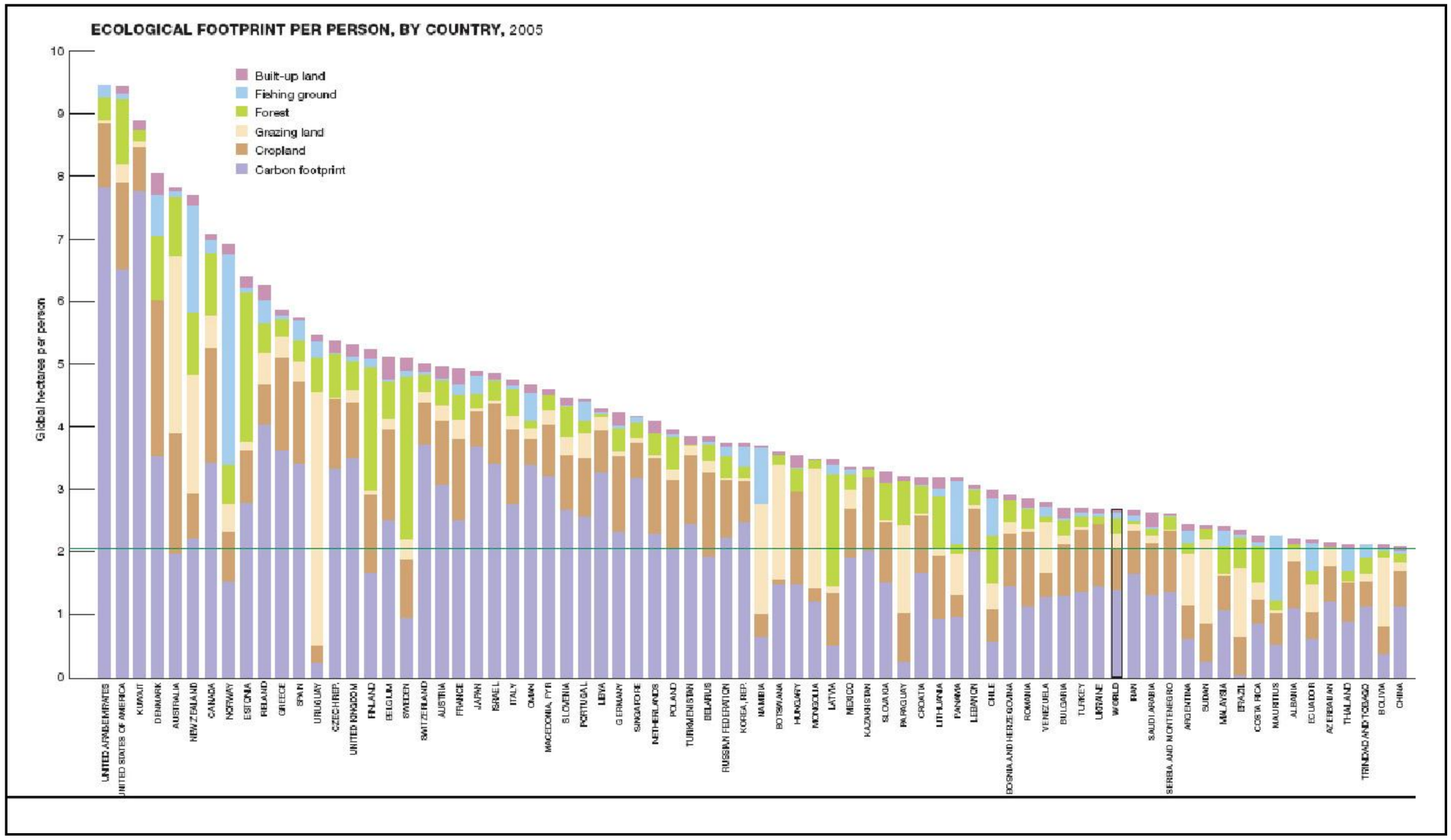

Figure 0-1 Ecological Footprint of Nations

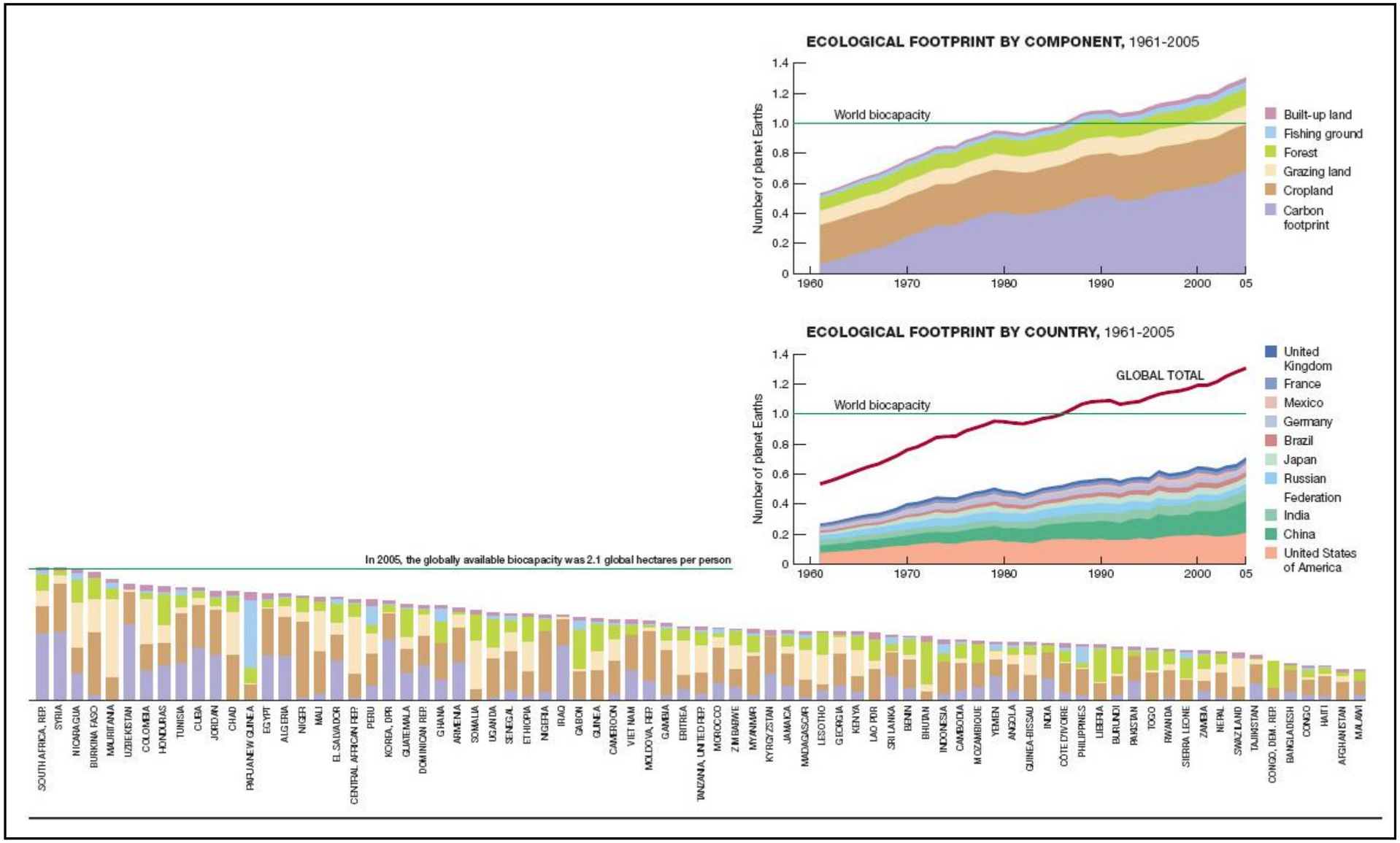

Figure C-1 Ecological Footprint of Nations (Continues)

APPENDIX D

GENERAL FRAMEWORK IN MODELLING LAND USE CHANGE

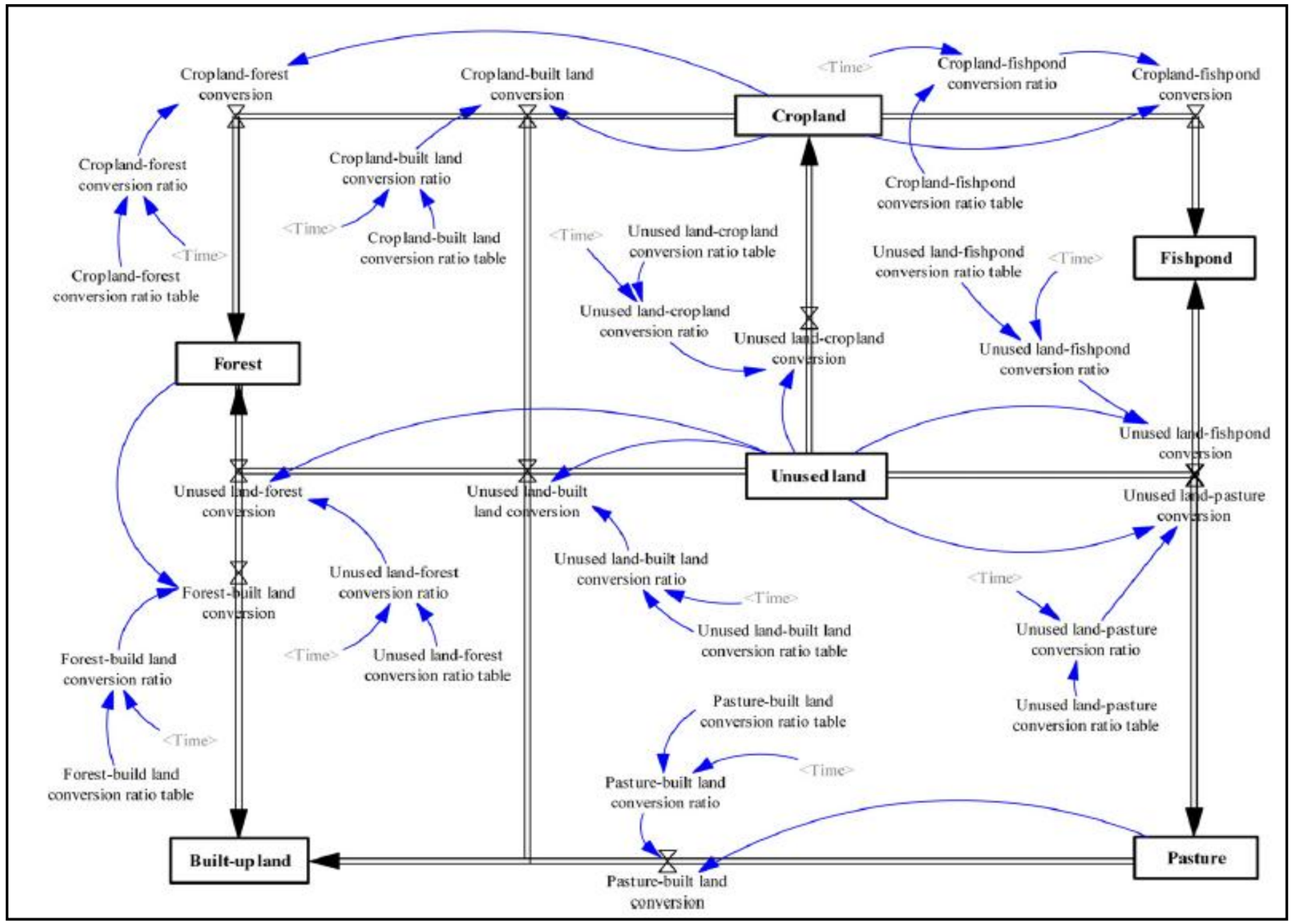

Figure D-1 General framework in modelling land use change. The six types of land uses are indicated by regtangles as stock variables.*(Adapted from* Wie Jin, Linyu Xu, Zhifeng Yang, 2009)

APPENDIX E

CATALOGUE OF PATTERNS

(Marshall, S., 2005)

A. General archetypes

Sitte ([1889]1945)

1. Rectangular system
2. Radial system
3. Triangular system
4. ‘bastard offspring’

Unwin (1920)

Irregular (Various)

Regular

1. rectilinear
2. circular
3. diagonal
4. radiating lines

Abercrombie (1933)

1. Gridiron
2. Hexagonal
3. Radial
4. Spider’s web

Tripp (1950:328)

Rectangular

Gridiron with Superimposed

Diagonals

Radial

Concentric

Topographical-Informal

Irregular-Medieval

Radials Blended with Gridiron

Combined Rectangular and

Irregular

Dickinson (1961)

1. Irregular
2. Radial-concentric
3. Rectangular or grid

Mumford (1961)

1. Street village (=)
2. Cross-roads village (+)
3. Commons village (#)
4. Round village (O)

Lynch (1962:34)

1. Grid
2. Radial (inc.branching)
3. Linear

Jamieson et al. (1967)

1. Cartwheel
2. Linear
3. Ring and radial
4. Single strand

5. Double strand etc.

Farbey and Murchland (1967)

1. Radial and circumferentiall system
2. Grid system
3. Hyperbolic grid system

Morlok (1967:65)

1. Spinal or Tree
2. Grid network
3. Delta network

Colin Buchanan and Partners (1968)

1. Centripetal
2. Linear
3. Grid

Moholy-Nagy (1968)

1. Geomorphic
2. Concentric
3. Orthogonal-connective
4. Orthogonal-modularClustered

Clifford Culpin and Partners (1969)

1. Centralised
2. Linked Radial
3. Radial
4. Web
5. Figure of Eight
6. Radial-Linear
7. Centripetal Net
8. Centripetal Grid
9. Ringed Spine

10. Spine
11. Triangular Net
12. Hexagonal Net
13. Regular Grid
14. Directional Grid
15. Nucleated Corridor
16. Dispersed
17. Honeycomb
18. Uniform Grid
19. Canalised Grid
20. Linear Grid
21. Linear

Abrams (1971)
City linear
Gridiron plan
Linear system
Radial street pattern

March and Steadman (1971)
Radio-axial city
Cellular city

Echenique et al. (1972)
1. Axial grid
2. Loose grid
3. Radial cross-shaped
4. Semi-radial

Stone (in Potter, 1977)
1. Linear
2. Rectangular
3. Star (inc. X & Y shapes)

Lynch (1981)

1. Axial network
2. Capillary
3. Kidney
4. Radio-concentric
5. Rectangular grid

Lynch (1981)

1. Star (radial)
2. Satellite Cities
3. Linear City
4. Rectangular Grid city
5. Other Grid (parallel, triangular, hexagonal)
6. Baroque axial network
7. The lacework
8. The "inward" city (eg, medieval Islamic)
9. The nested city
10. Current imaginings (megaform, bubble, floating, underground, undersea, outer space)

Pressman (1985)

1. Dispersed Sheet (orthogonal gridiron)
2. Spider Web (Radio-concentric) or (Ring Radial)
3. Star (Finger)
4. Satellite (Cluster)
5. Linear
6. Ring

7. Galaxy
8. Polycentred Net

O'Flaherty (1986)
1. Gridiron
2. Linear
3. Radial

Rickaby (1987)
0. Existing configuration
1. Concentrated-nucleated
2. Concentrated-linear
3. Dispersed-nucleated (satellite towns)
4. Dispersed-linear
5. Dispersed-nucleated
(villages)

DoE/DoT (1992)
Curvilinear (Network)
Hierarchical
Rectilinear (grid)

McCluskey (1992)
1. Branching pattern
2. Grid
3. Radial
4. Serial
5. Web pattern

Southworth and Owens (1993)
1. Fragmented parallels

2. Interrupted Parallels
3. Lollipops on a stick
4. Loop and cul-de-sac
5. Loops and lollipops
6. Warped parallels

AIA (Culot, 1995)
1. Curvilinear
2. Diagonal
3. Discontinuous (Radburn)
4. Grid with Diagonals
5. Organic
6. Orthogonal

Brindle (1996b)
1. (Grid)
2. Tributary

Bell and Iida (1997:19)
1. Path
2. Tree
3. Cycle
1. Linear
2. Grid

Satoh (1998)
1. Warped grid
2. Radial
3. Horseback
4. Whirlpool
5. Unique Structures

Frey (1999)

1. The Core City
2. The Star City
3. The Satellite City
4. The Galaxy of Settlements
5. The Linear City
6. The Polycentric Net

or, Regional City

DTLR & CABE (2001:42)

1. Regular blocks
2. Concentric blocks
3. Irregular blocks

Boarnet and Crane (2001)

1. Grid
2. Cul-de-sac
3. Mixed

B. Mixed & miscellaneous urban forms

A) typologies that are arranged by a mixture of classification themes

B) themes by which different typologies might be generated

Boarnet and Crane (2001)

1. Density
2. Extent of land use mixing
3. Traffic calming
4. Street and circulation pattern
5. Jobs-housing and/or land use balance
6. Pedestrian features (e.g. sidewalks)

Stead and Marshall (2001)

1. distance of residence from the urban centre

2. settlement size
3. mixing of land uses
4. provision of local facilities
5. density of development
6. proximity to transport networks
7. availability of residential parking
8. road network type
9. neighbourhood type

von Borcke (2003)

1. Inner urban areas (positional)
2. Dense residential areas (land use spatial)
3. Mixed-use areas (land use spatial)
4. Terraced housing (built form)
5. Semi-detached, with small gardens (built form)
6. Semi-detached, with medium gardens (built form)
7. Detached houses with large gardens (built form)

Barton (1992)

1. Density
2. Location of jobs and facilities
3. Shape of the city.

Jenks and Burgess (2000)

1. urban size
2. urban structure (see under urban structure)
3. urban regions and agglomerations;
4. urban form at city scale;
5. density and urban intensification;
6. urban sprawl and peripheries;
7. urban compaction;
8. polynucleated urban form.

Composite (more than one variable)

Mohammed-Reza Masnavi (2000)

1. Compact mixed use;
2. Compact mono use;
3. Dispersed mixed use;
4. Dispersed mono use.

Composite: types of neighbourhood or suburb

Kulash (1990)

1. Traditional neighborhood development

(a) mixed use;

(b) connected/gridded streets;

(c) reduced street hierarchy

2. Conventional suburban development

(a) segregated uses;

(b) partially connected streets and cul-de-sacs;

(c) hierarchical street networks

Friedman *et al.* (1994)

1. Traditional communities

(a) mostly developed before 1940;

(b) mixed-use downtown commercial district with significant on-street parking;

(c) interconnecting street grid;

(d) residential neighbourhoods in close proximity to non-residential land uses.

2. Suburban communities

(a) developed since the early 1950's with segregated land uses;

(b) well-defined hierarchy of roads;

(c) access concentrated at a few key points;

(d) relatively little transit service.

Cervero and Gorham (1995)

1. Transit neighborhoods

(a) initially built along a streetcar line or around a rail station;

(b) primarily gridded (over 50 per cent of intersections four-way or 'X' intersections);

(c) laid out and largely built up before 1945.

2. Auto neighborhoods

(a) laid out without regard to transit, generally in areas without transit lines, either present or past;

(b) primarily random street patterns (over 50 per cent of intersections either 3-way, 'T' intersections or cul-de-sacs);

(c) laid out and built up after 1945.

McNally and Kulkarni (1997)

1. Traditional neighborhood design (TND)

(a) gridlike transportation networks with few or no access cul-de-sacs;

(b) a large number of access points into the neighbourhood;

(c) high population densities

2. Planned unit development (PUD)

(a) circuitous transportation networks with many cul-de-sacs;

(b) a very limited number of access points in the neighbourhood;

(c) very segregated land uses;

(d) low residential densities.

3. *Hybrid*

Gwilliam *et al.* (1998:8) 'Types of suburbs'

1. Historic inner suburb

Established terrace or semi-detached developments now integrated to the rest of town; urban qualities, e.g. mix of uses, 'walkability', good public transport.

2. Planned suburb

Few enclaves now absorbed into the rest of town; usually successful.

3. Social housing suburb

High or low rise housing estates often with problems of maintenance, safety, vandalism, lack of social mix and non-residential uses.

4. Suburban town.

Suburbs acquiring urban village functions for a wider sub-metropolitan area.

5. Public transport suburb.

Medium density homogeneous speculative suburbs, usually in a closely structured urban fabric.

6. Car suburb.

Low density, detached housing, homogeneous speculative suburbs, often in an 'open' townscape fringe area (motoways, out of town shopping centres and golf clubs).

Gwilliam, M., Bourne, C., Swain, C. and Prat, A. (1998) *Sustainable Renewal of Suburban Areas*. York: York Publishing Services.

Urban Structure

Jenks and Burgess (2000)

1. Concentrated decentralisation;
2. Monocentric;
3. Polycentric.

Land use pattern

Orrskog and Snickars (1992)

1. Land use disposition 1
2. Land use disposition 2
3. Land use disposition 3
4. Land use disposition 4

Rickaby *et al.* (1992)

1. Concentrated development in the central city;
2. High-density linear development along main roads;
3. New satellite towns;
4. High density linear development along secondary roads;
5. Development dispersed to villages.

Headicar (2000)

Headicar refers to two 'trends':

· *Counter-urbanisation:* shift downwards in the hierarchy (e.g., decline in population of big cities, growth in population of small towns.

· *Deconcentration:* shift in population within settlements, from inner to outer areas.

Hall and Marshall (2000)

Notes where clarification of terminology may be beneficial, concerning the following 'spatial' pattern terms:

(a) Deurbanisation;

(b) Deconcentration;

(c) Deintensification (or de-densification);

(d) Decentralisation;

(e) Dispersal;

(f) Diffusion.

Some may mean the same thing, others may usefully be used to distinguish quite distinct concepts, for example:

(i) the general reduction in density of a city;

(ii) the enlargement of a city by low density peripheral development, which reduces the net density of the whole city;

(iii) the scatter of existing functions, once centralised, throughout an urban area;

(iv) the scatter of existing functions, once centralised, to the periphery;

(v) the removal of the bundle of central functions from an original central location to a new off-centre or peripheral location;

(vi) the 'devolution' of the bundle of city-wide functions to become a series of local functions at local 'centres';

(vii) the loss of population from higher order centres (big cities), and the growth of lower order centres (eg, small towns) – approximately what is referred to as 'counter urbanisation' by Headicar (2000).

Forms of Urban Growth

Breheny, Gent and Lock (1993)

Note: these refer to planning strategies, rather than observed

(i) *urban infill* – urban growth takes place within the boundaries of existing cities and towns (SM – perhaps 'existing built-up area' would be clearer);
(ii) *urban extensions* – development takes place at the edges of existing urban areas, typically on green fields or on other open land at the urban fringe;
(iii) *key village extensions* – new development takes the form both of expansion at the edge of the village, and intensification at its centre;
(iv) *multiple village extensions* – as above but spread through any/all villages (without selecting any in particular for provision of critical mass of services, etc.);
(v) *new settlements* – a free-standing settlement, where the completed new development – of whatever size – constitutes 50% or more of the total size of the settlement, measured in terms of population or dwellings.

Cambridge Futures (Echenique et al., 1999)

Note that although these are generic options, they relate to the specific context of Cambridge and its hinterland.

1. Minimum Growth
2. Densification
3. Necklace development
4. Green swap
5. Transport links
6. Virtual highway
7. New Town