An analysis of the relationship between sustainable development and the anthroposystem concept

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Abstract: In the 1980s, the concept of sustainable economic development emerged to try to deal with the complex and pervasive aspects of the environmental problem. However, an ecological perspective of sustainability requires taking a holistic approach that uses the ecosphere as a frame of reference. This paper describes the anthroposystem model that philosophically views the notion of sustainability in terms of a human-ecological system functioning within the ecosphere with some considerations on its implications.

Keywords: anthroposystem; sustainable development; industrial ecology; system analysis.

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1 Introduction

In the 1980s**,** the notion and philosophy of sustainable economic development emerged to try to deal with the different aspects of the environmental crisis [1,2]. In many aspects, this movement is quite different from the preceding ones in the sense that environmental matters were more broadly regarded. Unlike wildlife conservation, antipollution, and the zero population growth movements of the past (which emphasised specific problems), the sustainability movement seeks to build a sustainable economic society, meant to satisfy the needs of today's population, without reducing the quality of the environment for future generations. Indeed, the sustainable movement may be the most significant stage of environmentalism "because it implies a thoroughgoing transformation of industrial society" [3].

Although the concept of sustainable economic development is advocated by many environmentalists and decision makers, a number of scholars have pointed out that the concept has problems [4–6]. Verburg and Wiegel [6] remarked that "The resulting ambiguity in the notion of sustainable development undermines the concept".

From the ecological perspective, the concept of sustainable economic development does not facilitate connection in the human mind of a stable society functioning within the ecosphere. The objective of this paper is to describe the anthroposystem concept that enables society to study the holistic nature of the interaction of humankind and its environment. The anthroposystem concept forces society to think in terms of sustainable human systems, not just sustainable economic development.

2 The sustainable system concept

The concept and philosophy of sustainability drew on an idea that has a history of over ninety years, known variously as 'spaceship earth', 'anthroposystem', 'sustainable society', and 'sustainable development' (Table 1). These overlapping notions suggested that the time was right for the concept of sustainability to appear. Regardless of the used term, they all supported the idea of a society in balance with its surroundings, thus, a self-sustainable system.

Table 1 Changing perception of a stable human-environment system

As a conservation concept Conservation means the greatest good to the greatest number for the longest time [7].
As a spaceship earth concept The closed earth of the future requires economic principles which are somewhat different from those of the open earth of the past … The essential measure of the success of the economy is not production and consumption at all, but the nature, extent, quality, and complexity of the total capital stock, including in this the state of the human bodies and minds included in the system. In the spacemen economy, what we are primarily concerned with is stock maintenance [8].
As a federal law It is the continuing policy of the Federal Government, …, to use all practical means and measures, …, in a matter calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfil the special, economics, and other requirements of present and future generations of Americans [9].
As an ecological concept The anthroposystem is the orderly combination or arrangement of physical and biological environments for the purpose of maintaining human civilisation … built by man to sustain his kind [10].

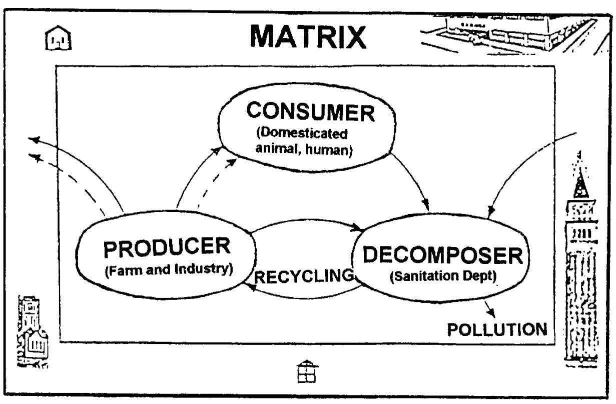
Table 1 Changing perception of a stable human-environment system (continued)

As a sustainable society The sustainable society is one that lives within the self-perpetuating limits of its environment. That society … is not a 'no-growth' society … It is, rather, a society that recognises the limits of growth … and looks for alternative ways of growing [11].
As development Development that is likely to achieve lasting satisfaction of human needs and improvement of the quality of life-by integrating conservation into development process [12].
As an economic definition Is the concept that current decisions should not impair the prospects for maintaining or improving future living standards. … This implies that our economic systems should be managed so that we live off the dividend of our resources, maintaining and improving the asset base [13].
As a United Nations policy Development which meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. Improving the quality of human life while living within the carrying capacity of supporting ecosystems [14].

In discussing 'sustainability', it is easy to get lost in details about our vanishing wilderness, toxic substances, ozone depletion, global warming, acid rain, overpopulation, depletion of resources, steady-state economy, and hundreds of other concerns on one hand and economic growth and ethics on the other. Therefore, it is wise to have an intuitive model that can serve as a framework, to bring the self-sustainable issue back into an ecological perspective whenever it becomes fuzzy.

In 1975 Miguel Santos coined the term anthroposystem referring to "the orderly combination or arrangement of physical and biological environments for the purpose of maintaining human civilisation" [10]. An anthroposystem is a structural and functional unit of the environment; it can be considered a self-contained system, provided that it has an energy source. An anthroposystem requires a sustainable economy to recycle used products and resources, and an economy that minimises pollution. Under the anthroposystem concept, the economic and ecological systems are interwoven and overlapping. As shown in Figure 1, the model is certainly oversimplified, but it is useful in the strategic planning for building a sustainable society and its provides an intellectual philosophy for linking wildlife conservation, pollution, and population issues.

Figure 1 The relationship between the four components of the anthroposystem



The anthroposystem is divided into components, based upon how they influence humankind's chances of survival in a stable environment. At this point, the anthroposystem may be broken down into four major components, which can then be separately defined and analysed. The four components of an anthroposystem, illustrated in Figure 1 are: matrix, producers, consumers, and decomposers. The matrix is composed of all non-living and non-productive parts of the system such as buildings, streets, land, air, and water. It also provides the structure or fabric in which the other components operate. The producer is a component that manufactures or yields products, comprising of three categories: agricultural, industrial, and ecospheric resources. The agricultural producers are green plants, such as wheat, barley, rice, and corn. The industrial producers are the machines and tools utilised by humans to produce shelter, clothing, transportation, etc. The ecospheric resources include parts of the ecosphere used by humans as a source of natural resource. For example, fish are used for economic harvesting and forests are used as a source of oxygen, wood, etc. The consumers consist of humans as well as domesticated animals. The decomposers in the anthroposystem are the waste-water treatment plants, resource recovery plants, electrostatic precipitators, spray collectors or scrubbers, and the natural decomposers of the ecosphere that can eliminate some by-products of society in a sustainable manner. A fully functional decomposer component also serves to maximise the recovery of resources.

Since different human environments or societies are to some degree intertwined, the division of an anthroposystem is a convenient way to organise our thinking. There is, however, a level of human organisation that is larger than the anthroposystem yet easier to see as a united whole. That is the nation, state, or country level. But air, water, transboundary pollutants, other molecules and compounds do not stop at the national boundaries. An anthroposystem exists in the ecosphere and should be viewed in an ecological context. The boundary between an anthroposystem and its surroundings is an imaginary one, used only for convenience in the discussion. An anthroposystem is an artificial system produced by human efforts, and it exists as a result of these efforts.

Ecosystems (for example, ponds and forests) and anthroposystems are interwoven, but a separation between the two enables us to organise these concepts. For obvious reasons, the divisions are mentally constructed and designed in order to cope with the tremendous diversity of the environment. They are not laws of nature; the environment does not come in two convenient categories of labelled ecosystems and anthroposystems. For example, the nitrogen element that forms a part of our eyes, may have been a part of a tadpole's nervous system, that was consumed by the fish we ate. Thus, there is an interrelationship of parts between and within ecosystems and anthroposystems.

In these interrelated or coupled systems, there is a cause-and-effect relationship whereby different variables affect each other, as with the cogs in a machine; turning one part inevitably causes motion somewhere else. As our comprehension of the biogeochemical cycles and energy flow of the earth has become less vague, more and more evidence has accrued, depicting that the separate spheres of the planet are really not separate at all, but are intertwined in both obvious and complex ways. Ultimately, we cannot separate the three general subdivisions (hydrosphere, atmosphere, and pedosphere) from the biosphere, because events in one part of the earth, are intimately connected to happenings elsewhere.

In 1988 Edward Shevardnadze, then foreign minister of the Soviet Union, viewed the world from a very different political perspective yet reached a similar conclusion. In an address to the UN General Assembly, he stated that

> "the dividing lines of the bipolar ideological world are receding. The biosphere recognises no division into blocs, alliances or systems. All share the same climatic system and no one is in a position to build his own isolated and independent line of environmental defense." [15]

It is ironic that the Soviet bloc in which Shevardnadze was such a vital component has fragmented, while the ecosphere has remained intact. Indeed, from an ecological perspective, there is only one ecosphere.

3 Industrial ecology and the anthroposystem model

Many environmental science textbooks use a non-thermodynamic definition of closed and open systems [16,17]. A system is said to be open to matter and energy when these qualities are transferred between the system and its surroundings, while closed system refers to a situation whereby qualities are not transferred between the system and its surroundings. In thermodynamics, a closed system can exchange energy with its surroundings but cannot exchange matter. An open system exchanges both energy and matter with its surroundings. The distinction between open/closed systems that we are using in this essay is not based on thermodynamics.

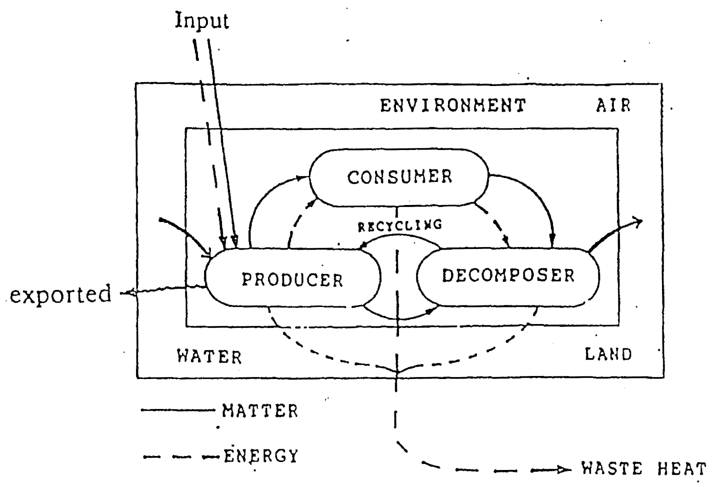
The human system becomes a closed one when material resources are recovered for recycling, reuse, or material conversion, because there is no significant exchange of resources between that system and its surroundings. All wastes are completely treated so that there is no discharge of pollutants into the environment. Hypothetically, in such a closed system, the resource can last indefinitely.

However, the real world differs significantly from the closed and ideal anthroposystem model. First, in every type of manufacturing, raw materials are extracted, refined, processed, and transformed into finished products. Along the way, these processes generate wastes that are inevitable byproducts of industry.

A second reason why the real world differs from the ideal anthroposystem model is based on the second law of thermodynamics. Because of this law, energy used is never completely efficient. This natural law states that whenever energy is converted from one form to another, some useful energy is lost. For example, a car converts the chemical energy stored in gasoline to the kinetic energy of movement. In such a process, 75% of the energy is immediately lost as heat and the same occurs in organisms. For example, glucose is used as energy, but only 40% of the energy is captured as biologically useful, while the other 60% of the chemical energy dissipates as heat.

Furthermore, the consequence of the second law of thermodynamics is that energy cannot be recycled or reused showing that in theory and in fact, real anthroposystems are open systems as far as energy is concerned. Finally, as previously mentioned, the ecosphere is composed of a mosaic that is interrelated with human and natural systems. Thus, human systems tend to be open systems since resources are both imported and exported (Figure 2).

Figure 2 Components of an anthroposystem



Recently, the term industrial ecology has been used to describe the study of the closed loop in which materials cycle and energy flows into production processes [18–20]. Industrial ecology, whose definition is provided in the *White Paper on Sustainable Development and Industrial Ecology,* issued by the Institute of Electrical and Electronic Engineers and quoted in Allenby [21], "is the objective, multidisciplinary study of industrial and economic systems and their linkages with fundamental natural systems." Under industrial ecology, excess materials are put back into the loop to minimise waste. Products used by consumers flow back into production loops through recycling, reuse, or material conversion to recover resources. Ideally, the loops are closed with respect to matter within factories, among industries in a region, and within national and global economies.

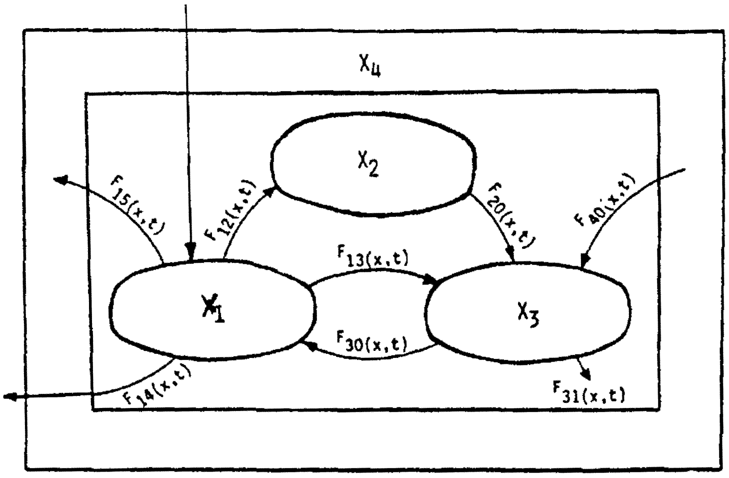
Industrial ecology requires environmental programmes that focus on all aspects of the economy, from product design and manufacturing, to product use and disposal. It requires a biogeochemical cycle or energy flow approach that captures the upstream environmental effects associated with raw materials or energy source selection. For example, when evaluating the resource consumption and pollution generated by the production of particular product, the manufacturing plant is often not the only place to look. There are more cost-effective and larger reductions of resource consumption and pollution generation, which can be found in analysing consumption and pollution from transporting and distributing the product.

Under the concept of the anthroposystem, the biogeochemical cycle and energy flow loops can be defined by a set of coupled differential equations. One for each of the four components (i.e. *X*: dynamic state variables), expressed in terms of matter cycling and energy flow loops between the components (i.e., *F*: nondynamic state variables):

$$Xi = F(X1, X2, X3, X4\ t)$$

where the function maps the *l*-space, where elements or energy are at time *t*, and the real *n*-space or vector space where they are vectors *X* [22]. The equations for matter cycling are provided in Figure 3.

Figure 3 Industrial ecology and the anthroposystem model



Anthroposystem components:

X, = process & modify resources by producer

X_z = consume products

Xs = resource recovery

Xa = extract & recover resources from matrix

Fij = Rate of cycling of matter from i to j

X_i = Concentration of matter in the donor component

X_i = Concentration of matter in the recipient component dX,

dt - FO 1 + F3° -F12 -Fi3 -Fta -Fls

dX_z

dt - F12 -FZo

$_dX^3$ = F2o + F,3 + Fao -Fso -F3,

dX_a

dt - Fls -Fao

4 Conclusions

In recent years, the realisation that the human population is depleting the planet's natural resources and polluting the environment, has generated a strong interest in the study of human environments. The study of humans and their environment covers a very broad range of topics. A part of the human environment includes the combination of physical and biological conditions that affect and influence mankind, as well as the complexity of social and cultural conditions that affect the nature of an individual or the community. In order to study people and their environment, one would need to know art, biology, chemistry, ecology, economics, engineering, physics, psychology, sociology, and just about all of the disciplines found in the university curriculum. The student becomes a 'jack-of-all-trades and a master of none'. To alleviate this dilemma, it is academically convenient to disregard the distinction between humans and their environments and instead, consider these as an interactive unit called the anthroposystem (Figure 1). From the environmental viewpoint, such a model will help the student focus its energy on understanding what is required to form a self-sustainable unit.

Rather than using terms like ‘steady-state economy’, which implies no growth, most politicians prefers the term ‘sustainable economic development’, which suggests a self-sustainable system. The latter concept originated as early as the 1970s, when such comparable terms such as ‘anthroposystem’ and ‘spaceship earth’ entered the environmental lexicon (Table 1). That which gave the sustainable movement a strong impetus was the publication of *Our Common Future* by the United Nations World Commission on Environment and Development in 1987 [1].

However, while economic and ecological systems have become totally locked and interwoven in the anthroposystem, they remain partially divorced when it comes to sustainable development. The anthroposystem gives impetus to the basic scientific principles that the economy is subject to the laws of ecology. From an ecological perspective, the concept of sustainable economic development does not facilitate the connection of a stable society functioning within an ecosphere. The anthroposystem concept, on the other hand, is more holistic and forces people to think in terms of sustainable systems, not just sustainable economic development.

The field of industrial ecology extends the concept of sustainability to manufacturing. Ecology is traditionally defined as the interaction of organisms with each other and with their environment, or as originally defined, “the investigation of the total relationships of the animal … to its environment [23]. From an ecological perspective, industrial ecology may be defined as the interaction of industry with each other and with their environment. Ecologically speaking, the anthroposytem is a broader concept. An anthroposystem is the interacting unit that is form by a society with its surroundings. Consequently, industrial ecology studies the manufacturing processes within an anthroposystem. In practice, industrial ecology seeks to reduce resource throughput, waste, and pollution. Moreover, the field is going through divergence of developmental stages [20].

Environmental policy makers’ preference for the term ‘sustainable development’ rather that ‘steady-state economy’ or ‘anthroposystem’ notwithstanding, the great majority of ecologists and environmental scientists agreed that no technical fix alone could change the stark reality of the fact that infinite growth on a finite planet is impossible. In sum, history and circumstances have locked human society when measured against expectations raised by human wants and needs that are ecologically unacceptable. Ecologists and environmental scientists urge society to acknowledge the constraints of the ecosphere.

Such acknowledgment and public policies that would evolve from it, have not yet occurred. For public decision makers to acknowledge these limits and for society to accept the verdict requires new sets of policies that would focus not only on how to make the economy grow beyond its carrying capacity, but also on how to progress within ecological limits. If sustainable development means progressing within ecological limits, then the anthroposystem seemed inevitable. As several ecologists and environmentalists have observed, when a society reaches its carrying capacity, the distinction among self-sustainable system, anthroposystem, steady-state economy, sustainable development, and industrial ecology will be in degree, rather than in kind.

Despite its shortcomings, the concepts of sustainable economic development or industrial ecology seem to be a viable way for businesses to understand the interdependence of economic prosperity, environmental quality and social equity. This concept may provide the intellectual framework for management theories to include the environment in the decision-making process. Furthermore, the three concepts, anthroposystem, sustainable economic development are not mutually exclusive. In fact, in order to build an anthroposystem, society requires a sustainable economic system and industrial processes that mimic natural ecosystems.

Another item to consider seriously is that the anthroposystem is a model that helps us comprehend the ways in which the real world diverges from the ideal. This, in turn, will help to identify possible targets for action. For example, the agricultural producer component (e.g. croplands and range farms) provides the consumer's daily nutrient requirements. Natural ecosystems also play an economic role. These ecosystems have carrying capacities of their own. What rights should they have? Should ecosystems be given the right to maintain their ecological integrity or will economic consideration be used to veto the rights of their species? This problem is illustrated by the famous snail darter controversy and the battles over the protection of the northern-spotted owl and other species. Apparently, judging by the results of the snail darter and spotted owl debates, as well as other cases, there is a growing surge of opinions that the controversies over the future of natural habitats are becoming less scientific and more political [24].

The anthroposystem model is also a working plan that has a wide range of applications and can be used to formulate other principles and laws. This is especially true if we consider that the interaction of a society and its environment would be difficult to comprehend without clear-cut experimental theories. Today the study of the human environment may be considered largely as a descriptive science. Out of necessity, however, it will become more of an experimental science in the future.

Certain well-formulated generalisations are indispensable to the unification and clarification of the relationship that exist between society and nature. These generalisations will help the examiner form basic theories. These theories, as in other sciences, should be based empirically on observation and experimentation. Increasing scientific sophistication makes it necessary to revise earlier theories.

Few people seem to realise that more progress has been made in dealing with discrete factors of our environment (e.g. with air and water pollution) than with the relationship between humans and their environments. This is primarily due to the fact that everyone can see and feel the immediate effects of the pollutants. However, it tends to obscure the most fundamental issue facing the ecosphere; a failure in the identification, measurement, and inclusion of all the variables interacting to form the various ecosystems and human system.

It is depressing to accept that our environment may be so complex in space and time, that a universal concept such as the anthroposystem must be either imaginary or unrealistic. To avoid the pitfalls of treating life-support systems as oversimplified black boxes, scientists must develop universal theories that clarify, identify and unify sustainable human-environment systems. Scientists must also develop testable theories that explain and predict the behaviour of the 'forest' (the entire human-environment system), not just the trees.

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