DIVERSE PERSPECTIVES OF SUSTAINABILITY

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Summary

The proliferation of definitions of sustainable development is regarded by some as evidence of its contestability. The most widely used definition, taken from the Brundtland Report, is that '*sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*' (WCED, 1987, p.43). This chapter takes a different view that diversity can be a source of richness provided it is handled with a spirit of common understanding.

It considers a variety of perspectives in which the criterion of sustainability of a process can be viewed and attempts to provide a possible common ground for discussions involving groups from different disciplines. If we seek to establish some 'science of sustainability' it needs to be considered basically in three dimensions - social, environmental, and economic, thereby spanning many aspects of natural and social sciences. The natural sciences perspective(s) can hardly be contested but those based on social sciences are very vulnerable. This chapter recognizes these facts and attempts to build pathways to connect the diverse perspectives into a common framework of understanding.

1. Introduction

The term "sustainability" originates from the Latin term *sustinere*, which means "under-hold" or hold from the bottom. It is used to mean ‘ability to keep going’. In the context of our present discussion it implies the security of Earth’s life support systems (LSS) to ensure longevity for all life on the planet including the humans. Every living organism has an inherent urge for longevity, first for itself, and then for its own species through reproduction. Every organism fights for survival both within against infection, and outside itself, with both predators and prey. The fittest survives. This urge is as old as life itself and its manifestation is the drama of life as we see on this planet.

Consider the following quotes for example:

A society grows great when old men plant trees whose shade they know they shall never sit in.
- Greek Proverb

In this proverb a concern for future generations is evident together with the responsibility of the previous generations.

The frog does not drink up the pond in which it lives.
- Chinese Proverb

This proverb cautions against any careless act that may endanger the system that support our life.

Only after the last tree has been cut down
Only after the last river has been poisoned
Only after the last fish has been caught
Only then you will find out that money cannot be eaten
- Cree Indian Prophecy

Here is a clear message that cautions against the dangerous consequences of overexploitation of natural resources. The last line is a sarcastic assertion about the fate of any enterprise which runs on greed and narrow short term economic goals.

Earth provides enough to satisfy every man's need, but not every man's greed.
- Mahatma Gandhi

Mahatma Gandhi reassures that we need not merely blame population growth for shortages if only we can control our wants and try to satisfy our needs.

Thus, human expression of this urge is not new; it has been there long before the present global urge for Sustainable Development (SD) which has just caught global attention.

On November 18, 1992, some of the world’s famous scientists from 70 countries, including 102 of the living scientists who are Nobel Laureates, signed and sent an urgent warning to government leaders of all nations as part of the *United Nations*

Conference on Environment and Development (the "Earth Summit") held in Rio de Janeiro, Brazil in 1992. The Talloires Declaration of October 1990, by the Association of University Leaders for a Sustainable Future, was a significant forerunner to the Rio Summit. The Rio summit was followed by several other events which include: the *Global Conference on Sustainable Development of Small Island Developing States*, Barbados, 1994; the *International Conference on Population and Development*, Cairo, 1994; the *World Summit on Social Development*, Copenhagen, 1995; the *Fourth World Conference on Women*, Beijing, 1995; the *Second UN Conference on Human Settlements, Habitat II*, Istanbul, 1996; The second World Summit on Sustainable Development (WSSD) held in Johannesburg in South Africa in 2002, as a follow up after ten years of the first summit in Rio, and other non-UN forums. All these, and many other events, have raised awareness and contributed to the concept of sustainable development. SD became a subject of active pursuit in academic institutions and an objective of priority in the world's policy and governing bodies. The academics research and provide decision support to the governments. In this process, the subject of SD is researched, formalized and organized by the wide global academic community. SD is defined many diverse ways but the Brundtland definition (WCED 1987): "*development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs*" is now widely accepted and official.

Development is the process of human policy and actions to create provisions that meet needs. As it happened traditionally, government departments of development were in the hands of planners who were mainly economists. Consequently development has often been equated to growth in terms of GDP, GNP etc. but this view has changed now especially with the emphasis on sustainability which cannot be assessed in such simple numerical entities. Imagine flying a jumbo jet with the help of just an altimeter and an anemometer. Therefore development is now regarded as a change that brings about an improvement in the welfare of society and conservation of natural resources.

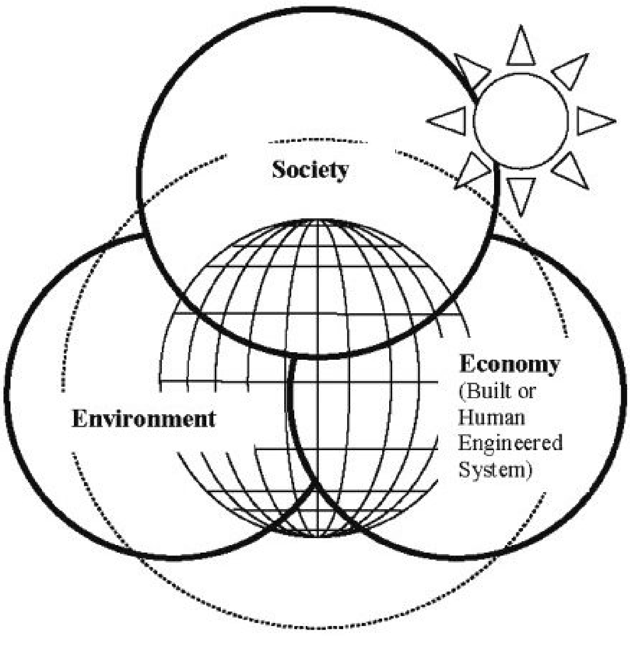

Figure 1: The grand scenario of the Earth system viewed as three interacting subsystems

The Brundtland definition is from the point of view of human society. It is understandable even to a nonprofessional. Although there is no explicit mention of the natural environment, inter- and intra-generational equity specification implicitly carries with it the condition on the natural environment. Otherwise, how can one think of equity within and across generations without caring for the environment?

Some economists think that inter-generational equity is taken care of by the overlap between adjacent generations. But the situation with overlapping generations needs to be handled with great care. That is, the overlap as a recurrence must specify that the same conditions must be maintained at the same level for all generations.

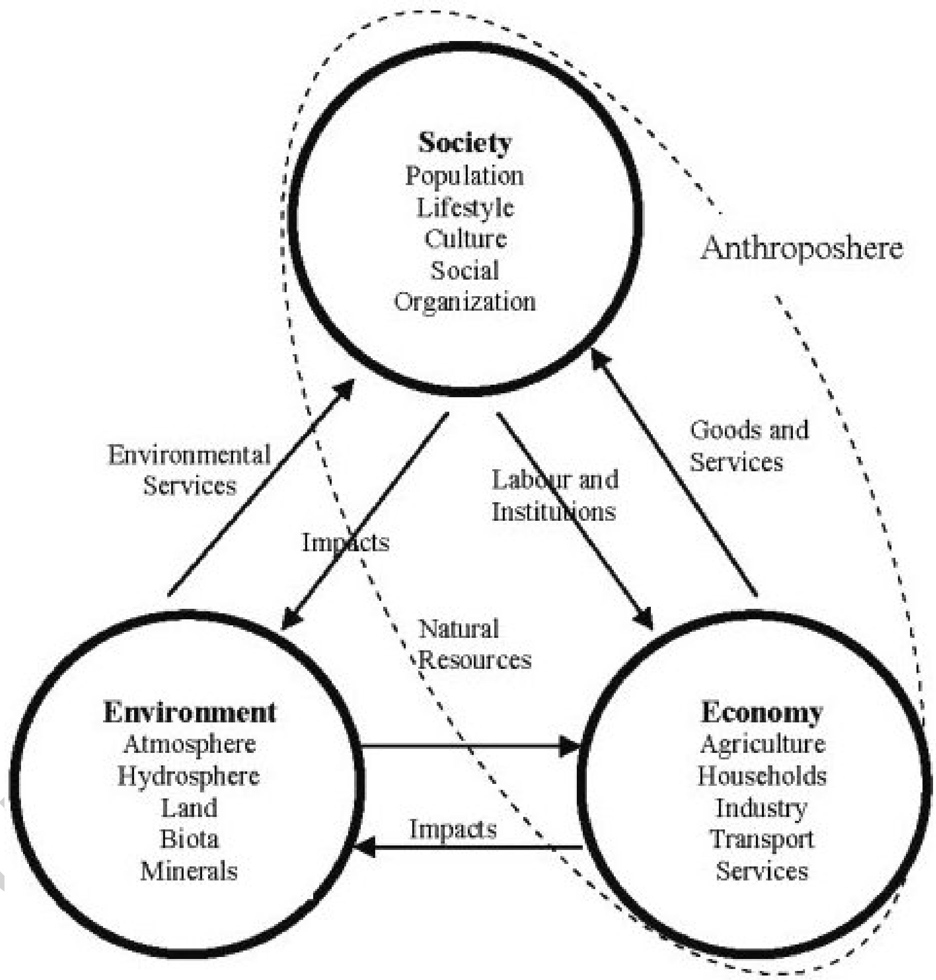

Figure 2. The three subsystems of the Earth system with their interactions

However, since professionals have to develop a policy for implementation they need to operationalize the definition. The proliferation of definitions and interpretations of SD seems to be caused by efforts to operationalize the Brundtland definition. But many of these definitions and interpretations are contested and actively debated. We will not enumerate them here as these arise from the diverse perspectives from different positions taken in the grand scenario. We will show that they can fall into three main categories. For this we consider the grand scenario in the widely accepted form shown in Figure 1 in which the total spatial view of sustainable development refers to the whole of planet Earth considered as three major subsystems in close interaction. Three ‘pillars’, Society, Economy, and Environment are distinguished in this picture of the grand Earth system. The interactions among these subsystems of the Earth System are shown in some detail in Figure 2. One may combine Society and Economy into one, as the Anthroposphere which is the well known model of the Human Economy. For sustainable development, we consider a model of the anthroposphere (human economy) in close interaction with the natural environment.

If one takes position on one of these pillars, a perspective with reference to that pillar emerges in a language typical to that position. If for instance, one takes the position of the **anthroposphere**, which is the whole human economy, the perspective of sustainable development that emerges from this position is characterized by the language of economics, social and political sciences. Development is often equated to growth in terms of GDP, GNP etc. but this view has changed now. Daly (1996) redefines sustainable development in an **ecological setting** as "*development without growth past **carrying capacity***," or in general terms "**development of quality, without growth in quantity.**"

2. Thermodynamics of Sustainable Development: A Natural Sciences Perspective

A point of view with reference to the **natural environment** will obviously be in the setting of natural sciences. Consider a perspective based on **thermodynamics**. Entropy is a term in thermodynamics that characterizes the quality of energy. High entropy signifies low quality in the sense that the amount of energy available for use is low and low entropy on the other hand implies that the amount of usable energy is high. When entropy is at the maximum, the situation is thermodynamic equilibrium, somewhat like death.

In the Earth’s biosphere, which is a closed system, the processes of photosynthesis capture and store the incoming solar energy. The local entropy of the Earth System is thus reduced due to the captured and stored solar energy. In any open system, on the other hand, entropy is always on the increase. Ilya Prigogine is credited for the concept of the so called *dissipative structures*. In many of the publications on this concept, there are discussions on broken symmetry, formation of patterns and structures with increased complexity due to the flow of energy from outside into a local system. The Second Law of Thermodynamics is often brought into the picture as an inevitable law of nature. It is the law of irreversibility of processes and the arrow of time is pointed towards the end that is thermodynamic equilibrium from which there is no return.

A well known statement in *Sanskrit* says *jaatasya maranam dhruvam* (The death of the born is certain). This in fact deeply implies the Second Law of thermodynamics. The entropy of any system will always increase and take the system towards thermodynamic equilibrium which is *death*. In this sense life should be considered as a system far away from thermodynamic equilibrium. Life exists only in a local system and in the *end* it has to *culminate in death*! Life can only exist in cycles in which order is created out of disorder; complexity is developed out of simplicity, of structures. Molecules of biotic elements are more complex than those of abiotic elements.

The present author is confused with the term *dissipative structures.* The term *dissipation* is depressive as it is associated with energy and especially with *waste* of energy and what is important here is not that kind of *dissipation*-throwing way of energy which cannot be used. The author would consider *entropy shedding structures* as a more sensible term in the context because such structures, especially biological structures such as cells, organisms, societal structures, etc keep up their structures by using the energy flowing into them from outside. *Nothing is free of charge!* It is a purely local phenomenon but nevertheless that is what we have to focus on in the context of sustainability of life on our planet in the universe whose fate we do not know and its time scale is comfortable to us.

In this perspective, we may rephrase the definition of sustainable development as: *development that maintains the complexity of the structure of the earth's biosphere by letting it maintain its capacity to shed entropy such that the growth of Earth System Entropy is arrested, and better still, kept at a reduced level.*

We can use complexity as a *synonym* for *life- order out of disorder, pattern out of randomness*. *Complex* certainly because we still do not understand life! It is better to take the positive meaning of complexity- that is, life, without reference to our *ability to understand*.

Life is a state that is far from thermodynamic equilibrium. Thermodynamic equilibrium, the state of maximum entropy, is death.

After all, to be able to *live*, that is to *spend or dissipate,* we first have to *earn,* conserve, store or *reduce entropy*. That is what the complex structures of life need, they have to earn (store energy received from an external source or shed entropy) and then to live (spend) there must be life (structures capable of shedding entropy).

The quality of natural resources can also be reckoned in terms of generalized entropy for the purpose. For example, water which is free from contaminants and/or possesses good hydraulic head can be associated with low entropy. When it is polluted and/or present in a state that is not easily accessible, it is of high entropy. Concentrated deposits of substances on the earth's surface form useful sources of natural resources, but if the substances are randomly and widely scattered, they become poor resources. Therefore, sustainable development may be dubbed in the language of thermodynamics as '*development that ensures arrest, and better still if it causes decrease, of entropy of the Earth System.'*

This is a language that may look weird to others who are not familiar with thermodynamics, especially economists, who take an active role in drawing policies to put development into practice. Transdisciplinary efforts must bridge the gap and make everyone to appreciate the viewpoints of others.

3. A Systems and Control Perspective of Sustainable Development

A **systems and control** view point attempts to present a unified perspective in which the various subsystems and their interactions are captured in the perspective. In the setting of systems and control, development is considered as the process of making provisions to meet the needs (Figure 3).

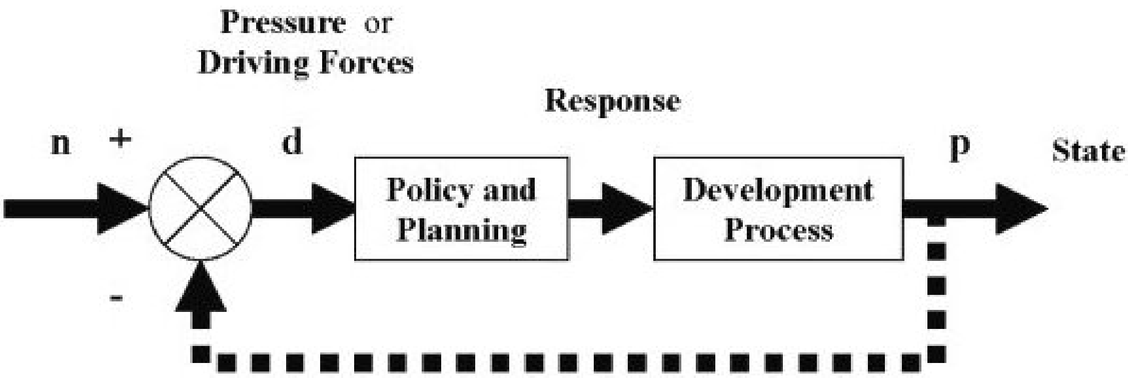

Figure 3. Development as a process of reducing deficiencies

Maslow (1954) classified and ranked human needs as:

- Self-actualization needs
- Esteem needs
- Belongingness and love needs
- Safety needs
- Physiological needs

The needs may be denoted by a vector $\mathbf{n} = [\mathbf{n}_m \vdots \mathbf{n}_s \vdots \mathbf{n}_e]^T$, where the subscripts m, s, and e respectively denote the material, social and ethical components. The first two are regarded as basic needs. Material needs are related to the requirements of air, water, food, shelter, etc. Social needs are related to safety, security, belongingness, acceptance in society, esteem by society, self esteem etc. At the ethical level are needs related to meaningfulness, aesthetics, perfection, justice, service, truth, love etc. Quantitative characterization of the socio-cultural ethical components is not as easy as that of the material components. The process of development (Fig.3) is to be driven by **d** to a develop **p** such that **d** is reduced in some sense as far as possible. It is important to recognize which needs are to be met by which kind of provisions. According to the structure of the needs vector, these are met by a vector of provisions: $\mathbf{p} = [\mathbf{p}_m \vdots \mathbf{p}_s \vdots \mathbf{p}_e]^T$, where the subscripts denote the same as in the needs vector.

The term ‘capital’ is typical to the world of economics that traditionally dominated and which continues to play the key role the field of development, as the entity of investment necessary to meet the needs.

The World Bank took the term ‘capital’ that is used in the context of traditional economic development and extended to the multidimensional context of sustainable development. Natural resources are denoted as ‘natural capital’ and are used to build the so-called ‘built capital’. This is also referred to in various ways as economic capital, human made capital, produced capital or human engineered capital. The systems and control description of the problem of sustainable development may be based on the partition of the global state into three major sub-vectors: natural capital (natural environment), built capital (economy), and social capital (society).Consequently, the global wealth is denoted as a multidimensional state vector with components as follows

$\mathbf{x}_{\mathrm{N}}(t)$ = **Natural capital** refers to a natural stock (e.g., a forest), which produces a flow of goods (e.g., new trees) and services (e.g., carbon sequestration, erosion control, habitat). Natural capital can be divided into renewable and non-renewable components. It is measured through six components: agricultural cropland, pastureland, timber, non-timber forest benefits, protected areas and non-renewable materials (metals, minerals, oil, coal, gas). Some renewable resources are not considered. It is an extension of the notion of economic capital (manufactured means of production) to environmental 'goods and services'.

$\mathbf{x}_{\mathrm{B}}(t)$ = **Built capital** (Human Engineered Systems) or produced assets are measured in the categories of fixed capital assets, including machinery, vehicles and buildings. Built capital is the result of some transformation of natural capital through economic activity. It is required in the form of assets with potential for use; it makes a range of opportunities available for the society to freely choose to attain desired level of welfare.

$\mathbf{x}_{\mathrm{S}}(t)$ = **Social (**including **cultural capital** and **human capital)** is the wealth of our society in terms of knowledge, skills and innovations. It is *cultural software* that enables the development process.

$\mathbf{x}_{\mathrm{I}}(t)$ = **Institutional capital** is the organizational ability and social structure of institutions that a society has its disposal.

$\mathbf{x}_{\mathrm{N}}(t)$ and $\mathbf{x}_{\mathrm{B}}(t)$ are physical components of the state vector and they obey the laws of nature while $\mathbf{x}_{\mathrm{S}}(t)$ and $\mathbf{x}_{\mathrm{I}}(t)$ do not.

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Bibliography

Allenby, B. R, (1999) *Industrial Ecology – Policy Framework and Implementation*, Prentice Hall. [A good treatise on the principles and applications of industrial ecology]

Aoki, M., (1976) *Optimal Control and System Theory in Dynamic Economic Analysis*, North Holland, Amsterdam [A well known text book that deals with the application of optimal control theory to resource allocation in economics]

Clayton Anthony M H., and Nicholas J Radcliffe, (1996) *Sustainability – A Systems Approach*: Earthscan

Publications Ltd [A systems approach to sustainable development is outlined in this book]

Costanza Robert, (1991) *Ecological Economics: The Science and Management of Sustainability*: Columbia University Press.[A perspective of ecological economics in the context of sustainable development]

Daly, H. E. (1996). *Beyond Growth: the Economics of Sustainability.* Boston, Beacon. [A book that follows an earlier publication- Limits to Growth. It looks at neo-classical economics from the perspective of sustainability, and presents foundations of a new approach including non-growth development.]

Georgescu-Roegen, N. (1971). *The Entropy Law and the Economic Process*, Cambridge, MA; Harvard University Press.Georgescu-Roegen, N. 1971. [A path breaking book which outlines new theories of production and utility based on the physical laws of nature.]

Gintis, Herbert (2000). *Game Theory Evolving*, Princeton, NJ, USA, Princeton U. Press. [This book is an introduction to evolutionary game theory with relevant information from anthropology biology, and psychology].

Hanna, Susan S. (1997). The New Frontier of American Fisheries Governance, *Ecological Economics*, 20, 221-233. [This paper discusses fisheries governance in an institutional framework.]

Kunte A., Kirk Hamilton, John Dixon and Michael Clemens, (1998) *Estimating National Wealth: Methodology and Results – Indicators and Environmental Valuation*: Environment Department, The World Bank, January 1998. [A comprehensive account of the methodology for national accounting]

Maslow A. H. (1954). *Motivation and Personality*. New York: Harper and Row. [The author organizes human needs in a hierarchy, ranging from physiological needs and safety needs to love, esteem, and self-actualization.]

Meadows, D. (1998) *Indicators and Information for Sustainable Development*, The Sustainability Institute.[Indicators for monitoring sustainable development are proposed]

Perrings C. (1997) *Economics of Ecological Resources*, Edward Elgar, UK and US. [A well known book giving a perspective of the economics of ecological resources]

Sen, A. (1999) *Development As Freedom*. p. 153. New York: Alfred A. Knopf, Inc., [A book that has to be read by all development practitioners not just those in developing nations]

Tisdell, C.A. (1999). *Biodiversity, Conservation and Sustainable Development*, Cheltenham, UK, Edward Elgar. [Discusses the constraints on economic growth due to conservation of biodiversity.]

United Nations (1993) *Agenda 21: Programme of Action for Sustainable Development*, United Nations, and New York. [The official declaration of the Rio Summit]

World Commission on Environment and Development (WCED). (1987). *Our Common Future:* New York, Oxford University Press. 400 pp. [A document that culminated in the organization of the Rio Summit.]

Biographical Sketch

GANTI PRASADA RAO was born in Seethanagaram, Andhra Pradesh, India, on August 25, 1942. He studied at the College of Engineering, Kakinada and received the B.E. degree in Electrical Engineering from Andhra University, India in 1963, with first class and high honours. He received the M.Tech. (Control Systems Engineering) and Ph.D. degrees in Electrical Engineering in 1965 and 1970 respectively, both from the Indian Institute of Technology (IIT), Kharagpur, India.

From July 1969 to October 1971, he was with the Department of Electrical Engineering, PSG College of Technology, Coimbatore, India as an Assistant Professor. In October 1971 he joined the Department of Electrical Engineering, IIT Kharagpur as an Assistant Professor and was a Professor there from May 1978 to June 1997. From May 1978 to August 1980, he was the Chairman of the Curriculum Development Cell (Electrical Engineering) established by the Government of India at IIT Kharagpur. From October 1975 to July 1976, he was with the Control Systems Centre, University of Manchester Institute of Science and Technology (UMIST), Manchester, England, as a Commonwealth Postdoctoral Research Fellow. During October 1982- November 1983, May-June 1985 and May-June 1991, July 2003, September 2004, and

August-September 2007 he visited the Lehrstuhl für Elektrische Steuerung und Regelung, Ruhr-Universität Bochum, Germany as a Research Fellow of the Alexander von Humboldt Foundation. He visited the Fraunhofer Institut für Rechnerarchitectkur und Softwaretchnik (FIRST) Berlin in July 2003, September 2004 and September 2007. He was a visiting professor in the summer of 2003 at University Henri Poincare, Nancy, France, and Royal Society Visiting Professor at Brunel University, UK during the summer of 2007. During 1992-1996 he was Scientific Advisor to the Directorate of Power and Desalination Plants, Water and Electricity Department, Government of Abu Dhabi and the International Foundation for Water Science and Technology where he worked in the field of desalination plant control. He is presently a Member of the UNESCO-EOLSS Joint Committee.

He has authored/coauthored four books: *Piecewise Constant Orthogonal Functions And Their Applications to Systems and Control, Identification of Continuous Dynamical Systems- The Poisson Moment Functional (PMF) Approach* (with D.C. Saha) , *Generalised Hybrid Orthogonal Functions and their Applications in Systems and Control* (with A. Patra) all the three published by Springer in 1983, 1983 and 1996 respectively, *and Identification of Continuous Systems* (with H. Unbehauen) Published by North Holland in 1987. He is Co-Editor (with N.K. Sinha) of *Identification of Continuous Systems - Methodology and Computer Implementation,* Kluwer, 1991. He has authored/coauthored over 150 research papers.

He is on the Editorial Boards of *ENCYCLOPEDIA OF DESALINATION AND WATER RESOURCES, International Journal of Modeling and Simulation, Control Theory and Advanced Technology (C-TAT), Systems Science (Poland), Systems Analysis Modeling and Simulation* (SAMS) and *The Students' Journal of IETE (India).* He was Guest Editor of two Special Issues: one of *C-TAT on Identification and Adaptive Control - Continuous time approaches,* Vol.9, N0.1, March 1993, and *The Students' Journal of IETE on Control*, Vols. I&II, 1992-93. He is on the Honorary Editorial Advisory Boards of *The American Biographical Research Institute* and UNESCO-EOLSS Joint Committee of *Encyclopedia of Life Support Systems*. He organized several invited sessions in IFAC Symposia on Identification and System Parameter Estimation, 1988, 1991, 1994 and World Congress 1993. He was a member of the International Program Committees of these Symposia during 1988-1997. He was a member of the IFAC Technical Committee on Modelling, Identification and Signal Processing in 1996. He was Chairman of the Technical Committee of the 1989 National Systems Conference in India. He is co-editor (with Achim Sydow) of the book series "*Numerical Insights Series*" published by Taylor and Francis. He is a member of the Advisory Board of the Internal Study Group on Water and Energy Systems (ISGWES).

Since 1996, Prof. Rao has been closely associated with the development, from the conceptual stages, of the *Encyclopedia of Desalination and Water Resources* (DESWARE) and *Encyclopedia of Life Support Systems* (EOLSS), two major publications of Eolss Publishers, Oxford, UK.

He received several academic awards including the IIT Kharagpur Silver Jubilee Research Award 1985, The Systems Society of India Award 1989, International Desalination Association Best Paper Award 1995 and Honorary Professorship of the East China University of Science and Technology, Shanghai. He was elected to the Fellowship of the IEEE with the citation ' FOR DEVELOPMENT OF CONTINUOUS TIME IDENTIFICATION TECHNIQUES'. The International Foundation for Water Science and Technology has established the 'Systems and Information Laboratory' in the Electrical Engineering Department at the Indian Institute of Technology, Kharagpur, in his honor. He is listed in several biographical volumes.

Prof. Rao is a Life Fellow of The Institution of Engineers (India), Life Member Systems Society of India, Indian Society for Technical Education, Fellow of The Institution of Electronics and Telecommunication Engineers (India), Fellow of IEEE (USA) and a Fellow of the Indian National Academy of Engineering.