Social Diversity and Technology for Sustainable Development

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DIVERSITY: THE EMERGING CENTRAL THEME

Nature abounds in diversity; material, biological, cultural and social. Science and technology are grasping this reality and we briefly review these changes.

Science of Material World: The physical world is full of regular and irregular coastlines, forests, mountain chains, ice sheets, and star clusters. Matter is manifested in diverse forms. Henri Bergson, one of the foremost philosophers of this century observed "The universe is not made, but is being made continually. It is growing, perhaps indefinitely...." The amalgamation of regularity and irregularity is considered as the very essence of growth of the physical or material world.

To understand the material world, the central concern of the natural sciences is shifting from uniformity and order to seek answers as to how the universe is advancing from a featureless simplicity to complex forms on all scales, from molecules to galactic clusters. A characteristic feature of complexity, chaos and disorder is that, by very nature, complex forms have a high degree of individuality. For example, we recognize the sakura tree as a sakura tree but no two trees are the same. This individuality in diversity can not be comprehended by the conventional scientific approach, rooted in the Newtonian paradigm. The conventional paradigm in which change is smooth and continuous is unsuited to deal with irregular real systems because:

(i) complexity often appears abruptly and not through slow smooth changes
(ii) complex systems often have a large number of degrees of freedom
(iii) systems are open to interaction with the complex environment that drives them
(iv) these systems are mainly non-linear.

An entirely new science paradigm is emerging to replace the three hundred years of entrenched philosophy; natural sciences are moving away from concerns with uniformity to concerns with diversity and complexity (Davies 1989).

Technology: We next turn to technology. Technology is changing in the direction of meeting the diverse requirements of individuals: from 'mass production' of uniform goods and services to those tailored to the needs and likings of individuals. We quote from Ayres (1992):

Computer-integrated manufacturing (CIM) — or 'flexible automation' — is a revolutionary response to the 'complexity — reliability — variety' barrier. In brief products are becoming more complex, quality control is becoming more difficult and customers are less satisfied with standardization. Managers of manufacturing firms face several critical questions and some strategic choices. Among them are the following: How must the firm change internally to compete successfully in the future? What technologies must be mastered and adopted 'in house', and what can be safely contracted out? Is there an important distinction to be made between 'human — centred' and 'machine — centred' approaches?

Fig. 1 shows the emergence of growing complexity in technological products (Ayres 1992).

In addition to the complexity in the final product the approach to *manufacturing process* itself is undergoing a change. Similar to the understanding of natural phenomenon, where open systems interacting with a complex environment are now being grasped, it has been realied that manufacturing is essentially an interconnected complex system, in which one step or stage depends upon all the others, i.e. a holistic approach is necessary. The conventional concept implied in Taylorism that the performance of an enterprise can be maximized by maximizing the performance of individual task elements is being questioned.

The paradigm shift in the 'manufacturing process' component of technology can be summarised as follows (Ayres 1992):

1880s : *The English System*: Application of power-driven machines to the old production methods used in the pre-industrial period.

1850–1920: *The American System*: This emphasized standardization of products and interchangeability of parts.

1920–1960: *Taylorism*: This emphasized mechanical integration, assmbly line, vertical integration and optimization of individual tasks.

1960–1985: *Quality Control*: This added to Taylorism, new techniques such as statistical quality control, total quality control and applications of computers to individual functions.

1990– : *Flexible and Holistic Approach*: The emphasis is on functional integration, flexibility, decentralization, horizontal management, team work and networking.

These changes are shown in Fig. 2 (Ayres 1992).

This new emerging technology paradigm, moving away from ordered and standardized products and processes to complex flexible and holisticc view, in its essence, is analogous to the emerging paradigm in natural sciences discussed earlier.

It is under this new overall paradigm of science and technology that the concept of human-centred systems has emerged in Europe (Gill 1990) and Japan (Sato 1991). According to Sato, this concept in Europe is rooted in the cultural diversity amongst the European nations and their industrial cultures.

In summary the concept of human-centred systems can be defined as (Cooley 1987):

> human centred systems ought to support human skills and acquisition of new skill and the design of these systems should consider technology as a tool and not a machine.

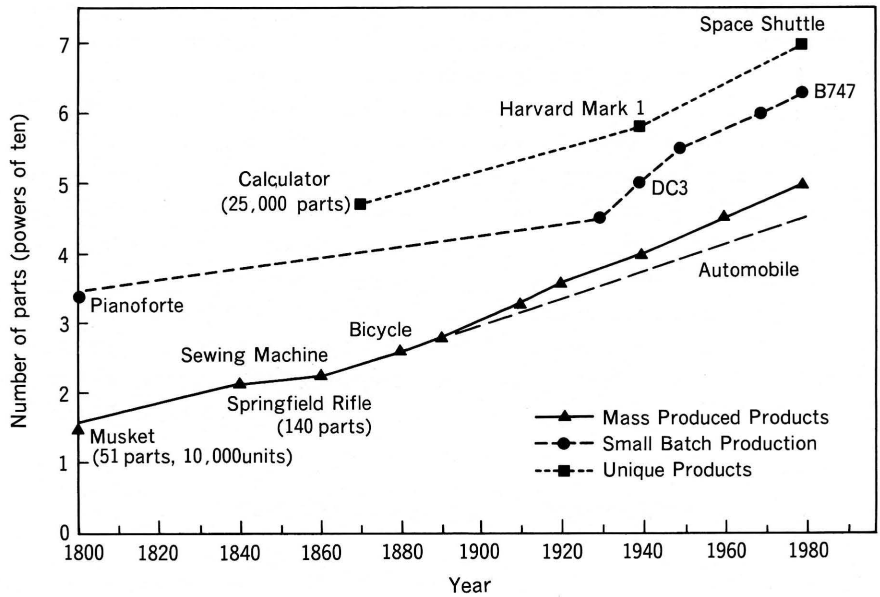


Fig. 1. Complexity trends.

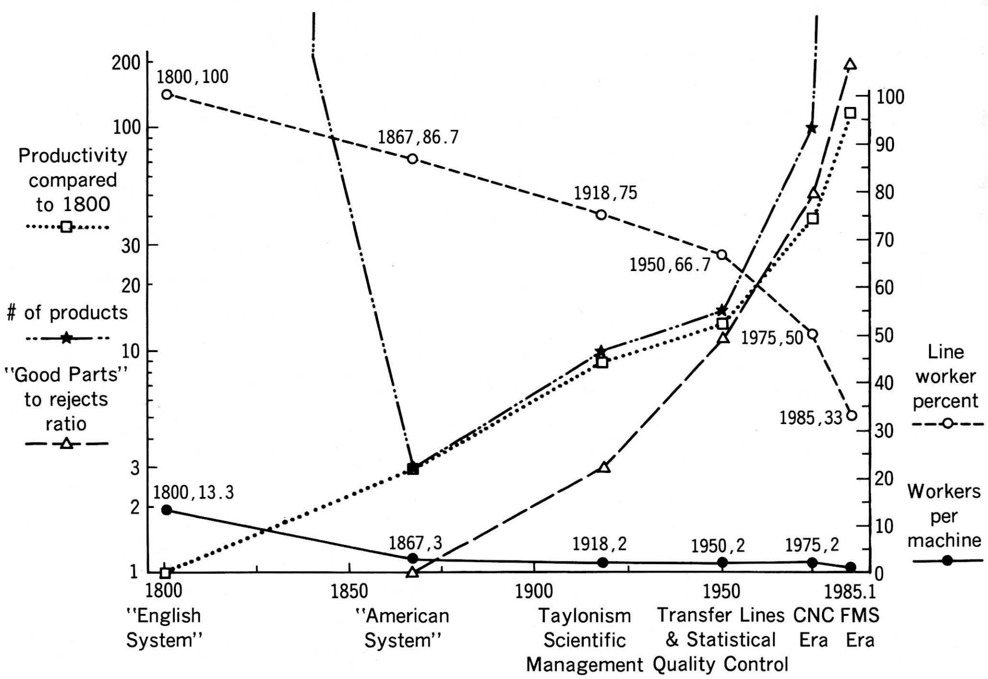


Fig. 2. Six epochs in process control.

The implication of this definition is that a 'machine' (or production process and technology) must be situated in the context of creativity, imagination, intuition, expertise etc., i.e. in the characteristics of "skills' of an individual.

The emergence of new paradigm in science and technology reflects the changing global scenario. Globalization of trade, finance and production systems, coupled with emphasis on decentralization and liberalization are leading to inter connections between different social systems, both internationally and intranationally. The complexity, plurality and instabilities inherent in connected diverse social systems are giving rise to new social, economic and technological processes (Xinhua 1992).

The essential point is to realise that these complexities and plurality are no longer hindrances that are to be avoided, but constitute the very core on which our understanding of nature and human kind is being built (Hansson 1991). This is a radical change and has direct bearing on our approacch to the issue of environmental crisis.

DIVERSITY AND ENVIRONMENT

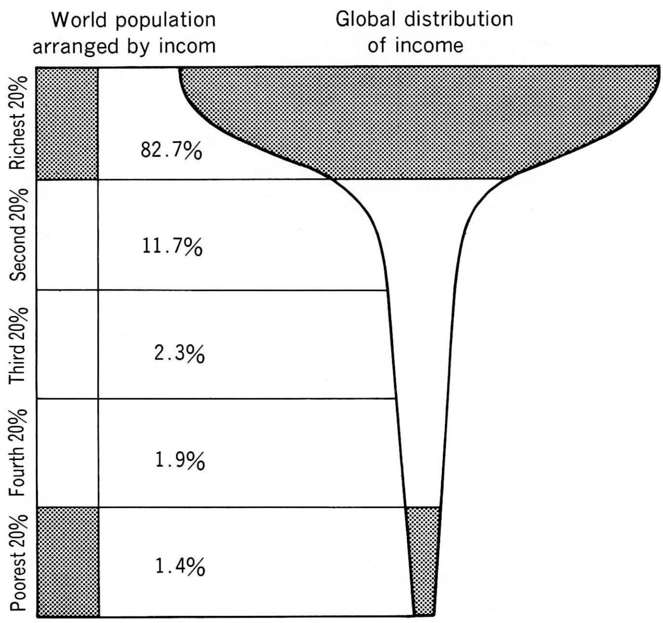
Events leading up to the 1992 Earth Summit in Rio highlight the deep concern of the world community at the deteriorating environment and possible destruction of our eco-system. However, the choice is not between development and environment, it is between environment-sensitive and environment- insensitive forms of development.

The basic elements of environmentally sensitive form of development are (Sachs 1992):

1. Social sustainability: The aim is to build a civilization of beings with equity in *assets and income distribution.*
2. Economic sustainability: Economic efficiency should be evaluated in *macroscopic terms* rather than only through the criterion of micro-entrepreneurial profitability.
3. Ecological sustainability: Intensifying the use of the resource potential of *diverse* ecosystems with minimum damage to the life supporting systems.
4. Spatial sustainability: Balanced distribution between rural-urban through exploiting the potential of *decentralized* industrialization linked with new technology.
5. Cultural sustainability: Devising *local* ecosystem-specific, *culture-specific* and *site-specific* solutions.

The connection between environmental degradation and economic disparities has been extensively discussed in the literature: "It is ironic that significant environmental degradation is usually caused by poverty in the South – and by affluence in the North" (UNDP 1991). Fig. 3 gives an indication of these disparities.

The strategies for sustainable development, the five dimensions mentioned above, require ability to deal with diversities in incomes, ecosystems and cultures on one hand, and a movement towards decentralization of production on the other. It is important to note that the conventional paradigms of science and technology considered diversity and complexity as hindrances and aberrations. The conventional view has



Source: UNDP, Human Development Report, 1992.

Fig. 3.

been that progress in science and technology proceeds either by ignoring these dimensions of reality, or by trying to eliminate these through usual technological mechanization and standardization. The inherent limitations of those approaches indicated a dead end, a saturation or plateuing of progress. The notion or perception of a 'crisis' of the environment is partly embedded in the saturation of the conventional science and technology paradigm. We now proceed to examine how does the new science and technology paradigm propose to overcome those limitations.

EMERGING TECHNOLOGY PARADIGM AND ENVIRONMENT

Within the new technological paradigm, the term emerging technologies refers to science intensive and knowledge based technologies. These technologies provide flexible production processes and allow for:

1. Decentralised production
2. Descaling
3. Better use of local resources and skills
4. Reduced affluent discharges
5. Improved energy efficiencies
6. Lower capital/labour ratios.

The above features make such technologies compatible with the five dimensions of sustainable development given by Sachs. They provide increased rural employment opportunities and help redress the rural-urban imbalance. An alternate small-scale industrialization system based on microelectronics, biotechnology and new materials, specially relevant for developing countries is emerging (James *et al.* 1991). These technologies can be effectively targeted to populations who otherwise have not yet been able to derive benefits from the results of advances in science.

We shall briefly indicate as to why science intensive production processes have these features. An example will then be provided. Finally the concept of bio-villages will be discussed as a possible implementational strategy.

FLEXIBILITY IN NEW TECHNOLOGIES

In its simplest form, a production technology is a method of combining the following five 'Ms':

M1: Machine/know-how
M2: Materials, including energy
M3: Money
M4: Management and Manpower
M5: Market and user needs

Any production process requires a synchronisation of the five Ms. Artisanal technologies use simple tools for M1, locally available materials M2, minimum investments M3, family unit for management and manpower M4 and small surrounding markets M5. Available industrial technologies are based on large M1, M4, M3 and M2 procured from different locations to produce standard goods M5.

It is clear that machine or know-how i.e. M1 in itself does not specify the technology. Indeed it is M2, M3 and M4 that decide the type of machinery or know-how that can produce M5, i.e. meet the user or market demand.

The main limitation of conventional technologies in use is that in the absence of detailed knowledge of materials M2 and of know-how M1, only a limited type of combinations of Ms i.e. technologies are tried. Artisanal technologies remained confined to limited markets and traditionally tried materials.

Developments in informatics, biology and material sciences have improved our understanding of process know how i.e. M1 and of materials M2. Microprocessors enable us to make machinery that is flexible and thus can easily adjust to a variety of materials and markets. This knowledge can now be used for combining Ms in new ways. Based on this knowledge new combinations or new technologies can be developed with desired type of Ms so that the production process has better environmental features. The table below compares features of these new technologies with those of conventional technologies.

CONVENTIONAL TECHNOLOGIES

Artisanal

M1: Tools, jigs and fixtures
Traditional processes (physical and chemical)
M2: Local traditionally used materials and human/animal power
M3: Small investments
M4: Family unit
M5: Local market and traditional uses

Industrial

M1: High cost machines. Know-how based on chemical or physical processes
M2: Metals, minerals, chemicals and petroleum products. High energy requirements.
M3: Large investments with high capital/labour ratio
M4: Factories and hierarchical management structure
M5: Standardised products transported from manufacturing site to spread out markets

NEW TECHNOLOGIES

M1: Small machine using informatics and flexible manufacturing.
Bio-chemical processes and a variety of new chemical and physical processes.
M2: Locally available materials, including hitherto unused bio-mass (produced through bio-technologies). Low energy requirements.
M3: Capital/labour ratios less than those in conventional industrial technologies.
M4: Smaller production units, family size units and less hierarchical than conventional industrial technologies.
M5: Standardised products and tailor made products. Both small and large markets.

Informatics, new materials and bio-technology, therefore, provide a new small-scale industrialization strategy as an environmentally-sensitive alternative economic and institutional mechanism (James *et al.* 1991) and enhanced opportunities for rural industrialization.

EXAMPLE OF NEW TECHNOLOGIES

As an example, we give salient details of flexible production and batch processing systems proposed by the Centre for Technology and Development (1991). This new technology is applicable to leather, fruit processing, pottery and ceramics, metalware and other such sectors. In India both artisanal and several conventional industrial technologies are being used in these areas. The new technology is to be based on micro-processor control systems. It derives its approach from the successful demonstration of a model for Rural Artisanal Leather Industries in Himachal Pradesh, India, being extended to an All India Coordinated Programme supported by the Department of Science and Technology, Government of India.

The technology being developed has the following features:

* Low cost automation tools that can be handled by relatively unsophisticated plant operators (e.g. family members of vegetable-fruit producers).
* Instead of a fixed plant for a specific product, the technology uses a generic plant. Several products can be processed. For example, different types of apples, oranges, tomatoes etc. can be converted into fruit juice of quality comparable to the best available in the market.
* Descaling is possible so that individual vegetable/fruit grower or small cooperatives can run the plant economically. Low volumes of batch production being compensated by the range of products that can be processed.
* Reduction in wastage. Special sensors combined with software cards will enable use of fruits and vegetables of different qualities which otherwise go waste.

These features have obvious environmental advantages. Wastage is reduced, transport of material and associated energy consumption and pollution is drastically cut. The plant itself is least-power consuming as it uses microprocessors for quality control of process parameters and human labour for cutting and crushing of fruits/vegetables. The capital/labour ratio is better than conventional industrial technologies. By locating small production units closer to the producers of raw materials migration and associted problems of urbanisation are avoided.

Although salient details have been indicated with reference to food processing industry a similar scenario emerges for pottery and ceramics,, leather, metal ware etc..

IMPLEMENTATIONAL STRATEGY – BIO-VILLAGES

Implementational strategy has to be founded on the existing occupational scenario in rural areas. New technologies have to increase productivity and profitability of these occupations. Farming and artisanal industries are the two main occupations in rural India. New technologies described in the earlier section indicate their relationship with artisanal occupations. The concept of bio-villages integrates farm and non-farm occupations for sustainable rural development.

Additional comments are necessary on bio-mass as a material resource M2 to appreciate the concept of bio-villages.

To start with biomass productivity per hectare should increase. This is possible through better soil health and water management, use of bio-pesticides, bio-fertilizers, tissue culture, propagation of superior strains and through agro-forestry. The biomass can then be used for food, fodder, energy and as raw material for industrial purposes. For example, agricultural raw materials can be used for non-food purposes.

The whole crop i.e. the seed, stem and leaves are harvested and collected for separation as useful components. There is an analogy with petroleum refineries that separate crude oil into products with different properties and uses which has given rise to the term biorefineries for units that convert bio-mass into raw materials for industrial purposes. The total utilization of bio-mass is summarized below:

Typical Products of Bio-Refineries:

* Food industry
* Starch for the textile, chemical and fermentation industries
* Resins & glue combined with straw chips for particle board
* Pelleting for fuel, feed and the chemical industry

Table 1. *The role of demand in the choice of microelectronics innovations in selected developing countries**

Country/HDI	Sectors	Determinants of the choice of technology
Malaysia/Singapore .8027 0879	General machine manufacturing; electrical and electronics; automobile assembly and component manufacturing; computer and computer component manufacturing	Despite the relatively low wages prevalent in developing countries, firms are willing to introduce ME technology. (higher and more consistent quality, shorter production time).
Republic of Korea .884	Automobile, electronics, industrial machinery and shipbuilding	Firm introduced FA machinery better quality control; for competing in the export markets; and due to the product standard imposed by domestic buyers.
Mexico .838	Electrical; electronics; automobiel; machinery and tool	The need to obtain a higher and more regular quality of work, to secure flexibility to produce in small batches and, to increase the speed of production
Brazil .759	Metal engineering	Greater control over the production process, increased flexibility of the production process, and increased product quality
Brazil	Automobiles	Quality control, flexibility in production and the characteristics of certain products
Colombia .757	Bottling plant	To achieve a better quality in order to maintain and enlarge export markets. In addition the size of the lots (fluctuating between 25 and 2000 pieces) facilitated the adoption of the machines.
Peru .644	Metal-working industry	To reduce costs, to improve quality, precision, piece complexity, increment in production and volume.

*Adapted from James et al. (1991). Human Development Index (HDI) taken from UNDP (1991).

Programmes such as Large European Bio-energy Network (LEBEN), Village Fuelwood Programme of Republic of Korea and India's experience of using forests for essential oils, gums, latexes, resins, steroids, waxes, esters, acids, phenols, alcohols, pesticides etc. (amongst many others) provide enough information for developing bio-refineries (Swaninathan 1991).

Increased bio-mass production, bio-refineries and flexible processing units are thus the key components of a bio-village development programme.

The implementational strategy consists of:

* Mapping of village or cluster of villages for land, water and human resources.
* Increase the bio-mass productivity to provide food, energy and materials for industrial production.
* Develop bio-refineries and new flexible manufacturing units using advances in informatics, new material and bio-technology for combining farm and non-farm activities.
* Make villages units of decentralized industrial production.

The strategy is to convert villages into bio-villages where industrial activity and traditional occupations will blend into a development programme that is sustainable.

Compared to the countries that have already industrialized under the conventional technology paradigm, India and many other developing countries are, as yet, much less burdened with conventional industrial technologies. These countries, therefore, have greater freedom to launch an industrialization strategy based on environmental friendly, science intensive, new technologies.

The perception of several developing countries regarding demand for micro-electronics based industries is summarised in Table 1.

We note that countries with diverse socio-economic status represented by Human Development Indices (HDI) perceive flexible manufacturing as useful. One of the reasons for it's usefulness is based on batch and small scale decentralized production possibilities.

TECHNO ECONOMIC NETWORKS

We summarise the changing scenario follows:

1. Science paradigm is shifting towards an understanding of complexity and diversity. Non-linear, open and self-organising systems are attracting attention.
2. Technology paradigm is also moving towards complexity, flexibility, decentralisation and human-centredness.
3. Flexible manufacturing coupled with bio-technology and the science of new materials has already given techniques for decentralized productions with better environmental features.
4. Political and economic forces are also leading to liberalization (i.e. human-centredness) and global connectivities.

All the above changes have shifted the focus of science and technology strategies from research and development to innovation strategies (Solomon 1990). Recognizing that innovation grows through heterogenous processes of social and technical change, the concept of techno-economic networks has emerged for implementing innovation strategies (Callon *et al.* 1989). In its simplified form, techno-economic networks (TEN) are organised around three poles:

Scientific Pole: This is where scientific research is practiced. For example, research centres and universities.

Technical Pole: Artifacts are conceived and developed at this pole. Its products include models, pilot projects, prototypes, tests and trials. These are the industrial technical laboratories, research associations etc.

Market Pole: this refers to users or consumers who express or seek to satisfy demands or needs.

TENs are not networks of the type one is familiar with in telecommunications or railways. Nor are they networks of families of actors. TENs are a mix of humans and non-humans with different sorts of identities. The dynamic behavior of TENs gives rise to innovation and its diffusion and can be studied through translation operations that identify the relevant prescriptions.

This approach is in conformity with the human-centred systems described earlier and hence is a useful practical tool for devising operational strategies for science and technology in the new paradigm.

CONCLUSION

The emerging world view places diversity at its centre. All the disciplines of natural and social sciences appear to move towards a paradigm that does not treat heterogeneity as an aberration, rather it is viewed as the very source of innovation and future movement. This is a major departure from the conventional paradigm.

The conventional paradigm has well served humankind for the last three hundred years. The industrial revolution in Europe triggering off its exploitation for the benefit of man. As is inherent in any evolutionary growth, a particular path reaches saturation and then growth occurs along a new path. Environmental crisis is a sign of the saturation of the conventional paradigm. The emerging paradigm with diversity as its central theme may be the new path for humankind. Developments in science and technology are beginning to emerge along the new path. Tools and techniques for devising strategies for moving along the new path are also available. A collective recognition of this change is required.

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