FUTURE VISION COMMISSION

Carrying Capacity and Its Application to the Portland Metropolitan Area

by

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CARRYING CAPACITY AND ITS APPLICATION TO THE PORTLAND METROPOLITAN REGION:

A DISCUSSION PAPER.

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EXECUTIVE SUMMARY[1]

The objective of this report is to assist Metro's Future Vision Commission as it develops a long-term "vision" for the Portland Metropolitan Region. By Charter, the Future Vision is:

> "...a conceptual statement that indicates population levels and settlement patterns that the region can accommodate within the carrying capacity of the land, water, and air resources of the region, and its educational and economic resources, and that achieves a desired quality of life..."

This report offers an appraisal of how the concept of carrying capacity can be incorporated in the work of the commission.

CHAPTER 1

In the first chapter, a historical background of the carrying capacity concept is given through an extensive literature review. The main conclusions of this literature review are:

1. The carrying capacity concept within the human context has two components: one is a *variable ecologically determined* within the ecological limits of resources consumed and wastes produced, the other is a *variable socially determined* depending on the perceptions of economic, social and environmental qualities and their perceived contribution in maintaining quality of life levels. The interactions between the two variables creates the *social carrying capacity*, the socially determined ecological carrying capacity.

2. Differences in consumption patterns and technological applications have a major impact on the ecological dimensions of the carrying capacity, and make explicit the relationship between consumption patterns, technology and carrying capacity. This implies that environmental damage within the human context is not simply due to *increased* numbers, but to the greater mobility of people, the intensity of their activities and the enhanced means in which they can inflict damage on the surrounding ecosystem in which they are embedded.

[1] This report is also summarized in a flow chart, which can be found at the end of the executive summary.

3. The social dimensions of carrying capacity are factors or variables which determine and influence the *perception, importance* and *validity* of the ecological dimension of the carrying capacity. Social dimensions of carrying capacity include factors such as lifestyle aspirations, the disparity between private and social costs, the difficulty in formulating rational policy in the face of uncertainty, technological innovations, perceptions of time and social values, and various other features of human sociopolitical and economic organization.

CHAPTER 2

In chapter 2, the carrying capacity concept is investigated within a context of sustainability. The main conclusions of this chapter are:

1. When the social carrying capacity is integrated within a sustainable perspective, a new interpretation of the social carrying capacity is established: sustainable carrying capacity.

2. By linking the carrying capacity concept with the concept of sustainability, the process of integrating the carrying capacity into urban development planning becomes synonymous for the process of moving towards ecological and social sustainability.

3. The most important consequence of framing the social carrying capacity concept within a sustainable context, e.g. sustainable carrying capacity, is that the limiting variable is not a limit of population, but a limit of *throughput*. Throughput is defined as the flow of energy and/or material from the original sources, through a system (where it may be transformed), and out to the ultimate sinks. The limit to the size of maintaining flows of matter and energy is set by *ecological thresholds which, if exceeded, cause a breakdown of the system.*

4. Addressing the scale of throughput means addressing issues related to affluence, standard of living and lifestyle. It also means that there is the need to fit human activities into nature's patterns as there are indeed limits to economic growth and urban growth insofar as the use of material resources from the environment and the ability to dispose of wastes are concerned.

CHAPTER 3

The third chapter presents a model to evaluate the likelihood of carrying capacity constraints in a metropolitan region. The carrying capacity evaluation model presented is comprised of six capacity levels. A capacity level is defined as a realm of potential and actual constraints which direct, limit and shape the growth of a metropolitan region.

The six capacity levels are:

* *infrastructural capacity level*: constraints of infrastructures, which determine the flow of resources through the metropolitan region.

* *institutional capacity level*: constraints of politically or legally enforced threshold standards with are enforced within the metropolitan region.

* *perceptual capacity level*: constraints of socially determined unacceptable changes in the metropolitan region.

* *environmental capacity level*: constraints at which environmental sources and sinks are diminishing the quality of the environment of the metropolitan region.

* *sustainable capacity level*: constraints of natural and social systems, which when exceeded, will threaten the ecological and social sustainability of the metropolitan region.

* *biocentric capacity level*: constraints of the region, which when exceeded, threaten the integrity, stability and beauty of the biotic community of the metropolitan region.

The carrying capacity evaluation model is grounded in three observations.

First, the carrying capacity concept is not defined as a *product*, but as a *discourse*[2]. It is a discourse on a set of ecological and social thresholds, desired levels of consumption of goods and services by a society and their interaction. Important components of this discourse is on the one hand identifying the different ecological and social constraints, on the other hand investigate their interactions with one another. The carrying capacity evaluation model defines carrying capacity as *a discourse on how to approach the various types of socially constructed capacity level constraints within the context of sustainability.* This implies that sustainability too is not a *goal*, but a *discourse* on what kind of limits we are willing to accept.

Second, all carrying capacity related limits or constraints can be seen as social carrying capacity constraints. Although they arise through an interaction with the natural world, they are ultimately *socially constructed* by the human community. It is important to underscore that this does not mean that the natural limits are not real. Socially constructed constraints within a sustainable context do reflect actual limits out there and are therefore absolute. It simply underscores the epistemological assumption that just as our understanding of nature is socially

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[2] A discourse can be defined as a process inclusive of social, ethical and political dialogues, scientific research and policy implementation.

constructed, so are the perceptions of the different constraints of nature.

Third, the carrying capacity evaluation model addresses carrying capacity related issues from a bioregional perspective. Because the metropolitan region has already exceeded the local ecological carrying capacity and because of its dependence on areas outside of its urban growth boundary, the boundaries of a metropolitan area relevant for carrying capacity related issues are better defined by the *bioregion* in which the metropolitan area is located. A bioregion is a distinct area with coherent and interconnected human, plant and animal communities, and is defined by a watershed or an inter-linking network of several watersheds. The Portland Metropolitan Region is part of the Cascadian bioregions, such as the Columbia bioregion and the Willamette bioregion.

The carrying capacity evaluation model is presented to provide insight regarding the degree to which issues pertaining to the carrying capacity could frame the thinking with respect of the resources of a metropolitan region. The model also encourages an on-going discourse to facilitate a clearer understanding of carrying capacity-related issues relevant to a metropolitan region.

CHAPTER 4

The fourth chapter applies the carrying capacity evaluation model to the Portland Metropolitan Region. The model suggests a framework for a discourse on how to respond to future growth within the Portland Metropolitan Region by identifying the most vital constraints of five key resources--air, water, land, energy, and transportation system. It also highlights the critical decision points which will need to be made in the future. The use of this model is advantageous for looking at the carrying capacity constraints from a long-term perspective and with respect to the ecological sustainability of the Portland Metropolitan Region.

After having analyzed the key constraints of the five evaluated resources of the Portland Metropolitan Region, three essential observations are made:

1. the limiting factor, which will constrain growth in the metropolitan region is the **air quality** of the region. The air quality, which is projected to exceeded the EPA federal standard in 2006 and will be 35% above federal standards in 2040, is a constraint for air, as well as a constraint for land and the transportation system.

2. the limiting system, which will constraint growth in the metropolitan region is the transportation system. Many key constraints are related to the **transportation system** (EPA air quality, CO_2 emissions, depletion of oil reserves, perception of congested highways, view of Mt. Hood).

3. the metropolitan region is likely to face **energy** constraints in the next century. Among the likely constraints to appear are the sustainable constraints of cheap non-renewable energy and the biocentric constraints of hydro-power.

The application of the model must be seen as a preliminary investigation into carrying capacity related issues for the Portland Metropolitan Region. Four further avenues for research are:

a. Collect more data collection and analysis of the resources investigated.

b. Evaluate other resources and human-based systems, such as fiscal related, economy-related, educational-related, safety-related and housing-related carrying capacity constraints.

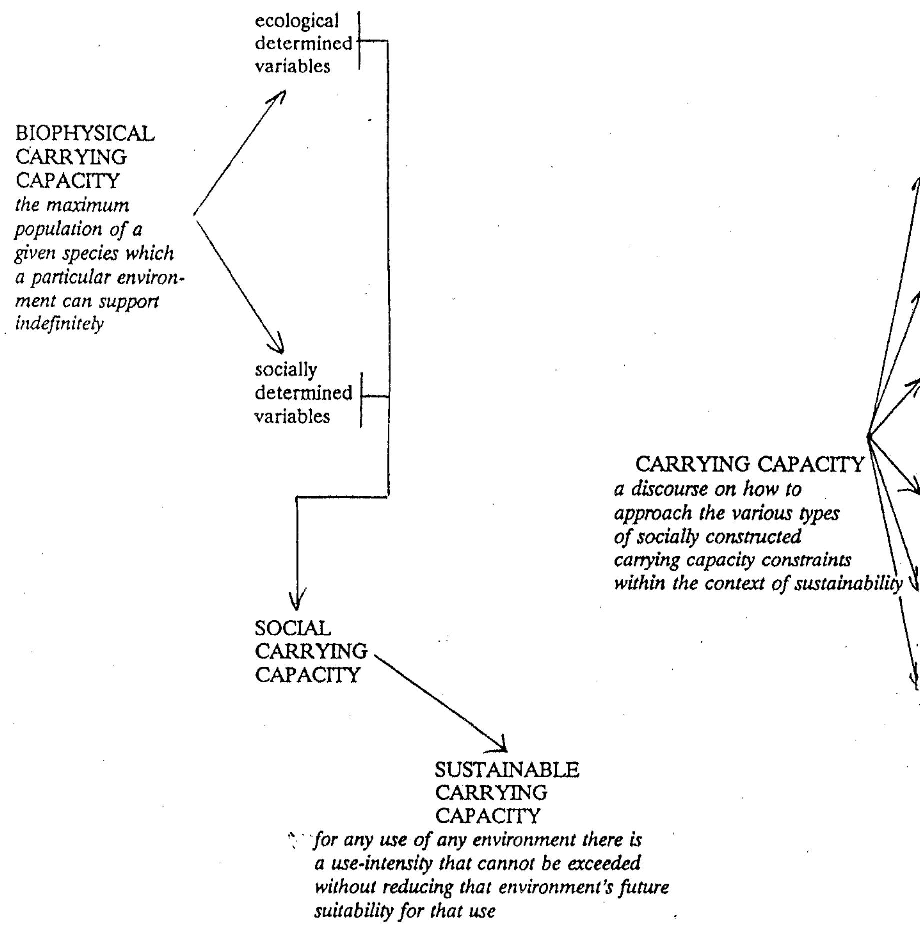
c. Analyze the complex interactions between the various multi-leveled constraints of the different evaluated resources.

d. Investigate the feasibility of establishing carrying capacity threshold standards for the region in order to ensure the long-term sustainability of the region.

CONCLUSION

This document should be seen as a preliminary investigation into carrying capacity related issues for the Portland Metropolitan Region. It is hoped that this report will help the Future Vision Commission in their effort to develop a guidepost for the long-term future of the metropolitan region and the larger bioregion.

non-human systems | human systems | context of sustainability | context of metropolitan region | carrying capacity evaluation model for a metropolitan region | carrying capacity constraints for the Portland Metropolitan Region



CAPACITY LEVEL	LAND	WATER	TRANSPORT	ENERGY	AIR
Infrastructural capacity level: constraints of infrastructures, which determine the flow of resources through the metropolitan region		1077 mgd	9, 279 miles of freeways and arterials		
Institutional capacity level: constraints of politically or legally enforced threshold standards with are enforced within the metropolitan region	EPA air quality standard		EPA air quality standard	180.5 BTUs	EPA air quality standard
Perceptual capacity level: constraints of socially determined unacceptable changes in the metropolitan region	greenspaces	water purity	congested roadways		view of Mt. Hood
Environmental capacity level: constraints of environmental sources and sinks which, when exceeded will lead to undesirable changes in the natural environment of the metropolitan region				energy investment ratio	
Sustainable capacity level: constraints of natural and social systems, which when exceeded, will threaten the ecological and social sustainability of the metropolitan region	rural resource land	watershed preservation	depletion of oil reserves	depletion of oil reserves horizontal/vertical ratio	8.1 MMT of CO_2 emission
Biocentric capacity level: constraints of the bioregion, which when exceeded, threaten the integrity, stability and beauty of the biotic community of the metropolitan region.	ecological footprint	preservation of ecosystems habitat		salmon habitat destruction due to hydropower	

FLOW CHART OF THE CARRYING CAPACITY CONCEPT

INTRODUCTION

A major focus of the Future Vision's Commission's efforts is to determine how and where to accommodate population growth while maintaining a desirable quality of life. An important component of this assignment is to examine how ideas of carrying capacity frame decisions about population growth and settlement patterns in the region.

This report is meant to provide insight regarding the degree to which issues of carrying capacity should shape the thinking of the Future Vision Commission in the months ahead.

The development of the report has taken place in several different stages:

a) Literature was reviewed which addresses the concept of carrying capacity in general as well as to territories that have specific physical, cultural, political, economic, and social dimensions. The carrying capacity concept was also examined in relation to the topic of sustainable development.

b) After having reviewed the literature, some conclusions were made. The main conclusion was that carrying capacity in the context of human systems is not a product but a discourse. Carrying capacity in this report can be defined as *a discourse on how to approach the various types of socially constructed carrying capacity constraints within the context of sustainability.*

c) A carrying capacity evaluation model was developed, based on the definition derived in the previous stage. The carrying capacity evaluation model presented in this report suggests a framework for a discourse on how to respond to future growth within a metropolitan region. The use of this model is advantageous for looking at the carrying capacity constraints from a long-term perspective and with respect to the ecological sustainability of a region. Also implicit in the model is the assumption that carrying capacity-related issues for a metropolitan region need to be inclusive of issues related to the larger bioregions in which metropolitan regions are embedded.

d) Information and data was gathered from Metro (land, transportation) and the City of Portland Bureau of Water Works. The Portland Energy Office provided information on energy.

e) The data furnished by Metro and Portland was applied to the carrying capacity evaluation model. The resources evaluated by the carrying capacity evaluation model are air, land, transportation system, water supply system and energy system.

f) The main conclusion made from analyzing the carrying capacity constraints for the Portland region is that critical decisions will need to made relating to air quality, the transportation system and the energy supply.

It needs to be underscored that the report is a preliminary investigation into carrying capacity related issues for the Portland Metropolitan Region. Further data collection and analysis will be needed. However it is hoped that this introductory investigation will frame a continuing discussion on carrying capacity related issues for the Portland region and larger bioregion.

CHAPTER 1: THE HISTORICAL DEFINITIONS OF THE CARRYING CAPACITY CONCEPT.

1. The carrying capacity concept

The carrying capacity concept as a formal concept has its origins in the disciplines of ecology and biology. Applied to non-human natural settings and described by the symbol **K** in the literature, the concept refers to the maximum population of a given species which a particular environment can support indefinitely (Catton, 1993).

The concept of carrying capacity, as used by ecologists and biologists, such as range scientists and wildlife managers, emphasizes the *interaction* between the population and its environment (Heady 1975). The basic function of population management is to avert environmental damage by intervening to prevent the population from exceeding the carrying capacity, which in turn prevents the reduction of carrying capacity. This relationship between overuse and environmental damage in wilderness settings as well as in human-managed ecosystems is the essence of the carrying capacity concept developed by ecologists and biologists. The main variable used in population management to determine the carrying capacity is the *food availability* in relation to the population studied.

Principles of the carrying capacity concept used in biological settings.

Three main rules or principles have emerged from the body of research on biological carrying capacity:

1. It is possible for a region to temporarily exceed its carrying capacity, which is called 'overshoot.'

2. A population can only exceed its carrying capacity by degrading its environment which results in diminished carrying capacity.

3. A renewable resource base cannot sustain a population indefinitely beyond its carrying capacity.

Overgrazing exemplifies these three carrying capacity principles. Overgrazing is an interactive process between animals and the environment where the carrying capacity has been exceeded (principle one) and this in turn has lowered the carrying capacity of the range area as plant cover decreases and soil erosion increases (principle two). The end result is a crash of the population (principle three). The most famous example of overgrazing and its consequences involves a case study , whereby 29 reindeer were introduced to St. Matthew Island in the Bering Sea in 1944. After expanding its population to 6,000 by the summer of 1963, the population crashed the following winter to fewer than 50 reindeer. The original carrying capacity was estimated to be about 2000 reindeer. According to a 1968 study of biologist David R. Klein, University of Alaska, the dominant reason for the population crash was due to overgrazing which had resulted in a lack of food supply (Klein, 1968).

2. The carrying capacity concept applied to human systems

> If ecologists were ever to ask to write a new Decalogue, their first Commandment would be: Thou shalt not transgress the carrying capacity (Hardin 1976).

Although the carrying capacity concept is recognized as one of the most important issues confronting humankind (Hawley, 1950; Hardin, 1986; Brown, 1994), opinions differ about the importance and validity of carrying capacity when applied to human systems. The reason for the reluctance to apply the bioscientific definition of carrying capacity to human systems, is that within human interactions with the environment, the carrying capacity concept is a more complicated process than measuring the amount of population in a given bioregion.

This complexity is due to the fact that the capacity to support humans is determined not just by the basic food requirements, but also by the various kinds of resources consumed, the many kinds of wastes generated and the great variability in technology, institutions and lifestyles created. When one applies the concept of carrying capacity to human beings it becomes a dynamic, context dependent and flexible concept as it varies with culture and degree of economic development. In contrast to animals, consumption by human beings is not fixed by biology. While animals consume not much else but their food, the bulk of human's material consumption consists of non-food items such as minerals, energy, forestry products, etc. For the average Canadian, the consumption measured in energy content adds up to over 200,000 kcal/day as opposed to the daily 3,000 kcal of food consumed. This means that the average North American who weighs less than a dolphin consumes more than an orca (Wackernagel, 1993).

Furthermore, the biological definition of carrying capacity implies that one user is essentially interchangeable with another, while within human systems, individual and cultural consumption levels can vary by many orders of magnitude. Differences in the per capita consumption of resources both within a particular society or among different societies competing for the same resource can easily differ from one social class to another or from one culture to another by ratios of 100 to 1 (Lenski and Lenski 1982).

Differences in consumption patterns and technological applications have a major impact on the carrying capacity, and make explicit the relationship between consumption patterns, technology and carrying capacity. Where in non-human systems population pressure contributes causally to degradation and depletion, in human systems degradation can arise under both *high* and *low* population densities and under both *poverty* and *affluence.* This implies that environmental damage within the human context is not simply due to *increased* numbers, but to the greater mobility of people, the intensity of their activities and the enhanced means in which they can inflict damage on the surrounding ecosystem in which they are embedded.

Another reason why the discussion around the importance and validity of carrying capacity when applied to human systems is complex and controversial is because the carrying capacity in human systems has two dimensions: an ecological *and* social dimension. The ecological dimension determines the ecological capacity, while the social dimension determines the socially acceptable ecological capacity. In the first, carrying capacity is determined by local and global ecological thresholds. In the second, the acceptable environmental quality of a region is a matter of subjective, perceptual and institutional judgment. Where the former is shaped by objective and scientific observations, the latter is grounded in individual and cultural values and assumptions.

Thus the discussion around carrying capacity within human systems involves a descriptive and an evaluative component, as well as the complex interactions between the two components--ecological constraints and cultural expectations and desires--, resulting in a socially determined carrying capacity or *social carrying capacity.*

ecological dimensions of the carrying capacity

The ecological dimensions of the carrying capacity are these factors that determine ecological thresholds, limits of the natural environment which constrain further growth. Ecological thresholds determine the limit at which human activity will lead to undesirable changes in the environment.

The most commonly accepted notion of ecological carrying capacity is that of an absolute physical limit that if exceeded creates irreversible ecological damage. There are different examples of absolute carrying capacity limits. The most basic example of an absolute carrying capacity limit is the earth's finite ability to produce food for an exponentially growing population.

Another absolute limit is the limit of impact or consumption of the human population. One measure of the impact of the global human population on the life support systems of the planet is the fraction of the terrestrial Net Primary Productivity (NPP) appropriated by human beings. Stanford ecologists (Vitousek et al.1986) estimated that recourse consumption or use by human activities already appropriates 40 percent of terrestrial Net Primary Production, the product of photosynthesis. Ecologists define the Net Primary Production (NPP) of the biosphere as the amount of energy captured from sunlight by green plants and fixed into living tissue. The NPP is the base of all food chains. Every other living thing eats plants, or eats some other creature that eats plants, or eats a creature that eats a creature that eats plants, and so on. The NPP is the energy flow that powers all nature. Humans consume *directly* only about 3% of the land-based NPP through food, animal feed, and firewood. *Indirectly* another 36% of NPP (on land) goes to crop wastes, forest burning and clearing, desert creation, and conversion of natural areas to settlements or cities. The calculation does not include reduction of primary production by pollution. Humans control about 40% of the NPP on land; humans may affect much more than that through pollution. There is much evidence that the current rate of appropriation is more than earth can sustain in the long run. If this appropriation increased at a constant growth rate of 1.7 percent per year (current world population growth), humankind would be appropriating all the products of photosynthesis within 54 years. Of course, a 100 percent appropriation rate could not be sustained because nature needs some "slack" to maintain essential life-support services. Ecologist Eugene Odum estimates that one third of the terrestrial ecosystems should be kept in wild configuration (Odum, 1971).

Another absolute limit is given by a study done by Bryson (1988). According to Bryson, there exist an absolute limit to the ability of the planet to provide sustainable energy for humans. He estimated that for an average level of human activity and using the sunlight efficiency, 0.22 acre of land is required to feed a person. Consequently, if all the farmland of the planet were used at the maximum allowed by the amount of sunlight falling on it, Earth could support 2.25 people per acre. There are currently about 1.2 persons per acre. But at the present rate of growth, the population of the planet will double in the next 40 years. If Bryson's calculations are correct, we will reach the sunlight limit in 35 years. Although science and technology may improve the storage efficiency of crops (assumed by Bryson to be four percent now) or increase the amount of edible biomass (assumed by Bryson to be about five percent now), in removing older constrains, it replaces them with newer ones. This fact points out that it is quite possible that humans who are alive today will witness a world where the sunlight limit will be reached.

The bottom line is that the laws of thermodynamics inevitably limit biophysical carrying capacity (Fremlin, 1964) if short-ages of inputs or ecological collapse do not intervene first.

These absolute limits all relate to a global level and are widely accepted as being real and absolute. More disputable types of carrying capacity limits are ecological limits which are influenced by the social dimensions of the carrying capacity, such as assumptions made regarding future technological innovations, perceptions of time and social values. Depending on changes in assumptions, the physical limits themselves are perceived to be pushed back. As thresholds shift depending upon social factors, it is argued that ecological thresholds become elusive to identify. Most of the ecological limits, relevant on a local level are influenced by the social dimensions of the carrying capacity.

social dimensions of the carrying capacity

The social dimensions of carrying capacity are factors or variables which determine and influence the *perception, importance* and *validity* of the ecological dimension of the carrying capacity. Social dimensions of carrying capacity include factors such as lifestyle aspirations, the disparity between private and social costs, the difficulty in formulating rational policy in the face of uncertainty, technological innovations, perceptions of time and social values, and various other features of human sociopolitical and economic organization.

One assumption which greatly influences the human perception of the importance and validity of the carrying capacity concept is the often unquestioned belief that social organization and technological innovations will steadily expand the functional ecological carrying capacity of the world. This belief in the ability of humans to increase their habitat's carrying capacity is known as 'cultural succession' (Boughey, 1975). As modern western humans imagine themselves to be set apart from other species and nature, there exists a strong belief that organization and technology can always be depended upon to increase the carrying capacity of the land for human kind in the future (Boughey 1975). In the past and at present, humans have expanded their local or global carrying capacity through mostly technology --resulting in resource substitution and increased efficiency-- and trade.

3. The interplay between the ecological and social dimensions of the carrying capacity: the social carrying capacity

The dynamic interplay between the ecological dimensions and social dimensions of the carrying capacity results in the creation of a socially determined carrying capacity or social carrying capacity: the carrying capacity determined and accepted by humans. The social carrying capacity is shaped by social factors, assumptions or variables which determine and influence the perception, importance and validity of the ecological dimension of the carrying capacity. The social carrying capacity is thus seen as flexible, dynamic and changeable, as it is conditioned by assumptions and cultural values. It is not fixed once and for all but depends on the conditions and context of human society at any specific time and place.

The historical evolution of the social carrying capacity applied in human systems can thus be seen as the interplay between ecological constraints and social expectations and assumptions which result in time- and place-dependent definitions of the social carrying capacity.

Because of the variation in social values and assumptions, the interaction between the ecological realities and social perceptions has not resulted in a single definition of social carrying capacity, but rather several contending definitions and theories which share a common base of ecological principles.

some historical definitions of the social carrying capacity

Historically, planning has been an effort to provide a desired array of 'quality-of-life' elements through physical, economic and social design of the human environment. Put differently, in planning, the question has been to design communities to be more humane, not how to redesign communities to be more "natural". In accomplishing this goal, planning has worked within the limits of what was technologically and economically feasible and what was socially, politically, and legally acceptable. Traditional planning processes did not examine the degree to which physical and functional plans are tied to ecological systems for resource supplies and for residuals assimilation. The driving force behind land use plans was the notion of accommodating projected increases in population and economic development. Demand dictated growth and land use planning was a servant of and facilitator for growth demand.

Ian McHarg (1969) was one of the first persons who departed from accepted land use planning in the early 1960's by trying to integrate the awareness of ecological constraints in urban development planning and management. Although his pioneering work, Design with Nature, does not explicitly refer to carrying capacity, it described projects to develop and apply land suitability methods and bringing applied ecological principles into land use planning. His major premise was that each location has an intrinsic suitability for certain types of land uses. Only those uses that do not interfere with the natural biological and physical processes of the area are suitable. McHarg therefore reversed the demand dictates growth equation, emphasizing the influence of the characteristics of the supply of environmental resources on the type and location of growth. Rather than a presumption in favor of development, his was a presumption for nature.

A second phase in integrating the carrying capacity into a comprehensive framework came from an array of urban ecologists. Holling and Goldberg (1971) using a systems approach suggested that the capacity of both ecological and urban systems is defined:

> not in terms of a fixed point, but as a domain of stability around a changing equilibrium point, which is constrained within upper and lower boundaries. Survival depends upon keeping the domain of stability, resilience, broad enough to absorb the consequences of change. These systems involve non-linear structural properties, due to lags, thresholds, and limits within their behavior. (Goldberg 1971)

Bishop et al (1974) developed another theoretical systems model and identified two main components of carrying capacity: **limiting factors**--environmental factors which physically or behaviorally limit growth; and **trigger factors**--factors which at a certain threshold set off a chain of events in ecological and urban environmental systems. Bishop and his colleagues defined carrying capacity as:

> ...the level of human activity (including population dynamics and economic activity) which a region can sustain (including consideration of import and export of resources and waste residuals) at acceptable 'quality of life' levels in perpetuity. (Bishop et al, 1974)

Godschalk has been a major proponent of integrating the carrying capacity concept within urban development planning. He identifies three types of capacity:

1. Environmental: the limit at which human activity will lead to undesirable changes in the environment.
2. Perceptual: the amount of activity or degree of change that can occur before we perceive the environment to be different than before.
3. Institutional: the ability of organizations in an area to guide development toward public goals. (Godschalk and Parker, 1975)

He further defines the process of analyzing the carrying capacity within urban settings

> ... as the study of the effects of growth rate, amount, type, location, and/or quality of the natural environment in order to identify critical thresholds beyond which public health, safety, or welfare will be threatened by serious environmental problems unless changes are made in public investment, governmental regulation, or human behavior. (Godschalk and Axler, 1977)

The key factors in this definition, according to Godschalk, are:

1. Concern for the impact of urban development on the environment which provides a focus on the growth management aspects of carrying capacity and visualizes protection of the supply of environmental resources as an important limit on urbanization, as compared with the traditional view of environmental elements as factors to be consumed in development.

2. Analysis of the various elements of the environment, such as air, water, and soil, as a linked system that affects public health, safety, or welfare through the services it supplies, including assimilation of wastes, provision of resources, etc.

3. Identification of critical thresholds, or upper limits of tolerance for various elements, beyond which continuation of development under present conditions is expected to cause environmental problems, as a way of isolating public decision points and defining potential governmental responses.

4. Recognition of governmental ability and responsibility to affect carrying capacity through public actions, such as investment on community facilities, enforcement of protective development regulations, or campaigns to influence public attitudes or behavior. (Godschalk and Axler, 1977)

4. Conclusion

Defining the carrying capacity concept in human systems as *social carrying capacity* underscores the awareness that deciding the limits of acceptable change is the key to determining the ecological carrying capacity (Frissell and Stankey, 1972). It stresses that capacity determination requires specific social judgements about levels of impact. Social carrying capacity evaluates the level of impact that is tolerable (the maximum) or most desirable (the optimum). The social carrying capacity determines how much is too much.

The interpretations of the social carrying capacity outlined above all stress the importance of ecological constraints, but argue that social factors prevent the carrying capacity from having any absolute value in human systems. They argue that the complexity of interactions between resources and socio-economic factors, between biophysical and social constraints, make it difficult to allow firm calculations of the social carrying capacity. Although there is some truth in this claim, none of the approaches outlined above have addressed the social carrying capacity within the context of ecological sustainability.

In order for the concept of carrying capacity to have any meaning when applied to human systems, it has been argued that the concept needs to be applied and understood within the context of sustainability (Catton 1992, Daly 1989, Brown, 1994). These authors argue that the main reason why the social carrying capacity has been an ambivalent concept is because the time factor in the bioscientific definition--for an indefinite period--has been ignored. The next chapter will investigate the social carrying capacity within the context of sustainability.

CHAPTER 2: THE SOCIAL CARRYING CAPACITY IN THE CONTEXT OF SUSTAINABILITY: THE SUSTAINABLE CARRYING CAPACITY

> As a result of our population size, consumption patterns, and technology choices, we have surpassed the planet's carrying capacity. This is plainly evident by the extent to which we are damaging and depleting natural capital. The earth's environmental assets are now insufficient to sustain both our present patterns of economic activity and the life-support systems we depend on.
>
> Postel (1994)

introduction

Although human ingenuity has enabled dramatic increases in the biophysical carrying capacities for human beings, and potential exist for further increases, from a long-term perspective, these increases are unsustainable. The current population of 5.6 billion is being maintained only through the exhaustion and dispersion of a one-time inheritance of natural capital (Ehrlich and Ehrlich 1990), including topsoil, groundwater, and biodiversity. The rapid depletion of these essential resources, coupled with a worldwide degradation of land (Jacobs 1991, Myers 1984, Postel 1989) and atmospheric quality (Jones and Wigley 1989, Schneider 1990) indicate that human beings have exceeded the carrying capacity. They have not only exceeded its current carrying capacity, but they are also reducing future potential biophysical carrying capacities by depleting essential natural capital stocks.

Studies have shown the complex results of what happens when the carrying capacity is exceeded and overshoot happens (Meadows et.al 1992). When human loads exceed carrying capacity, ecosystems are stressed. Ecological stresses translate into economic problems. These, in turn, produce social stresses such as hunger, demoralization, forced migration, higher infant mortality, and reduced life expectancy (Brown 1981) or sharpened group conflict, sometimes leading to repressive government (Milbrath 1989). Within this context, the relevance of the concept of carrying capacity does not stay within the physical sciences, but becomes of interest for social and political scientists (Burch 1971; Boulding 1978; Dunlap 1980; Humphrey and Buttel 1982; Campbell 1985; Milbrath 1989).

It has been argued that it is essential to apply and understand the carrying capacity concept within the context of sustainability (Catton 1993, Brown 1994).

These authors claim that the carrying capacity concept has been mis-interpreted as the largest number of persons that a given area can carry *at a given time*. By opting for the temporary version of carrying capacity, leaving out the very heart of the bioscientific definition *for an indefinite period*, the concept becomes meaningless, especially in the context of sustainability.

The long-term aspect of sustainability is central to the widely cited definition of sustainable development from the 1987 report by the World Commission on Environment and Development, Our Common Future: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Unfortunately, this definition is so general that it can be met via several mutually exclusive strategies, creating a real danger that sustainability as a goal will lose its credibility. It is for that reason that several authors argue that within the discourse of sustainability, the attributes of the environment are of prime concern. Physical sustainability is seen as a prerequisite to social or economic sustainability. This suggests the adoption of a hierarchy built on sustaining the integrity of the natural environment. As James Baines puts it,

> There is a need to accept that ecological sustainability is an underlying principle for sustainable resource use and waste management, which is, in turn, the basis for a sustainable society (Baines, 1989).

1. Sustainable Carrying Capacity

When framing the carrying capacity concept within a sustainable context, the social carrying capacity becomes a more radical term, not so much shaped by what people want, but rather by what the natural world can provide. The social carrying capacity grounded within a sustainable framework can properly be called "sustainable carrying capacity." The most important consequence of framing the social carrying capacity concept within a sustainable context, e.g. sustainable carrying capacity, is that the limiting variable is not a limit of population, but a limit of *throughput*.

Throughput can be defined as

> The flow of energy and/or material from the original sources, through a system (where it may be transformed), and out to the ultimate sinks. (Meadows et.al 1992)

The level of throughput is defined by the economic subsystem: the human population, manufactured capital, the structural relationships between human beings, institutions and the natural world, the given technology and the type of social organization.

The limit of throughput is defined by the state of the planetary sources and of the planetary sinks, the state of the natural support system, including all the components of the ecosphere, and the structural relationships among the components of the ecosphere.

According to the First Law of Thermodynamics, matter and energy cannot be created nor destroyed. Therefore, production inputs must be taken from the environment, which leads to depletion; and, an equal amount of matter and energy in the form of waste must be returned to the environment, leading to pollution. Hence, lower rates of throughput lead to less depletion and pollution, high rates to more. According to Herman Daly (1980), a main proponent of sustainable practices, the definite limit to the size of maintaining flows of matter and energy is set by *ecological thresholds which, if exceeded, cause a breakdown of the system.*

When these limits or ecological thresholds are exceeded, *the sustainable yield of biological systems* is also exceeded and humans start to consume the productive resource base itself, engaging of what Lester Brown calls the biological equivalent of deficit financing (Brown 1981). It is important to stress that these *limits of throughput* are ultimately **limits to the rates at which things can happen**, not to the amount that can happen. (Meadows et al., 1992). Sources and sinks from a long term perspective are not things, like buckets that can be refilled and emptied, but processes. They are buckets that are being continually refilled or emptied by nature at varying rates. Sources and sinks have limits to systems, but these ecological thresholds are ultimately limits to rates at which things happen, not to the amount that can happen.

Ecological threshold, limits of throughput and sustainable yield are therefore three ways of expressing the sustainable carrying capacity concept. William Catton (1993) suggests three variations of describing the sustainable carrying capacity. The first one addresses the limit of throughput:

> For any use of any environment there is a use-intensity that cannot be exceeded without reducing that environment's future suitability for that use (Catton, 1993).

The second, more general and explicitly time-dependent definition of sustainable carrying capacity is:

> Carrying capacity is the maximum use of a given kind that a particular environment can endure year after year without losing its suitability for that use. (Catton, 1993)

A third variation of the sustainable carrying capacity concept takes into account the inter-individual or inter-cultural differences, and is defined as

> Human-carrying capacity is the maximum population equipped with a given technology and a given type of social organization that a particular environment can support indefinitely (Catton, 1993).

All three of these variations stress the maximum sustainable load a human population can impose on a supporting ecosystem and involves the dimension of population, technology and organization. Second, they emphasize that what matters is the impact an environment can endure indefinitely, not just for a short period in which depletion and pollution have not yet made the environment unsupportive. And third they make explicit the importance of ecological thresholds.

The same three principles apply for the sustainable carrying capacity as the principles emerged from the body of research on biological carrying capacity:

1. It is possible for a region to temporarily exceed its sustainable carrying capacity.

2. A human population can only exceed its sustainable carrying capacity, by degrading its environment, which results in a diminished sustainable carrying capacity.

3. A renewable and non-renewable resource base cannot sustain a human population indefinitely beyond its sustainable carrying capacity.

It is important to underscore the fact that the sustainable carrying capacity is not an impenetrable ceiling. There can be temporary increases of population or of impact beyond sustainable carrying capacity limits if the human system subsists on capital rather than income. Examples of relying on natural capital instead of income are overfishing fisheries, overgrazing pastures, relying on the use of nonrenewable resources, and using renewable resources faster than their rates of renewal. A population is at a level below its sustainable carrying capacity when it is living of the "interest", not irreversibly damaging its environment, and can sustain this level indefinitely. At any level above the sustainable carrying capacity, however, it must depend upon reserves or "principal" of its environment, thus causing deterioration and a lower sustainable carrying capacity (Wisniewski, 1980).

Sustainable carrying capacity says that to secure ecological sustainability of human society, each generation should inherit at least an adequate stock of essential biophysical resources independent of the amount of human-made goods they receive (Rees and Wackernagel, 1993). Simply put, staying within the sustainable carrying capacity requires the preservation of nature's productivity. The sustainable carrying capacity concept shows that there are indeed limits to economic growth and urban growth insofar as the use of material resources from the environment and the ability to dispose of wastes are concerned. And these limits are limits of throughput, not limits of population only.

2. Examples of operationalizing the sustainable carrying capacity

Examples of operationalizing the sustainable carrying capacity can be divided into two groups. The first group represents the limits of throughput, while the second group represents the level of throughput.

a. operationalizing limits of throughput

A first example of operationalizing the sustainable carrying capacity can be found in the work of Howard Odum, an ecologist whose theories focus on the flows of energy in natural and manmade systems (Odum, Brown, Costanza, 1976). Odum sees energy availability as the ultimate limiting factor on development, and determines an area's carrying capacity by the combination of local natural energy resources (sunlight, water, soil, and nutrients) and energy imported and released by humans (fuels, materials, soil, and services). He evaluates the relative economic positions of regions through an index called the "Investment Ratio", which is the ratio of (high quality) fossil fuel energy support to the (low quality) free resident energy of a region. Comparing a region's investment ratio with the national investment ratio gives the competitive position of the region. A lower ratio indicates more natural energy "subsidies", and hence a better economic position.

Odum's energy-based regional planning approach requires mapping all the components (from swamps to business districts), energy sources (from sun and rain to government payrolls), and process interactions (from plant productivity to economic transactions) of a regional system. His energy diagrams are complex representations of the stocks and flows of regional energy. According to Odum:

> Planning has sometimes been regarded as the process of choosing what people want. However, the energetic view regards planning as the process of finding the pattern of humans and nature that is competitive, energetically sound, economically vital, and achieved with the least energy waste. The energy view sees relatively few choices as possible. Plans that are not energetically sound ultimately fail and are replaced with energy patterns whose trends are more competitive. (Odum, Brown, Costanza, 1976)

A variation of Odum's energetic approach is suggested by Thayer (1994). He argues that sustainable landscapes (human systems which respect the sustainable carrying capacity) use horizontal, renewable energy, and are necessarily limited by the rates and locations at which horizontal energy can be regenerated. Horizontal energy is the amount of useful solar energy, falling upon the surface of the earth at any given time. Vertical energy is energy that has been stored for billions of years, such as coal and oil. Horizontal energy is "contemporary" energy or energy in the "here and now". Living within the sustainable carrying capacity is here thus seen as increasing the ratio between horizontal and vertical energy.[1]

Another approach towards a sustainable carrying capacity concept has been suggested by Wisniewski (1980). He has developed an equation which reflects that a population can only stay within the limits of a sustainable carrying capacity when supply on a sustainable basis (instead of total stock, including principal) regulates demand. Derived from range management literature, his equation tells us that demand for a resource can no more than temporarily exceed recurrent supply. In the long run, demand must be equal to or less than supply. Letting P=population; Rt=renewal rate of limiting resource (amount produced in time interval t) and Dt=demand per capita (during interval t) for limiting resource, he has created the following equation:

$$P.Dt = \backslash< Rt$$

Rt only takes on large positive values of t is a very long time span. On the demand side of the equation, however, P.Dt can become very large even when t represents a short time span, either because P may become excessive or because

[1]The dysfunctional relationship between horizontal and vertical energy consumption is well demonstrated by the following statistic: every day the worldwide economy burns an amount of energy the planet required 10,000 days to create. Or, put another way, 27 years worth of stored solar energy is burned and released by utilities, cars, houses, factories, and farms every 24 hours. (source: Paul Hawken: The Ecology of Commerce: A declaration of Sustainability, 1993)

per capita appetites may be increased. This equation stresses the importance of using sustainable yields as an information source which keeps the system within the boundaries of the sustainable carrying capacity.

A final example of operationalizing the limits of throughput has been advocated by Herman Daly (1989). He introduced the concept of Total Natural Capital (TNC) as the sum of the Renewable Natural Capital with the Non-Renewable capital (TNT = RNC + NNC). Throughput is here the consumption of TNC and reflects the scale of consumption of total natural resources. Natural capital is a stock that yields a flow of valuable goods and services into the future. What is important is the relation of a stock yielding a flow. Stocks are processes which provide a flow or annual yield that can be sustained year after year. Natural capital may also provide services such as recycling waste materials, or water catchment and erosion control, which are also counted as natural income. Since the flow of services from ecosystems requires that they function as whole systems, the structure and diversity of the system is seen as an important component of natural capital.

Accepting that the constancy of total natural capital (TNC) is the key idea in sustainability, Daly (1989) suggests three ways to realize the sustainable limits of throughput and therefore staying within the carrying capacity:

* for a renewable resource--soil, water, forest, fish--the sustainable rate of use can be no greater than the rate of regeneration.

* for a nonrenewable resource--fossil fuel, high-grade mineral ore, fossil groundwater--the sustainable rate of use can be no greater than the rate at which a renewable resource, used sustainable, can be substituted for it.

* for a pollutant, the sustainable rate of emission can be no greater than the rate at which that pollutant can be recycled, absorbed, or rendered harmless by the environment.

b. operationalizing levels of throughput

The Task Force on Healthy Planning and Sustainable Communities at the University of British Columbia has proposed a way to operationalize the sustainable carrying capacity concept by measuring the level of throughput which flows through the economic system. Called the "ecological footprint" of the economy on the earth, this ecological impact indicator uses land-area as its biophysical measurement unit (Rees and Wackernagel, 1993). It is reasoned that every major category of consumption or waste discharge requires the productive or absorptive capacity of a finite area of land or water. Adding up the land requirement of all these categories gives an aggregate or total area, ecological footprint, of the economy on the earth. This area represents the carrying capacity *appropriated* by the economy from the total flow of goods and services provided by the ecosphere. The ecological footprint is also referred to as "the appropriated carrying capacity" of the economy (Rees and Wackernagel, 1993).

Simply put, the Appropriated Carrying Capacity (ACC) measures the land that would be required at present on this planet to support the current lifestyle indefinitely. Rees and Wackernagel have calculated that the average North American's land appropriation has grown to approximately 5 hectares of land for resource production alone. They also estimated that the Lower Fraser Valley--the Vancouver, B.C. region-- appropriates 21 times more land than the area contained within its geographic boundaries. By comparison, the Netherlands, with a similar population density, appropriates approximately 15 times more land.[2]

Paul Ehrlich (1990) has suggested another way to operationalize the level of throughput by measuring the impact of the human interaction with the environment. He proposes that an impact(I) of any population can be expressed as a product of three characteristics: the population's size (P), its affluence or per-capita consumption (A), and the environmental damage(T) inflicted by the technology used to supply each unit of consumption. Affluence (A) is defined as capital stock per person--the number of television sets or cars-- per person. The impact or throughput due to affluence consists of the material flows needed to <u>maintain</u> each form of capital. The impact of technology on throughput is defined as the energy needed to make and deliver each material flow, multiplied by the environmental impact per unit of energy. Using the IPAT formula, each habitant of the rich countries does roughly 7.5 times more damage to earth's life-support systems than does and habitant of poor nations. Extremes ratio between the poorest nation and an average citizen of the U.S. is one-thirtieth (Holdren 1991).

Measuring the throughput of any population, nation or region by the ACC indicator and IPAT formula underscores the importance of affluence, standard of living and lifestyle in carrying capacity-related issues.

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[2] The ecological footprints of average citizens in rich countries are estimated to exceed the average personal planetoids by a factor three. This means, that if everybody on Earth lived like today's North Americans, it would require three Earths to provide all the resources (Rees and Wackernagel, 1993).

3. Investigating the social dimensions within a sustainable context

When approaching the carrying capacity within a sustainable context--bringing in the time factor, energy limits, throughput limits, and concepts such as the ecological footprint--, the assumptions regarding our belief in pushing upward the ecological carrying capacity are seen within a different perspective.

While the approaches in the previous chapter suggest that the carrying capacity can be increased at will through further investment in technology, Odum's energy-related analysis states that there is a threshold beyond which the excessive use of imported fossil fuel energy involved in applying further technology may be self-defeating. The critical measure is "net energy"--the useful energy left from an energy source after the energy costs of exploration, extraction, production, and transportation are subtracted (Odum et al., 1975). It takes energy to get energy, and the less an area depends on its resident natural energy, the more expensive and less competitive its development becomes. At some point, further investment in technology to increase carrying capacity may change from a solution to a problem.

Framed within a sustainable context, the faith and preoccupation with technology as a way to increase the carrying capacity has ignored the fact that many of these increases have been temporary ones achieved by degrading or "overgrazing" the environment and by mining accumulated resources of the ecosystem. Further, increases in human's habitat's carrying capacity have been realized at the expense of displacing nonhuman biomass with human and domesticated (dogs, cows, etc.) biomass, therefore reducing the carrying capacity and biomass of competing species population with the result of bringing many native species to the brink of extinction.

In the present global economy, regions are not isolated. In an increasingly interdependent world, people consume resources from all over the world. Trade can expand the local carrying capacity by exchanging resources that are locally plentiful for those that are locally scarce. Trade can also increase global biophysical carrying capacity by lifting regional constraints arising from the naturally heterogeneous distribution of resources and through the increased efficiency that results from regional specialization in the production of goods. Economists therefore regard trade flows as one way to overcome the constraints on regional carrying capacity imposed by local shortages and to increase the global carrying capacity. However, exceeding local and regional carrying capacities on a sustainable basis through trade encourages the "Netherlands fallacy": the idea that *all* regions could simultaneously sustain populations that sum to more than global carrying capacity (Ehrlich and Holdren, 1971). Further, completely unregulated international trade could reduce the sustainable carrying capacity by tending to diminish international diversity, thereby increasing the vulnerability of nations to disasters in other regions and limiting their ability to learn lessons from their own successes and failures (Culbertson, 1991).

Importing from a resource base of the past (by exploiting non-renewable resources), from the present (by exploiting other regions unsustainable, therefore diminishing *their* carrying capacity) and of the future (exploiting renewable resources beyond the sustainable yield, therefore diminishing the future carrying capacity) is what Catton (1980) calls being dependent on a *phantom carrying capacity*. So, within a sustainable framework, what traditionally has been perceived as an expansion of the carrying capacity, in reality is a overshooting the sustainable carrying capacity by living on phantom carrying capacity.

4. Implications of defining the carrying capacity concept within the context of sustainability

Implied in defining the carrying capacity from a long-term perspective is the need to fit human activities into nature's patterns. In order to embrace the concept, it is imperative to let go of the assumption that the environment exists solely to gratify human desires, with no intrinsic value left for nature. Another tenet of the sustainable carrying capacity concept is the conviction that it is both morally and economically wrong to treat the world as a business in liquidation (Daly, 1989).

Ultimately, the prime issue to be addressed from a sustainable carrying capacity perspective is the *throughput of matter-energy across the environment-economy-environment boundaries*. From this perspective, thinking about sustainable carrying capacity is predominantly a matter of scale, the quantity of matter and energy processed by an economy. Furthermore, sustainable carrying capacity-based policies are policies which develop a political-economic context which address the scale of throughput.

Addressing the scale of throughput means addressing issues related to affluence, standard of living and lifestyle. It also means investigating growth vs. no-growth issues. Managing the scale of throughput also means having to face the issue of fair distribution. As long as the total pie is growing, absolute but not relative wealth can be increased. If growth stops for any reason, the questions of distribution and high standard of living become acute.

As Daly (1989) argues, it is extremely important to clearly distinguish between sustainable development and sustainable growth. The first is concerned with quality, the second with quantity. Sustainable development is a qualitative change without a change in throughput of energy and matter, while sustainable growth is an uncritical pursuit of growth, which ignores the fact that the size of the throughput is the principal cause of environmental damage and collapse. In short, Daly (1989) sees sustainable development as a process of directed change which stays within the sustainable carrying capacity of the region.

5. Conclusion

In the first chapter, it was explained that the dynamic interplay between the ecological dimensions and social dimensions of the carrying capacity results in the creation of a socially determined carrying capacity, the social carrying capacity. This social carrying capacity is shaped by social factors, assumptions or variables which determine and influence the perception, importance and validity of the ecological dimension of the carrying capacity.

This chapter integrated the social carrying capacity within a sustainable perspective, resulting in a new interpretation of the social carrying capacity: sustainable carrying capacity.

Based on the presented information, it must be clear that complex interactions are involved in defining carrying capacity limits when applied to human systems. Two insights are pivotal for the carrying capacity to have any meaning in the context of human systems.

First, it is essential to understand that the carrying capacity concept is not a *product*, but a *discourse*[3]. It is a discourse on a set of ecological and social thresholds, desired levels of consumption of goods and services by a society and their interaction. Important components of this discourse is on the one hand identifying the different ecological and social constraints, on the other hand investigate their interactions with one another.

Second, all carrying capacity related limits or constraints can be seen as social carrying capacity constraints. Although they arise through an interaction with the natural world, they are ultimately *socially constructed* by the human community. It is important to underscore that this does not mean that the natural limits are not real. As was mentioned in this chapter, socially constructed constraints within a sustainable context do reflect actual limits out there and are therefore absolute. It simply underscores the epistemological assumption that just as our understanding of nature is socially constructed, so are the perceptions of the different constraints of nature.

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[3] A discourse can be defined as a process inclusive of social, ethical and political dialogues, scientific research and policy implementation.

Grounded in these two essential observations, the next chapter will present a carrying capacity evaluation model, which, in the final chapter, will be applied to the Portland Metropolitan Region.

CHAPTER 3: A CARRYING CAPACITY EVALUATION MODEL FOR A METROPOLITAN REGION.

> Issues of sustainability are ultimately issues about limits. If economic growth is sustainable indefinitely by technology, then all environmental problems can (by theory at least) be fixed technologically. Issues of equity and distribution (between subgroups and generations of our species and between our species and others) are also issues of limits. We do not have to worry so much about how an expanding pie is divided, but a constant or shrinking pie presents real problems. Finally, dealing with uncertainty about limits is the fundamental issue. If we are unsure about future limits the prudent course is to assume they exist. One does not run blindly through a dark landscape that may contain crevasses. One assumes they are there and goes gingerly with eyes wide open, at least until one can see a little better.
>
> Robert Costanza (1989)

introduction

This chapter presents a carrying capacity evaluation model for a metropolitan region in an effort to encourage an on-going discourse around carrying capacity related issues; facilitate a clearer understanding of carrying capacity-related issues relevant to a metropolitan region; and evaluate the likelihood of carrying capacity constraints for different key resources (such as air, water, land, transportation, energy) in a metropolitan region.

Two points need to be made relating to the carrying capacity evaluation model. First, as was concluded in the last chapter, carrying capacity is not a product, but a discourse. The conclusion was also made that carrying capacity constraints in human systems are socially constructed. The carrying capacity evaluation model outlined below defines carrying capacity as *a discourse on how to approach the various types of socially constructed, multi-leveled, carrying capacity constraints within the context of sustainability.* This implies that sustainability too is not a *goal*, but a *discourse* on what kind of limits we are willing to accept.

Second, the carrying capacity evaluation model addresses carrying capacity related issues from a bioregional perspective. Carrying capacity for a metropolitan region is an ambivalent term. The very nature of metropolitan regions is that they are entities which have violated Hardin's maxim: thou shall not exceed the carrying capacity of the environment. They have exceeded the local carrying capacity because they require enormous concentrations of food, water, and materials in a small area, concentrations far beyond the local carrying capacity can provide. And in turn, as these resources are consumed, they generate enormous quantities of garbage and sewage which cannot be properly assimilated within the local carrying capacity. Metropolitan regions extend thus far beyond municipal boundaries. Their survival depend on the carrying capacity of the surrounding countryside or hinterland. Aquifers, waterways, wetlands, farmlands and forests are all essential to an urban region's survival.

Because the metropolitan region has already exceeded the local ecological carrying capacity and because of its dependence on areas outside of its urban growth boundary, the boundaries of a metropolitan area relevant for carrying capacity related issues are better defined by the *bioregion* in which the metropolitan area is located. A bioregion is a distinct area with coherent and interconnected human, plant and animal communities, and is defined by a watershed or a set of inter-linking watersheds. The Portland Metropolitan Region for example is part of several Cascadian bioregions, such as the Columbia bioregion and the Willamette bioregion.

Addressing carrying capacity issues from a bioregional perspective addresses the dual nature of the metropolitan area. It deals with constraints relevant to the region as a self-contained entity within its Urban Growth Boundaries, as well as constraints related to the region as a sub-system embedded within the bioregion (constraints on watersheds, native species, etc.) and larger biosphere (CO2 emissions, green house effect).

1. THE CARRYING CAPACITY EVALUATION MODEL.

The carrying capacity evaluation model presented is comprised of six capacity levels. A capacity level is defined as a realm of potential and actual constraints which direct, limit and shape the growth of a metropolitan region: The six capacity levels are:

1. **Infrastructural capacity level:** constraints of infrastructures, which determine the flow of resources through the metropolitan region.

2. **Institutional capacity level:** constraints of politically or legally enforced threshold standards with are enforced within the metropolitan region.

3. **Perceptual capacity level:** constraints of socially determined unacceptable changes in the metropolitan region.

4. **Environmental capacity level:** constraints at which environmental sources and sinks are diminishing the quality of the environment of the metropolitan region.

5. **Sustainable capacity level:** constraints of natural and social systems, which when exceeded, will threaten the ecological and social sustainability of the metropolitan region.

6. **Biocentric capacity level:** constraints of the bioregion, which when exceeded, threaten the integrity, stability and beauty of the biotic community of the metropolitan region.

The carrying capacity evaluation model can be represented by the following table.

TABLE 1: CARRYING CAPACITY LEVELS

	CAPACITY LEVEL	EVALUATED RESOURCE
LEVEL ONE	INFRASTRUCTURAL CAPACITY LEVEL	
LEVEL TWO	INSTITUTIONAL CAPACITY LEVEL	
LEVEL THREE	PERCEPTUAL CAPACITY LEVEL	
LEVEL FOUR	ENVIRONMENTAL CAPACITY LEVEL	
LEVEL FIVE	SUSTAINABLE CAPACITY LEVEL	
LEVEL SIX	BIOCENTRIC CAPACITY LEVEL	

Each evaluated resource 'enters' the model at the first level and is evaluated at each subsequent level. At each level potential constraints are possible, depending on the type of resource and the interaction with constraints of other resources.

2. DESCRIPTION OF THE SIX LEVELS OF THE CARRYING CAPACITY EVALUATION MODEL

1. INFRASTRUCTURAL CAPACITY LEVEL

Capacities at this level are constraints related to infrastructures, which determine the flow of resources through the metropolitan region. Examples of relevant infrastructures include the water supply system, sewage treatment system, transportation highway system, public transportation system, waste disposal system, stormwater control system. This level of constraint can be crossed through infrastructural capacity improvement or expansion.

2. INSTITUTIONAL CAPACITY LEVEL

Capacities at this level are constraints of politically or legally enforced threshold standards of the metropolitan region. They include zoning regulations, building permits, land use ordinances, as well as EPA imposed air quality and water quality standards and protection acts such as the Endangered Species Act.

3. PERCEPTUAL CAPACITY LEVEL

Capacities at this level are specific constraints, which when exceeded will create perceived unacceptable changes in the metropolitan region. Perceptual constraints are constraints which are shaped by the values and icons of the metropolitan region. Perceptual constraints reflect the perceptions of what the human community, individually *and* collectively, feels and thinks is valuable.

4. ENVIRONMENTAL CAPACITY LEVEL

Capacities at this level are constraints of environmental sources and sinks which, when exceeded will lead to undesirable changes in the natural environment of the metropolitan region. Constraints at this level are shaped by the trade-offs between desired production, consumption and resource use levels on the one hand, and desired expectations for a clean and pleasant environment on the other hand. At this level, short term socio-economic benefits outweigh long-term environmental costs.

5. SUSTAINABLE CAPACITY LEVEL

Capacities at this level are constraints of natural and social systems, which exceeded, will threaten the ecological and social sustainability of the metropolitan region. The constraints at this level are the limits of throughput, the flow of resources (energy and matter) from the original sources, through the metropolitan region and out to the ultimate sinks.

The constraints of this level--limits of throughput--are long-term absolute constraints and can not be expanded. The sustainable capacity constraints are determined by the state of the planetary sources and of the planetary sinks, the state of the natural support system, including all the components of the ecosphere, and the structural relationships among the components of the ecosphere. Sustainable capacity constraints are constraints of **the rates at which things can happen, not to the amount that can happen.** When sustainable constraints are exceeded, *the sustainable yield of biological systems* is also exceeded and the metropolitan region starts to consume the productive resource base itself, therefore threatening the ecological and social long-term sustainability of the bioregion.

6. BIOCENTRIC CAPACITY LEVEL:

> A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community; it is wrong when it tends otherwise.
>
> Aldo Leopold. A Sand County Almanac (1949)

Biocentric capacities are constraints which when exceeded, threaten the integrity, stability and beauty of the biotic community of the metropolitan region. This level radically breaks with the other levels in the way that it looks at the natural world from a different perspective. The previous levels operate from the perspective of resourcism, the idea that the natural world has value for human purposes-only (a re-source is a source of the natural world re-directed for human use). The natural world is thus transformed and measured in terms of resources for human consumption. The biocentric capacity level are constraints of an ethical nature. The ethic is grounded in the belief that the well-being and flourishing of human and nonhuman life have value in themselves, i.g. intrinsic value, inherent value. These values are seen as independent of the usefulness for human purposes. A biocentric viewpoint sees the human species as one among billions of other life forms on the planet.

Biocentric constraints are also shaped by the belief that the current economic industrial system is inherently anti-ecological. As industrialism is based on the growth of capital and necessarily promotes consumerism as part of this growth, the system is perceived as being inherently unsustainable.

In short, constraints at the sustainable and biocentric level reflect the following commitments:

a. to facilitate directed change with the least amount of increase of throughput of energy and matter.

b. to use more primarily renewable, horizontal energy at rates which can be regenerated without ecological destabilization.

c. to maximizes the recycling of resources, nutrients, and byproducts and produce minimum "waste," or conversion of materials to unusable locations or forms.

d. to maintain local structure and function, and not reduce the diversity or stability of surrounding ecosystems.

e. to preserve and serve the local human communities rather than change or destroy them.

f. to preserve and serve the local and surrounding non-human community rather than change or destroy them.

g. to enhances the quality of life.

h. to increase intra-generational, as well as inter-generational equity.

3. THE ROLE OF VALUES IN THE EVALUATION OF CARRYING CAPACITY CONSTRAINTS IN A METROPOLITAN REGION.

It is important to underscore that value judgments enter into virtually every level of the evaluation process relating to carrying capacity. Cultural values are not the same as goals, tastes, desires, needs, or attitudes. Values are criteria or evaluative standards for judgement provided by culture. Values and value systems are embedded within tradition and culture. Culture can be understood as the shared patterns that set the tone, character, and quality of peoples lives (Bowers, 1992). Because they are deeply embedded in culture, values influence our behavior and the way we think and feel about the world mostly on an unconscious level.

Values operate in the perception and determination of needs as well as in the production and distribution of wealth. Values determine what standard of living and what distribution of wealth is acceptable. Values also influence the decision making process relating to carrying capacity. Choices which need to be made, reflect assumptions and goals that are, at the root, of an ethical nature.

> Value systems and ethics, far from being peripheral, are the dominant driving variables in all economic and technological systems. (Henderson, 1991)

Values also determine the evaluation process of carrying capacity constraints at the different levels of the carrying capacity evaluation model. Where level three incorporates a wide range of values, level four to six are each embedded in a distinct type of values. The values in each of these three levels reflect a different relationship towards the natural world. At level four, the environmental constraints need to be respected but ultimately outweigh human desires and expectations; at level five, absolute sustainable constraints are seen as the primary force in directing urban change; and at level six, ethical constraints limit any further physical growth of a metropolitan region.

4. RESISTANCES INHERENT IN A CARRYING CAPACITY EVALUATION MODEL

> Systems strongly resist changes in their information flows, most especially in their rules and goals.
>
> Meadows et. al (1992)

Constraints are pieces of information. Constraints inform us of the likelihood of limits. When these limits prevent the system from continuing its course, resistances arise. It is likely that psychological, economic and social resistances arise when using a carrying capacity evaluation model which incorporates sustainable and biocentric capacity constraints. The main reason for the emergence of resistances at these levels is the call for change inherent in the constraints at these levels. As these changes need personal and institutional commitment, several resistances, denial and institutional barriers are inevitable.

a) Trade-offs

A major challenge which complicates the evaluation process is the inherent emergence of trade-offs, differences between "real", ecologically or socially determined, and "desired" carrying capacities. Trade-offs are a central dynamic of a carrying capacity-based identification process. They are inevitable in any process which creates a tension between institutional, community or individual efforts to increase environmental quality and a degree to which that society desires to utilize the productive and assimilative capabilities of the natural environment.

There are some fundamental trade-offs inherent in dealing with constraints at a sustainable and biocentric capacity level. These trade-offs include economic trade-offs, such as getting away from the obsession with economic growth and buying power as the prime indicator for well-being; structural trade-offs, such as letting go of the sole dependence on the automobile; and long term versus short term benefits/costs in general.

b) social traps

Another social dynamic which is responsible for the resistance to face constraints at level five and six is our entrapment in social traps--situations, in which the immediate economic and social incentives are inconsistent with the long-run, global or local interest of both the individual and society (Orr 1992, Constanza 1987). The social traps are very much a result of the structure of our current socio-economic system, where inherent conflicts between shorter-term economic and social goals and longer-term ecological sustainability exist.

One of the most pervasive causes of social traps, therefore one of the most pervasive causes which prevent us from facing up to sustainable and biocentric constraints, is the natural human tendency to discount costs that appear remote, either in time or space. Discounting is done routinely in the context of cost/benefit analysis. Although in principle discounting is valid, within a sustainable context it is problematic. First estimates of future costs are uncertain, and there is both subjectivity and uncertainty in the selection of an appropriate discount rate. And when essential resources are involved, the gamble is with future carrying capacity. The very process of discounting encourages underestimating the importance of future costs and defers their payment. Applying this method of analysis to long-term resource management constitutes a recipe for a growing burden on the environmental debt, resulting in lower future carrying capacities.

Another example of social trap is discounting the significance of events occurring at a distance, such as domestic/urban environmental health versus foreign/rural health. Overestimates of distance can lead to profound environmental problems with direct implications for carrying capacity as the ability of humanity to vastly alter biogeochemical cycles through local and regional habitat conversion has become apparent. Discounting over time and discounting over space both encourage behavior that may reduce carrying capacity for future generations. One example of such an unsustainable behavior is underpricing of resources which encourages unsustainable consumption and management. Underpricing often occurs because future generations and other non-human species have no means of making their demands for a resource known.

c) other obstacles and barriers

Other general barriers inherent in processes which intent to address sustainable capacities and biocentric capacities include:

* the obsession with technology and the belief that technological innovations will steadily increase the functional carrying capacity (addressed in the second chapter);

* the addiction to consumerism and a material high standard of living, well documented in Allen Durning's book, How much is enough? (1992);

* the human inability to perceive that environmental degradation is occurring at all, or that it is occurring fast enough to require change;

* the lack of perception that degradation represents a serious threat or could cause personal harm;

* misinformation, conflicting information, and uncertainties about the seriousness of degradation, about its causes, or about the effectiveness of changing policies or behavior designed to reverse the degradation;

* the assumption that it will be easier to adapt to environmental degradation than to prevent it;

* the belief that measures to reverse degradation would be very difficult or costly, that costs would greatly outweigh benefits, or that possible benefits would be insufficient or delayed;

* the belief that the economic resources or physical means for causing change are unavailable, inaccessible, or inadequate;

* the belief that action to reverse allegedly unsustainable practices is incompatible with one's belief or worldview (e.g. environmental protection is not compatible with the belief that natural resources should be exploited rather than conserved);

* institutional rigidity, bureaucratic momentum, and unwillingness or lack of motivation to change long-standing policies or practices;

* the existence of organizations or groups with strongly vested interests in the status quo that oppose change, or with views that deny the need for change (Corson, 1994).

5. DATA COLLECTION

In order for the carrying capacity evaluation model to be operationalized, information is needed. There are different kinds of data collection which are relevant to identify the likelihood of constraints. Carrying capacity related data is provided through Environmental Impact Statements, threshold studies, surveys, and the development of indicators or benchmarks.

1. Environmental Impact Statement.

An Environmental Impact Statement is an analysis which provides information about the environmental impact of a proposed action; any adverse environmental effects which cannot be avoided should the proposal be implemented; and alternatives to the proposed action; the relationship between short term economic benefits and long-term costs to the environment. An EIS can be used to provide capacity constraints for proposed expansions of infrastructural capacities, such as the water supply system or the transportation highway system. Environmental Impact Statements provide information which is especially relevant for identifying constraints at the environmental capacity level.

2. Threshold studies

Another method to contribute to the analysis of carrying capacity is the use of threshold studies. These studies examine the effects of future population growth on a variety of systems. In these analyses, natural and human-made systems are analyzed to indicate their capacity to offer services and projected demands and to assimilate increased pollution due to population growth. These studies are then used as an informational tool for policy decisions. Many threshold studies focus on water quality or supply, air quality, or infrastructural capacities. Other studies analyze economic, energy or fiscal capacities to sustain additional growth. Some studies focus on the capacity of public safety systems, such as wastewater treatment and sewerage, water supply and distribution, and transportation networks.

The simplest methodology used in threshold studies is identifying single indicators to reflect the capacities of the public service system capacities (sewage treatment system, transportation system, water distribution system) and inventories of natural resource capabilities (groundwater, air quality, land use). A second more complex method used in studies which examine the effects of future population growth on a variety of systems is the use of computer models that describe environmental and human systems. Through a systems approach, these models bring together all the relevant aspects of the region's environment, land use, and economic activity in search of factors that might limit growth. Some models single out a few critical environmental systems such as water quality for detailed impact analysis. Analyzing the carrying capacity through computer modeling accentuates the dynamic perspective of the carrying capacity by integrating more than one limiting factor, such as land and water resources, into consideration in the management of urban growth. However, computer modeling approaches involve high development costs and situation-specific data that limit their transferability to other places.

3. Surveys

A third type of data collection relevant for identifying carrying capacity related constraints is the use of telephone surveys, interviews and questionnaires to determine what people value about their region and want to protect versus what people do not value and want to change. This information provides data to identify constraints at the perceptual capacity level. Surveys are also helpful to collect information about lifestyle expectations and desired levels of standard of living and material wealth. This data is relevant for constaints at the sustainable and biocentric capacity levels.

4. Indicators of sustainability

A fourth method to provide carrying capacity-related information is the development of indicators of sustainability. Indicators are dynamic variables which monitor the state of the system. They are variables which provide data about a given situation. Indicators are bits of information which monitor the state of the system. They are helpful in identifying the likelihood of constraints as they monitor the system in relation to perceived constraints at different levels.

Since the publication of Our Common Future, and especially since the 1992 Earth Summit in Brazil, many communities have used indicators an benchmarks as a major strategy to move towards ecological and social sustainability.[1] Portland-Multnomah County too has developed benchmarks to monitor community progress. Metro itself is in the process of developing 30 descriptive indicators and performance indicators for the Portland Metropolitan Region. These indicators cover the fields of air quality, open space, rural resource land, sense of place, community, transportation, land use, noise, energy costs, water quality, housing, employment, human services and regulation.

Relevant indicators in the context of carrying capacity related issues can be divided into two groups: ecological impact indicators and social indicators.

a. ecological impact indicators.

Ecological impact indicators are indicators which provide a wide array of information. They measure the variable flows of throughput of natural resources and environmental sinks; they describe the current state of the metropolitan region in relation to the socially determined ecological sustainable carrying capacity; they monitor the impact of the metropolitan region on the ecological system, in which the region is embedded; and they give feedback to the sustainability of this human impact.

Ecological impact indicators measure the extent of appropriation or impact human systems have on the larger eco-system in which they are embedded. Ultimately, these ecological impact indicators reflect the *level* of throughput of human systems. Impact indicators estimates the impact of the consumption of a population. Where the ecological sustainable carrying capacity thresholds are based on maximum acceptable numbers, such as maximum yields allowed of a given resource stock, impact indicators focus on the current consumption of resources by a given population.

Table 2, on the following page, lists some ecological impact indicators which are relevant for a carrying capacity-based evaluation process within a metropolitan region.

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[1] Appendix A gives an overview of different initiatives which have developed indicators and benchmarks in the United states. This overview has been collected by the Global Coalition Tomorrow, a Washington, D.C. based sustainable development agency.

TABLE 2: ECOLOGICAL INDICATORS RELEVANT FOR CARRYING CAPACITY RELATED ISSUES IN METROPOLITAN REGIONS

ENERGY:	- Energy use, total and per person - Percent of energy from renewable sources - Energy Use Index
FRESH WATER SUPPLY:	- Water withdrawals, total and per person - Water withdrawals as percent of water resources - Ground water levels
FRESH WATER QUALITY:	- Concentration of nitrogen, phosphorus, and organic chemicals in surface and groundwater. - Biological and chemical oxygen demand
SOLID WASTE:	- Municipal solid waste, total and per person - Percent of solid waste recycled
HAZARDOUS WASTE:	- Hazardous waste generated, total, per person, and per square kilometer. - Emissions of selected gaseous, liquid, and solid toxic substances.
ATMOSPHERE:	- Carbon dioxide emissions.
ACIDIFICATION:	- Acidity of rainfall, surface water, soil
AIR POLLUTION:	- Concentrations of carbon monoxide, nitrogen and sulfur oxides, ozone.
FOOD:	- Percent of food consumption produced locally. - Percent of food produced without chemical pesticides.
LAND AND SOIL	- Rate of rural to urban conversion - Percent of area in parks, gardens, open space.
FORESTS	- Percent of land area in forest and woodland - Number of tree planting.
NATURAL HABITATS	- Number and extent of protected areas
TRANSPORTATION	- Motor Vehicle Use. - Mass transit passenger miles - Passenger car per 1000 people - Percent of people using carpool - Number of bike paths

b. social indicators

It has been argued that there is a mutual interdependence between ecological sustainability and social and economic security. Studies show that the liveability and the ecological sustainability of a community is enhanced or diminished, depending on the presence or absence of certain social and economic conditions. Different socioeconomic factors have thus different effects on ecological sustainability. For example, a high education level could contribute to ecological sustainability, while a high income level may have a negative ecological impact. It is therefore important to identify these socio-economic components or variables that influence the ecological component of the carrying capacity. Examination of the links between socioeconomic indicators and measures of ecological sustainability are fundamental to clarify to what extent different economic and social aspects of "sustainable development" are ecologically sustainable.

Although extensive literature exist regarding social indicators and quality of life indicators, few studies have tried to explicitly develop social and economic indicators which exclusively increase people's quality of life *and* decrease their impact on the environment. Most of them have not made this differentiation and have ignored the influence of these socio-economic indicators on the ecological dimensions of the sustainable carrying capacity. In the context of a carrying capacity-based framework, is it essential to develop social and economic criteria which make explicit the interconnection between socio-economic behavior and the environmental *impact* of that behavior.

The Task Force on Healthy planning and Sustainable Communities at the University of British Columbia has developed a selected set of social criteria and indicators which they argue increase the quality of life *while* decreasing the impact on the environment. The social criteria and indicators, called **Social Caring Capacity** criteria and indicators are divided in seven criteria: social equity, diversity, interconnection, safety, functional recreational space, inclusion in decision making process and the presence of household/familial stressors. The task Force defines social caring capacity criteria

> "...as these criteria which help *increase* people's quality of life while *decreasing* their impact on the environment, by allowing a community to understand the consequences of particular choices on equity, health, and the economy on the environment" (McIntosh, 1993).

These social and economic criteria therefore help guide the question how to reduce the ecological impact without compromising its residents' quality of life. The City of Richmond, B.C. has been using the social caring capacity criteria and indicators, since August of 1993. They are presented on the following two pages.

TABLE 3: SOCIAL CARING CAPACITY:CRITERIA AND INDICATORS WHICH INCREASE THE QUALITY OF LIFE WHILE DECREASING THE IMPACT ON THE ENVIRONMENT.[2]

Social Equity: Equal opportunity for all members of the community to meet their basic needs and enjoy a good quality of life, achieved through equal access to the decision making processes affecting the community, education, and training, health care, social support services, housing, a quality environment, and the opportunity to earn a livelihood.

indicators:
- demographic profile and satisfaction of health care, social service, educational and recreational facility users
- equal pay for equal work
- involvement of all echelons of society in decision making processes
- availability of adequate housing facilities for all income groups in the community

Diversity: A variation in social mix, age, socioeconomic status, culture, gender, family type, education, housing design, employment opportunities, and health status.

indicators:
- demographic data including age groups, ethnicity, healthy life expectancy, social economic status, education, family type, average number and age breakdown per household, natality, percentage of employed/unemployed
- range of employment opportunities (i.e. secretarial, skilled, professional, unskilled)
- employment status by age, ethnicity, education, gender, disability
- availability of housing options (rental, owned, multifamily, cooperative, subsidized, mixed use, cohousing)
- availability of educational programming, for immigrants about local culture and expectations
- availability of multicultural educational programming for host society members of all ages
- prevalence of prejudiced attitudes

Access to recreational/open space: The presence of functional parks and recreational areas that are easily accessible and extensively used by the community for a number of different recreational activities.

indicators:
- percentage of recreational space that takes into consideration the demographic make-up of a community
- presence of recreational space developed according to community specific standards
- use of recreational facilities by heterogeneous populations

Minimization of Household/Familial Stressors: Social, physical and political interventions which serve to minimize daily personal and familial strains and pressures.

indicators:
- average distance and time taken to get to work, school, daycare, recreational facilities, shopping, and services without the use of a vehicle
- percentage of households with cost of housing greater than 25% of income
- percentage of households with unaffordable care giving costs

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[2] SOURCE: Aronson & Charles (1993). "The Social Caring Capacity of a Community: A Literature Review." UBC Task Force on Healthy planning and Sustainable Communities, the University of British Columbia (1993).

- degree of access and availability of public transportation, subsidized daycare, local employment opportunities, formal/informal services, affordable housing options, and safe areas
- number of reported cases of family violence
- satisfaction with parenting roles
- unemployment rates

Inclusion in the Decision Making Processes: Community involvement in social, political, health, and environmental related decision making processes, in order to elicit, understand, and attempt to meet community member's needs, provide empowerment, and facilitate a sense of responsibility and commitment to the community.

indicators:
- encouragement by Mayor and Council for citizen involvement in decision making processes
- degree of commitment and support by community agencies and institutions for inclusion of community members in decision making processes
- number of active community residents planning and decision making groups
- demographic characteristics of citizens participating in decision making initiatives

Safety: The presence of a psychological sense of security, ease and comfort in one's daily activities; the absence of unnecessary dangers, risks and hazards in the physical environment; and the presence of measures in the environment implemented for the purpose of decreasing possibilities of victimization (i.e. education, adequate lighting, and neighborhood watch programs).

indicators:
- crime rates
- community involvement in crime prevention strategies
- perceptions of personal safety in the community
- presence of safety features designed into the physical environment
- design of access routes to public transportation
- frequency of public transportation, especially at night
- distance between walkways, bus stops, stores, and places of residence
- presence of adequate lighting at bus stops, and along roads and walkways

Interconnection: The presence of opportunities to develop support networks enabling reciprocity between community services and community members, and between community members themselves; and involvement in community activities and programs which foster a sense of community belonging.

indicators:
- degree of social support experienced by community members
- presence of community self-help groups, volunteer groups, citizen advisory groups, extracurricular/recreational activities
- community participation rates in self-help groups, volunteer groups, citizen advisory groups, extracurricular/recreational activities
- availability of recreational spaces, parks, walkways, community centers, community gardens
- area available for common use by interest groups
- presence of block parties, babysitting co-ops, cooperative daycare
- formal community services (health care, social services, etc.)
- number of co-op/co-housing units

In conclusion, the development of social indicators relevant to carrying capacity related issues is still in its beginning phases and it is still unclear how economic and health related indicators are actually integrated towards policies which promote ecological sustainability.[3]

6. SIGNIFICANCE OF THE CARRYING CAPACITY EVALUATION MODEL

There are two main avenues of significance in applying a carrying capacity evaluation model. It shapes the discussion of carrying capacity around issues of sustainability; this in turn can prepare the way for an ecological-based threshold approach to control urban growth.

An environmental threshold approach operationalizes the carrying capacity through the establishing of a set of threshold standards as a legal framework to constraint development. An environmental threshold approach can be seen as an essential strategy to reconcile the attitudes and expectations for the human environment and the quality and stability of the natural environment, as well as to frame choices which insure ecological sustainability. The threshold approach provides a general framework for prioritizing competing "rights" and creating a hierarchy of policy choices, based on ecological and social sustainability.

The Lake Tahoe Regional Planning Compact created in 1980 an amendment that requires the adoption of environmental threshold carrying capacities to set standards for the development of the region. The plan established environmental threshold carrying capacities, a regional plan and implementing ordinances. The goal was to achieve and maintain such capacities while providing opportunities for orderly growth and development. The environmental carrying capacity thresholds established the environmental standards for the region and, as such, indirectly defined the capacity of the region to accommodate additional development. The environmental thresholds study report provided the basis and rationale for the establishment of thresholds while the regional plan and implementing ordinances defined the actual limits and potential for new development consistent with the constraints imposed by the thresholds.

Included in the regional plan requirements are a land use element, transportation element, conservation element, recreation element, and public services and

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3 At present, no comprehensive body of research is available which examines and understands how the indicators of sustainability and benchmarks interact in a given community and what effect knowledge of these indicators may have on the activity of the community.

facilities element, setting forth standards for water quality, air quality, soils, wildlife, fisheries, vegetation, scenic quality, and recreation.

The Lake Tahoe Regional Planning compact defined an environmental threshold carrying capacity as

> an environmental standard necessary to maintain a significant scenic, recreational, educational, scientific or natural value of the region or to maintain public health and safety within the region.(Tahoe Regional Planning Agency, 1986)

Thresholds were established to identify a particular event, circumstance, or condition that would create an unacceptable change or degradation of a particular resource of interest.

The development of environmental thresholds carrying capacities followed a four step process. The first step incorporated participation by state, federal and local agencies, and the general public and identified issues and components of the environment that are of local, regional and federal significance. Value and goal statements established the parameters of interest for each component and narrowed the focus for establishing thresholds. The second step identified the variables that affect each environmental component. From this, cause and effect relationships were established. In the third step, these relationships were evaluated according to their individual contributions to the resource. Thresholds were then established only for those causal factors that were most significant to the resource. The second and third step thus identified the factors responsible for unacceptable changes in the resource and identified the appropriate threshold necessary to protect the resource or to achieve a particular value. The fourth step highlighted the mechanisms necessary to achieve or maintain the thresholds.

The development of the regional plan was structured around the adopted thresholds and other issues of local and regional significance. The plan identified goals that depicted the desired ends or values to be achieved and policies that established the strategies necessary to achieve the goals. The major purpose of the regional plan was to establish regulations and programs to achieve and maintain these thresholds. Provisions were made for regular review of the threshold standards and the regional plan.

The threshold standards and the regional plan was revised in 1987, and has since been totally adopted in the Lake Tahoe Region. The first 5-year evaluation of the thresholds and the 1987 regional plan was conducted in 1992. The results were mixed. While progress was made toward reaching the threshold standards, the progress hasn't been as broad and as rapid as many had hoped (TRPA newsletter, 1992). However, it is reasonable to conclude that the concept of environmental threshold carrying capacities or environmental quality standards has shaped the way development projects have been evaluated. This assumes that the thresholds and the regional planning to achieve the thresholds have influenced the direction of development and growth in the region.

CHAPTER FOUR: APPLICATION OF THE CARRYING CAPACITY EVALUATION MODEL TO THE PORTLAND METROPOLITAN REGION

introduction

A major focus of the Future Vision's Commission's efforts is to determine how and where to accommodate population growth while maintaining a desirable quality of life. An important component of this assignment is to examine how ideas of carrying capacity frame decisions about population growth and settlement patterns in the region.

This chapter applies the carrying capacity evaluation model outlined in the previous chapter to the Portland Metropolitan Region. This model is meant to provide specific insight regarding the degree to which issues of carrying capacity should shape the thinking of the Future Vision Commission in the months ahead.

The model suggests a framework for a discourse on how to respond to future growth within the Portland Metropolitan Region. It also highlights the critical decision points which will need to be made in the future. The use of this model is advantageous for looking at the carrying capacity constraints from a long-term perspective and with respect to the ecological sustainability of the Portland Metropolitan Region. Also implicit in the model is the assumption that carrying capacity-related issues for the Portland Metropolitan Region need to be inclusive of issues related to the larger Cascadian bioregions in which the Portland region is embedded.

It needs to be underscored that the application of the model is a preliminary investigation into carrying capacity related issues for the Portland Metropolitan Region. Further data collection and analysis will be needed. However it is hoped that this introductory investigation will frame a continuing discussion on carrying capacity related issues.

data collection

Data for the evaluation model has been provided by threshold studies done by Metro (land, transportation) and the City of Portland Bureau of Water Works. The Portland Energy Office provided information on energy. The basic assumption of most of the data provided is that the population in the Portland Metropolitan Region in the year 2040 will be 2,674,355.

The resources evaluated by the carrying capacity evaluation model are air, land, transportation system, water supply system and energy system. Other resources which could be investigated are the school system, economic system, safety system, waste disposal system, stormwater system, recycling system.

tables

The tables, presenting the different carrying capacity constraints of the resources evaluated, are all situated at <u>the end of this chapter.</u> Table 1 to 8 covers water-related constraints; Table 9 presents air-related constraints; Table 10 land-related constraints; Table 11 energy-related constraints; and table 12 transportation related constraints. Table 13 gives an overview of the most important carrying capacity related constraints for the Portland Metropolitan Region.

1. IDENTIFICATION OF THE DIFFERENT CONSTRAINTS FOR THE PORTLAND METROPOLITAN REGION

WATER

With an average rainfall of 45" per year , two large river systems fed by many other surface rivers and streams, and abundant groundwater, the Portland Metropolitan Region has an abundance and quality of water resources in the area. Water literally flows through the metropolitan region, originating as well as arriving in places outside of the Urban Growth Boundary (UGB). These water sources and deposits are themselves habitats of fish and wildlife, as well as part of a complex network of ecosystems.

The main water-related system crucial to evaluate as a potential constraint for the Portland Metropolitan Region is the water supply system.

present water supply system

The Portland Water Bureau has issued a comprehensive threshold study on the regional water supply, distribution and demand system of the Portland Metropolitan Region. The water system study developed regional water demand forecasts, and covered the counties in the Metro UGB--the Washington, Multnomah and Clackamas counties.

The water demands were projected for ten-year increments from 1990 to the year

2050 and included mid-range and high-range estimates. Mid-range estimates were based on the assumption that population will increase from about 1,285,000 residents in 1990 to 2,081,000 residents by 2050, while the high estimates were based on the assumption that population will reach approximately 2,500.000 residents, or about an 89 percent increase over 1990 population estimates (about 75 to 80 percent of the region's population are expected to reside in Oregon, while about 20 to 25 percent would be located in Washington).

Other assumptions the study was based on include:

* the assumption that the metropolitan UGB will not change until the year 2010. At that point in the forecast period it was assumed that the UGB would be expanded to accommodate new urban residents in the area.

* the assumption, that conservation efforts, including both supply and demand savings projections, will reduce per capita demand by up to 20 gallons per day.

* extremely severe hot, dry peak summer periods will occur more frequently in the future.

In addition to mid-range and high estimates, separate predictions were developed for average day demand, summer or "peak season" demand, and "peak day" demand. All water demand forecasts were prepared both with and without water conservation assumptions.

The results of the water supply threshold study can be summarized as followed:

* Mid-range estimate demands are estimated to increase 41 percent, from 208 to 294 mgd (average annual demand); 42 percent, from 264 to 376 mgd (peak season demand); and 47 percent, from 394 to 579 mgd (peak day demand) between 1990 and 2050 (mgd refers to million gallons per day).

* High estimate demands are estimated to increase 83 percent, from 255 to 467 mgd (average annual demand), 84 percent, from 325 to 597 mgd (peak season demand), and 89 percent, from 544 to 1,026 mgd (peak day demand) between 1990 and 2050.

The two main conclusions drawn from the water demand study are twofold. First, population and the effect of the seasons of the year will have the strongest influence on water demand; and second, future water demand needs in the Portland Metropolitan Region will exceed the current existing water supply capacity, which at present is about 477 mgd (system constraints were already felt in 1987 and in 1991). This infrastructural constraint is presented in Table 1.

expanded water supply system

As the infrastructural constraints are reached, at some point in the future, assuming growth, new supply sources will need to be developed. Critical decisions will have thus to be made around expanding the capacity of the water supply system to accommodate future demand. The Portland Water Bureau has identified six options that could provide enough water to cover future water supply deficits.

Option 1: Willamette River-Diversion (this includes run-off-river, stored water from existing Corps reservoirs, and a treatment facility).

Option 2: Columbia River (Run-off-river diversion, and treatment facility).

Option 3: Bull Run River, building a new dam and reservoir.

Option 4: Clackamas River (run-off-river diversion, treatment facility expansion).

Option 5: Trask River (expansion of Barney Reservoir)

Option 6: Aquifer Storage and Recovery through injection

All options assume that a regional transmission system will be established. It would link together all major, regional water sources, thereby increasing system flexibility and efficiency. It would allow distribution of water among the region's communities and would be able to transmit different sources of water, should a particular source or facility be temporarily out of service.

Evaluating the six different options through the carrying capacity evaluation model is shown in Tables 2 to 7. Table 8 shows a summary of all the options and different constraints.

There is much ambivalence and uncertainty in identifying the different constraints. One main reason for this is the uncertainty involved; the different perceptions on risk and water quality, and the uncertainty about catastrophic events and the effects of global warming.

AIR

A recent study done by Metro, projecting air quality projections for ozone precursors (VOC) for 1990 to 2040, suggest that in the year 2040, total emissions will be 35% above the federally determined Clean Air Act threshold standard. The study shows that the region will exceed the standard level by the year 2006, as a result of the estimated growth rate in vehicle miles traveled (VMT) (approximately 1.4% per year). The area emission projections are based on Metro's 2040 population projections (1.2% growth rate per year) and assume significant control of architectural coatings, autobody refinishing, and consumer solvent use in future years, as well as the Governor's Task Force strategies and Transportation Planning Rule (see Figure 1).

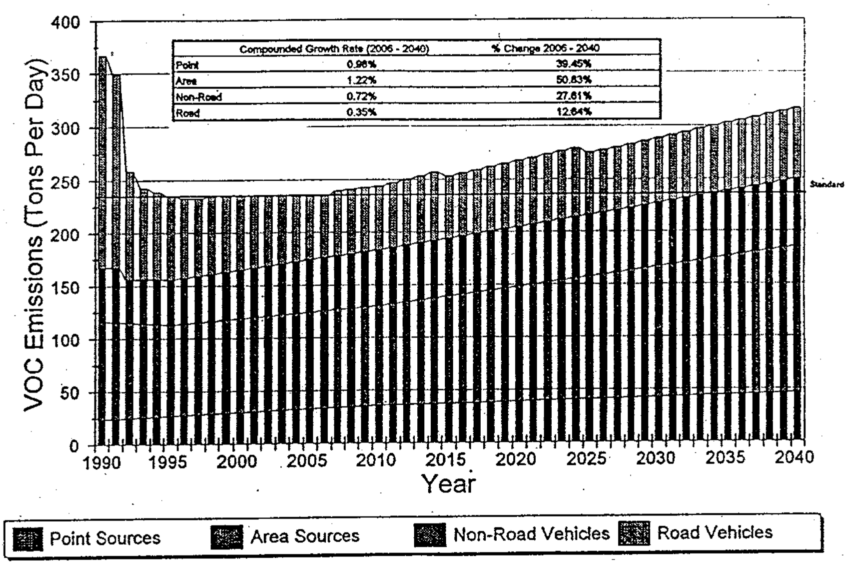

Figure 1: Portland-Vancouver Ozone Precursors
Human caused emissions: 1990-2040

Another study done by the Portland Energy Office has calculated that in 1988, carbon dioxide emissions in the Portland Metropolitan Region were 10.1 million metric tonnes(MMT). The forecast for 2010 shows CO2 emissions rising to 13.9 MMT. Additional emissions are due to population growth, increased use of natural gas for electrical power production and increased vehicle miles traveled. The World Conference on the Changing Atmosphere held in Toronto, Canada in 1988 has suggested that a significant target in order to reduce the green house effect is the reduction of CO2 emissions *20% below 1988 levels.* This means that the sustainable constraint for the Portland Metropolitan Region is 8.1 MMT.

The identification of constraints for air is displayed in Table 9. The conclusions of evaluating the likelihood of air-related constraints are two-fold:

The first constraint will be an institutional constraint: the federally imposed air quality standard. The region is thus faced with a major set of decision points related to the air quality. Reductions in addition to the Governor's Task Force strategies and Transportation Planning Rule will thus be required to maintain the air quality under federal EPA standards. This will mean more radical changes in the transportation system, as well as developing land-use patterns which will encourage less automobile dependency.

The second constraint is a sustainable capacity constraint: a constraint on CO2 emissions suggested as necessary to curb global warming (carbon dioxide emissions are the primary gas contributing to the threat of increased global warming). The sustainable constraints for the Portland Metropolitan Region of 8.1 MMT means a reduction of 42% or 5.8 MMT below the 2010 forecast. Portland is participating with 13 other local governments in the Urban CO2 Reduction Project, to reduce CO2 emissions 20 percent below 1988 levels. To achieve this goal six strategies have been outlined, covering transportation, energy efficiency, renewable resources and cogeneration, recycling, tree planting and federal actions.

LAND

Metro has estimated that the region would need to add as many as 47,000 acres to the urban growth boundary in 1995--and continue at a rate of about 25,000 every 10 years--if past land-use practices are used. This means that by the year 2000 the urbanized area of the region would extend from Newberg in the south to Battle Ground, Washington, in the north, North Plains in the west and Sandy in the east. In between all those areas, most of the vacant land would be developed. This has prompted the Region 2040 to propose different land use patters, resulting in the development of three different growth concepts (A, B, and C) to accommodate the expected growth of the region. (Total amount of acres within the UGB is 1,320,779.)

Land-related constraints are presented in Table 10. The following points can be made:

* As there is a direct relationship between land use patterns and needs for transportation, i.g. the amount of Vehicle Miles Travelled, deciding land use patterns has a direct influence on the air quality thresholds. Air quality standards here can be seen as a *secondary constraint*, in that the capacity of the land is indirectly influenced by a constraint of another resource.

* The Master Green Plan, another institutional constraint, protects the minimum amount of public green spaces. Within 7-10,000 acres of land within the current UGB are assumed to be protected as natural areas.

* Rural resource land--community gardens, agricultural land and forestry--is a sustainable constraint as they provide the ability for the region to produce food for its citizens. The Portland Metropolitan Region, as any metropolitan region of its size, has exceeded this constraint as the region is mostly sustained by food produced outside of its boundaries as part of a globalized food economy. The rural resource constraint puts a limit on land used for urban development, the amount of land covered by human infrastructures.

* The ecological footprint or Appropriate Carrying Capacity is here presented as a biocentric constraint. As was outlined in the second chapter, the ecological footprint uses land-area as a biophysical measurement unit to measure the land that would be required at present on this planet to support the current lifestyle of a metropolitan region forever. Ultimately the ecological footprint constraint, like every constraint of this level, is an ethically-based constraint.

ENERGY

Metropolitan regions are very dependent on energy. Moving large quantities of food, water, and fuel into the region and disposing of garbage and sewage are both logistically complex and energy-intensive. The larger and more sprawling the region, the more complex and costly its support systems. Many carrying capacity-related constraints in the future can result from the dependency on non-renewable energy sources, such as oil and coal.

Where the institutional constraint (180.5 BTUs per year) refers to a per capita consumption, sustainable constraints address the collective energy consumption constraints. Sustainable constraints in the Portland Metropolitan Region means constraints of energy which fuels the "metabolism" of the metropolitan region as a whole.

Energy constraints arise at Level 4 and 5 and 6. Energy related constraints are presented in Table 11. The following observations can be made.

* An environmental constraint is the investment ratio, which according to Odum, is the critical measure of urban growth. It is the net energy or useful energy left from an energy source after the energy costs of exploration, extraction, production, and transportation are subtracted as well as estimating energy investment ratio's. Net energy depends on the ratio between local available energy sources and out-of-state energy sources. The energy environmental constraint

arises when the true costs are incorporated of the exploitation of these sources for fueling and accommodating the expected urban growth.

* A sustainable energy-related constraint in the Portland Metropolitan Region is the types of energy sources that are used to supply energy to the Portland Metropolitan Region. At present, the majority of energy is provided by vertical energy or non-renewable energy sources such as coal, gas and oil. Hydropower, a horizontal or renewable type of energy provides around 10% of the electrical power to the metropolitan region.[1]

* Another energy-related sustainable constraint is transportation energy, i.g. oil. At the rate oil is being consumed on a global scale, oil reserves are expected to run out in the next forty years.

* A biocentric energy-related constraint is the limit to expand the hydropower capacity for the region. Hydropower, although a renewable resource, at a biocentric level becomes a major constraint as it participates in the destruction of the integrity of the salmon community in the bioregions in which the Portland Metropolitan Region is embedded.[2]

The above observations illustrate the likelihood that energy-related constraints will arise in the next century. This suggests that it could be useful that the Future Vision Commission incorporates energy-related issues in their discussion.

TRANSPORTATION SYSTEM

An important carrying capacity related system that needs to be evaluated is the transportation system. The transportation system consist of the highway transportation system and the transit system, light rail and buses.

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[1] Environmental and sustainable energy related constraints at present are illusive to identify (no data for the Portland metropolitan region is available to calculate the energy investment ratio and the horizontal/vertical ratio).

[2] The American Fisheries Society has identified more than 200 stocks in the Northwest region at risk of extinction or of special concern (Nehlsen et al. 1991). Salmon numbers in the Columbia River Basin fell from between 10 to 16 million adult salmon in the mid-1800s to about 2 million today (NWPPC 1992).

Based on population growth projections, infrastructural constraints will happen. The present infrastructural constraint of the highway transportation system is 9,279 miles for freeways and arterials regionwide. Expansion of the infrastructural transportation constraints will depend on the growth concept adapted by Metro. Transportation would include road improvements, high capacity transit (concept A, B and C) and the construction of three freeways-the Westside Bypass (linking Hillsboro and Tualin), the Sunrise Corridor (between Oregon City and the Boring/Damascus area), and the Mt. Hood Parkway (I-84 to Highway 26 through Gresham) (concept A and C).

Table 12 illustrates the different transportation-related constraints. Whatever concept will be adapted, the constraint on transportation will be the EPA air quality standards. One of the main reasons for air pollution is the production of ozone or smog. The primary source of this pollution is the automobile.[3] This institutional constraint is a *secondary constraint* as it is a constraint of another resource (air). Another secondary constraint is the energy-related constraint of oil reserve depletion.

2. CONCLUSION

When analyzing the key constraints of the five evaluated resources of the Portland Metropolitan Region, presented in Table 13, three essential observations can be made:

* the limiting factor, which will constrain growth in the metropolitan region is the **air quality** of the region. The air quality, which is projected to exceeded the EPA federal standard in 2006 and will be 35% above federal standards in 2040, is a constraint for air, as well as a constraint for land and the transportation system.

* the limiting system, which will constraint growth in the metropolitan region is the transportation system. Many key constraints are related to the **transportation system** (EPA air quality, CO_2 emissions, depletion of oil reserves, perception of congested highways, view of Mt. Hood).

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3 The amount of Vehicle Miles Travelled in 1990 was 26,708,898 or 17.67 VMT/capita. Assuming the adaptation of Concept B, it is estimated to be 45,780,241 in 2040 or 17.12 VMT/capita. (population estimated to be 2,674,355). Concept B estimates show less VMT/capita at 17.12. (Present transit riders are 140,100, expected to be 362,600 in 2040).

* the metropolitan region is likely to face energy constraints in the next century. Among the likely constraints to appear are the sustainable constraints of cheap non-renewable energy and the biocentric constraints of hydro-power.

The application of the model must be seen as a preliminary investigation into carrying capacity related issues for the Portland Metropolitan Region. Four further avenues for research are:

1. Collect more data collection and analysis of the resources investigated.

2. Evaluate other resources and human-based systems, such as fiscal related, economy-related, educational-related, safety-related and housing-related carrying capacity constraints.

3. Analyze the complex interactions between the various multi-leveled constraints of the different evaluated resources. This systems analysis will help

* understand better the dynamic behavior of the metropolitan region as an integrated whole;

* identify emerging properties that are a consequence of the interactions of the different constraints;

* keep account of how one activity may impinge on another;

* be aware that a given activity may cause perturbations that have unintended, indirect effects on other system elements. The resolution of conflicting demands on interdependent resources involves a complex set of social and economic considerations;

* assess whether a given human activity creates constraints by incorporating *the time that passes between the onset of the activity and human perception of its impact.* The delay in perceiving the impact may result from either an actual lag time before its manifestation or from an inability to detect the impact under routine monitoring. By the time the effects are manifest, irreversible changes may have occurred (Meadows et al. 1992).

4. Investigate the feasibility of establishing carrying capacity threshold standards for the region in order to ensure the long-term sustainability of the region. Adopting a threshold approach into the Regional Master Plan of the Portland Metropolitan Region would:

* integrate ecological principles more forcefully in institutions and policies;

* promote policies which a)adopt a hierarchy of policy making, committed on sustaining the integrity of the natural environment; b) promote efficiency, minimizes incidence of unsustainable outcomes, and avoids risks at all possible. c) are both anticipatory, proactive and adaptive; d) policies which are shaped by baseline information;

* incorporate time horizons reflecting intergenerational responsibility in decision making process;

* encourage new levels of business responsibility and opportunity;

* conserve ecological life-support systems and biodiversity and help realize a respect and dignity for all forms of life;

* ensure that uses of renewable resources are sustainable and minimizes the depletion of nonrenewable resources;

Achieving some level of global sustainability is largely an urban challenge, given the dominant place of urban places in population distribution, in the production and consumption of goods and services which impact on interdependent economic and ecological systems, and in the governance of all levels (Roseland, 1992). A sustainable metropolitan region is one which recognizes its place in nature --it knows its ecological capacity and limits and works towards living within the sustainable carrying capacity of the region, being as self-sufficient and self-reliant as possible:

> Redeveloping our communities for sustainability means closing the loop between 'input' (energy and materials) and 'output' (pollution and wastes). Developing sustainability requires that our social and economic living patterns do not bankrupt the resource systems upon which we depend. (Roseland, 1992).

Achieving some level of sustainability for the Portland Metropolitan Region and the larger bioregion thus implies the inevitability of making choices. Choices which are difficult and complex. The intend of this preliminary report is to provide background as well as a useful framework in the service of the Future's Vision's Commission's effort to envision a sustainable future for the Portland Metropolitan Region and the different bioregions in which the Portland area is embedded.

TABLES

TABLES

TABLE 1: WATER-RELATED CARRYING CAPACITY CONSTRAINTS
THE PRESENT WATER SUPPLY SYSTEM

	CAPACITY LEVEL	PRESENT WATER SUPPLY SYSTEM
LEVEL ONE	**INFRASTRUCTURAL CAPACITY LEVEL**	The current existing water supply capacity is about 477 million gallons per day. This constraint was already felt in 1987 and 1991.
LEVEL TWO	**INSTITUTIONAL CAPACITY LEVEL**	N/A
LEVEL THREE	**PERCEPTUAL CAPACITY LEVEL**	N/A
LEVEL FOUR	**ENVIRONMENTAL CAPACITY LEVEL**	N/A
LEVEL FIVE	**SUSTAINABLE CAPACITY LEVEL**	N/A
LEVEL SIX	**BIOCENTRIC CAPACITY LEVEL**	N/A

TABLE 2: WATER-RELATED CARRYING CAPACITY CONSTRAINTS
THE WATER SUPPLY SYSTEM OPTION 1

	CAPACITY LEVEL	WATER SUPPLY SYSTEM OPTION 1: WILLAMETTE RIVER DIVERSION
LEVEL ONE	INFRASTRUCTURAL CAPACITY LEVEL	The expansion would provide an added peak day capacity of up to 600 mgd.
LEVEL TWO	INSTITUTIONAL CAPACITY LEVEL	- permits for irrigation use of Corps reservoirs. - water rights (both instream and out-of-stream) - unadjudicated pre-1909 claims on the Willamette River System - cost of treatment
LEVEL THREE	PERCEPTUAL CAPACITY LEVEL	-individual constraints related to taste problems.
LEVEL FOUR	ENVIRONMENTAL CAPACITY LEVEL	- water quality related concerns about sewage treatment, pulp mill, and other industrial effluent discharges, agricultural run-of, and stormwater run-off.
LEVEL FIVE	SUSTAINABLE CAPACITY LEVEL	
LEVEL SIX	BIOCENTRIC CAPACITY LEVEL	

TABLE 3: WATER-RELATED CARRYING CAPACITY CONSTRAINTS
THE WATER SUPPLY SYSTEM OPTION 2

	CAPACITY LEVEL	WATER SUPPLY SYSTEM OPTION 2: COLUMBIA RIVER
LEVEL ONE	INFRASTRUCTURAL CAPACITY LEVEL	* An added peak day capacity of up to 600 mgd
LEVEL TWO	INSTITUTIONAL CAPACITY LEVEL	* Federal drinking water standards.
LEVEL THREE	PERCEPTUAL CAPACITY LEVEL	* Contamination from the Hanford facility and other existing of future upstream sources over which the region's providers have no control creates perceptual constraints such as fear.
LEVEL FOUR	ENVIRONMENTAL CAPACITY LEVEL	* same as level two and three
LEVEL FIVE	SUSTAINABLE CAPACITY LEVEL	* same as level two and three * constraints related to intakes and treatment facilities on wetlands
LEVEL SIX	BIOCENTRIC CAPACITY LEVEL	* At this level, there is no *safe* level of intake.

TABLE 4: WATER-RELATED CARRYING CAPACITY CONSTRAINTS
THE WATER SUPPLY SYSTEM OPTION 3

	CAPACITY LEVEL	WATER SUPPLY SYSTEM OPTION 3: BULL RUN RIVER DAM
LEVEL ONE	**INFRASTRUCTURAL CAPACITY LEVEL**	* Added peak day capacity of up to 270 mgd
LEVEL TWO	**INSTITUTIONAL CAPACITY LEVEL**	* The Endangered Species Act and Wild & Scenic Rivers Act.
LEVEL THREE	**PERCEPTUAL CAPACITY LEVEL**	* Removal of water from the Bull Run River will change the stream flow in the Sandy River, which is a state scenic waterway and federal wild and scenic river. Perceptual constraint is the change flow of the Sandy river which will impact on the recreational uses of the River.
LEVEL FOUR	**ENVIRONMENTAL CAPACITY LEVEL**	* Same as three as well as *concern* for the northern spotted oil, wetlands and riparian areas, impact on aquatic life in the Bull Run and Sandy Rivers.
LEVEL FIVE	**SUSTAINABLE CAPACITY LEVEL**	* Same as level four, but absolute.
LEVEL SIX	**BIOCENTRIC CAPACITY LEVEL**	* Same as level six.

TABLE 5: WATER-RELATED CARRYING CAPACITY CONSTRAINTS
THE WATER SUPPLY SYSTEM OPTION 4

	CAPACITY LEVEL	WATER SUPPLY SYSTEM OPTION 4: CLACKAMAS RIVER
LEVEL ONE	INFRASTRUCTURAL CAPACITY LEVEL	* Added peak day capacity of up to 75 mgd
LEVEL TWO	INSTITUTIONAL CAPACITY LEVEL	* no constraints. This option would be developed under existing water rights and land use rights around the existing dam.
LEVEL THREE	PERCEPTUAL CAPACITY LEVEL	* recreational use
LEVEL FOUR	ENVIRONMENTAL CAPACITY LEVEL	* pollution
LEVEL FIVE	SUSTAINABLE CAPACITY LEVEL	* watershed protection
LEVEL SIX	BIOCENTRIC CAPACITY LEVEL	* watershed protection

TABLE 6: WATER-RELATED CARRYING CAPACITY CONSTRAINTS
THE WATER SUPPLY SYSTEM OPTION 5

	CAPACITY LEVEL	WATER SUPPLY SYSTEM: OPTION 5 TRASK RIVER
LEVEL ONE	INFRASTRUCTURAL CAPACITY LEVEL	* added peak day capacity of up to 20 mgd
LEVEL TWO	INSTITUTIONAL CAPACITY LEVEL	* no constraints. This option would be developed under existing water rights and land use rights around the existing dam. * Potential constraint: stormwater regulations on uses of the tualatin river, to which trask river water would be diverted and conveyed.
LEVEL THREE	PERCEPTUAL CAPACITY LEVEL	
LEVEL FOUR	ENVIRONMENTAL CAPACITY LEVEL	* impacts on endangered plants and wetlands.
LEVEL FIVE	SUSTAINABLE CAPACITY LEVEL	* impacts on endangered plants and wetlands.
LEVEL SIX	BIOCENTRIC CAPACITY LEVEL	* impacts on endangered plants and wetlands.

TABLE 7: WATER-RELATED CARRYING CAPACITY CONSTRAINTS
THE WATER SUPPLY SYSTEM OPTION 6

	CAPACITY LEVEL	WATER SUPPLY SYSTEM: OPTION 6 AQUIFER STORAGE
LEVEL ONE	**INFRASTRUCTURAL CAPACITY LEVEL**	* Added peak day capacity of up to 100 mgd
LEVEL TWO	**INSTITUTIONAL CAPACITY LEVEL**	
LEVEL THREE	**PERCEPTUAL CAPACITY LEVEL**	
LEVEL FOUR	**ENVIRONMENTAL CAPACITY LEVEL**	* compatibility between recharge water and the water quality of receiving groundwaters, existing and potential contamination, and hydrogeologic suitability.
LEVEL FIVE	**SUSTAINABLE CAPACITY LEVEL**	
LEVEL SIX	**BIOCENTRIC CAPACITY LEVEL**	

TABLE 8: WATER-RELATED CARRYING CAPACITY CONSTRAINTS
THE EXPANDED WATER SUPPLY SYSTEM OPTIONS

	CAPACITY LEVEL	EXPANDED WATER SUPPLY OPTIONS
LEVEL ONE	**INFRASTRUCTURAL CAPACITY LEVEL**	* 600 mgd (total of about 1077 mgd)
LEVEL TWO	**INSTITUTIONAL CAPACITY LEVEL**	* the Endangered Species Act and other federal laws. * water rights. * allocation of water in existing storage projects. * instream flow needs and other competing water uses.
LEVEL THREE	**PERCEPTUAL CAPACITY LEVEL**	* acceptability regarding raw water purity, value of upstream water sources and risk of using downstream water sources. * recreational constraints
LEVEL FOUR	**ENVIRONMENTAL CAPACITY LEVEL**	* watershed protection and control when evaluating risk of source degradation and preserve source quality. * constraints on rural land use patterns.
LEVEL FIVE	**SUSTAINABLE CAPACITY LEVEL**	* watershed preservation for future needs and present habitats. * net-energy costs/constraints.
LEVEL SIX	**BIOCENTRIC CAPACITY LEVEL**	* native american value of cultural and historic resources. * preservation of spotted oil habitat. * preservation of salmon and other endangered species habitat.

TABLE 9: AIR-RELATED CARRYING CAPACITY CONSTRAINTS

	CAPACITY LEVEL	AIR
LEVEL ONE	**INFRASTRUCTURAL CAPACITY LEVEL**	* as air does not need any infrastructural systems to be useful to humans, there are no constraints on this level.
LEVEL TWO	**INSTITUTIONAL CAPACITY LEVEL**	* federal clean air threshold standard (EPA Clean Air Act). The standard will be exceeded in 2006 and air quality will be 35 % over the threshold in 2040.
LEVEL THREE	**PERCEPTUAL CAPACITY LEVEL**	* views of Mts. Hood, St. Helens, Adams and Jefferson everyday without smog from Powell Butte and Council Crest.
LEVEL FOUR	**ENVIRONMENTAL CAPACITY LEVEL**	
LEVEL FIVE	**SUSTAINABLE CAPACITY LEVEL**	* 8.1 million metric tonnes (MMT) or 20% below 1988 levels. (target set by the World Conference on the Changing Atmosphere to reduce the green house effect). The forecast for 2010 shows CO2 emissions rising to 13.9 MMT.
LEVEL SIX	**BIOCENTRIC CAPACITY LEVEL**	

TABLE 10: LAND-RELATED CARRYING CAPACITY CONSTRAINTS

	CAPACITY LEVEL	LAND
LEVEL ONE	**INFRASTRUCTURAL CAPACITY LEVEL**	
LEVEL TWO	**INSTITUTIONAL CAPACITY LEVEL**	**primary constraints** * land use regulations. * zoning regulations. * Green Spaces Master Plan. **secondary constraint** * EPA air quality standards.
LEVEL THREE	**PERCEPTUAL CAPACITY LEVEL**	* the protection of greenspaces within the metropolitan region, such as natural areas, parks, greenways and open space.
LEVEL FOUR	**ENVIRONMENTAL CAPACITY LEVEL**	
LEVEL FIVE	**SUSTAINABLE CAPACITY LEVEL**	* rural resource land.
LEVEL SIX	**BIOCENTRIC CAPACITY LEVEL**	* ecological footprint

TABLE 11: ENERGY-RELATED CARRYING CAPACITY CONSTRAINTS

	CAPACITY LEVEL	ENERGY
LEVEL ONE	INFRASTRUCTURAL CAPACITY LEVEL	* Infrastructural constraints which provide energy for the Portland metropolitan region are not expected to be happening as the energy supply system of the Portland Metropolitan Region is diversified (coal, oil, gas, hydro) and the flow of power is linked with 13 other states.
LEVEL TWO	INSTITUTIONAL CAPACITY LEVEL	* The city energy office of Portland has developed policies to promote energy efficiency in all sectors of the City by ten percent by the year 2000. The annual energy use in 1991 for the City of Portland was $714.2 million, consuming 200.5 million BTUs per year per capita. The institutional constraint (for the city of Portland) is thus 180.5 BTUs per year per capita.
LEVEL THREE	PERCEPTUAL CAPACITY LEVEL	
LEVEL FOUR	ENVIRONMENTAL CAPACITY LEVEL	* energy investment ratio.
LEVEL FIVE	SUSTAINABLE CAPACITY LEVEL	* dependence on unrenewable resources. * depletion of oil reserves. * horizontal/vertical energy ratio
LEVEL SIX	BIOCENTRIC CAPACITY LEVEL	* salmon habitat destruction due to hydropower.

TABLE 12: TRANSPORTATION-RELATED CARRYING CAPACITY CONSTRAINTS

	CAPACITY LEVEL	TRANSPORTATION SYSTEM
LEVEL ONE	**INFRASTRUCTURAL CAPACITY LEVEL**	* 9,279 miles for freeways and arterials regionwide.
LEVEL TWO	**INSTITUTIONAL CAPACITY LEVEL**	**secondary constraint:** * EPA air quality standard.
LEVEL THREE	**PERCEPTUAL CAPACITY LEVEL**	* distaste for traffic congestion. It is estimated that 909.99 miles of roadways (or 13.45% of total) will be congested in 2040. Present levels are 162.47 or 2.45% of the total of roadway miles. This means an 460% increase which is likely to create individual or collective perceptual dislikes for trafic congestion. * commuter times
LEVEL FOUR	**ENVIRONMENTAL CAPACITY LEVEL**	
LEVEL FIVE	**SUSTAINABLE CAPACITY LEVEL**	**secondary constraint:** * oil reserves depletion
LEVEL SIX	**BIOCENTRIC CAPACITY LEVEL**	

TABLE 13: OVERVIEW OF THE MOST IMPORTANT CARRYING-CAPACITY RELATED CONSTRAINTS FOR THE PORTLAND METROPOLITAN REGION

	LAND	WATER	TRANSPORT	ENERGY	AIR
LEVEL 1		1077 mgd	9, 279 miles of freeways and arterials		
LEVEL 2	EPA air quality standard		EPA air quality standard	180.5 BTUs	EPA air quality standard
LEVEL 3	greenspaces	water purity	congested roadways		view of Mt. Hood
LEVEL 4				energy investment ratio	
LEVEL 5	rural resource land	watershed preservation	depletion of oil reserves	depletion of oil reserves horizontal/vertical ratio	8.1 MMT of CO2 emission
LEVEL 6	ecological footprint	preservation of ecosystems habitat		salmon habitat destruction due to hydropower	

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