TECHNOLOGY DESIGN as if DEVELOPMENT MATTERED[1]

Anil Date
Mechanical Engineering Department
Indian Institute of Technology, Bombay
Mumbai - 400076
India
Email:awdate@me.iitb.ac.in

ABSTRACT
This paper addresses certain important issues related to *Appropriate Technology*. At the outset, the *problematique* of linking Technology to Development is introduced. Evolution of societal forms and Technology-Development paradigms are discussed next. On the basis of this discussion, the main task of Technology Design or the Innovation chain and Transfer Mechanisms are presented. The theoretical propositions of the paper are illustrated through case-studies.

1 Introduction

The title of this paper contains three key words; Design, Technology and Development. At best, they only represent certain thought structures. The word *development*, for example, defines typical desirable attributes (both in terms of means and ends) of *social change*; it being implicitly assumed that social change is an inherent characteristic of all societies. The objective of the *development process* is to steer social change in the desirable direction. Modern societies perceive that one of the powerful methods for steering social change is through the instrument of *Technology*. During the past 400 years or so, this instrument along with its enormous capabilities, has been viewed extremely favorably. At the same time, whenever the *rate of social change* implied by the use of this instrument is rapid or abrupt, doubts have been raised about the use of this instrument not only on economic grounds but also on the basis of cultural, ethical or, environmental considerations. Can this instrument therefore be designed ? What are

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the sets of ideas that provide framework for design of such an instrument ? This paper is concerned with such questions.

The answers are explored through the discussion of the problematique of linking Technology to Development (section 2), through viewing of this conscious linking as a design problem that requires certain procedural steps (section 3), and through discussion of case studies which illustrate the nature of the design problem (section 4).

2 Technology and Development

2.1 The Problematique

Modern civilization, it is said, is characterized by an urge for Problem-Solving which implies that men and women wedded to the pursuit of knowledge have turned their backs on fatalism and in-action; and instead, are engaged in applying knowledge for obtaining desired goals. Thus, whereas knowledge in earlier times was a speculative activity that was divorced from action which was empirical, the modern times represent merging of theoretical knowledge and empirical observations of practitioners. This merging between knowledge and action (or practice) is the essence of the scientific method that accounts for the sudden acceleration in technological progress.

The scientific method is now applied to several spheres of activity. For example, in the spheres involving material world, the method has been used extensively a) to meet demands of competition between industrial firms b) to meet demands of military rivalry and c) to surmount natural and man-made obstacles such as floods, desertification or pollution. The results of application of the scientific method in these spheres has been so startling that there has emerged a faith or a confidence to base policies and plans of action not only in areas of activity of the contemporary practitioners but also on as yet untested truths or on technical feats not ascertained by experience. In recent times, the early space missions and the development of nuclear energy, for example, were certainly results of this new confidence.

The success of the physical sciences in solving several problems developed so much confidence that the scientific method soon penetrated into the biosphere. In the latter, which involves social groups, organizations and societies, the scientific method is applied to study, monitor and even to predict behaviour of men as well as social groups. It is assumed that knowledge in this field (often called social sciences) increases the power of action oriented planning. There is limitation here however on the extent to which knowledge can be applied in this way. This is because in the biosphere, both the subject and the object and even the instrument of action involves men. At once, ethical problems arise and what is questioned in such circumstances is the respect for and the dignity of the human being. In recent times, however, ethical problems have been raised even in respect of application of the scientific method to the natural environment since so many delayed and unexpected impacts of past actions have surfaced as man-made calamities. It is through such perceptions of the ethical problem that enlightened men have given calls for *convivial technologies* [3] or *technologies with a human face* [1]. Obviously, limits must be fixed on the extent to which this kind of knowledge through action be pursued. This is the negative side of the ethical problem. It is assumed however that it is possible to recall basic human sensibilities and values; and when such a recall is made, it is also possible to define ends for which the new power of action can be used. Considerable emphasis in decision-making sciences is thus directed towards defining of these ends.

Societies or nation-states in fact have, in the broadest sense, defined extremely complex goals or ends in the past. Typical examples are:

1. Deliberate speeding up of economic growth at constant technology (through its extensive application) or through continuous technological innovations and modernization.

2. Building up of a welfare state or even a classless society by changing relationships between men and means of production.

3. Peaceful coexistence on the basis of cooperation rather than rivalry among small clusters of societies equipped with spontaneity for localized action.

Clearly, the first two have enjoyed considerable support from the governments in power and are thus well known. The third, which is born out of disenchantment with the first two, however, has remained largely a paradigm around which people's movements have been built up. It aims at a more humane, ecologically conscious and sustainable societal arrangement. At the same time, it must be emphasized that none of the above conceptions view human existence in terms of poverty or a very low level of material consumption as being a desirable feature. To that extent, use of technology and, innovation in it, is certainly embodied in all conceptions. What the foregoing discussion emphasizes, however, is that it is necessary to guard against the ethical problems. Confronted by such a situation, one can only be clever or wise. A healthy attitude may probably emerge from the adoption of a holistic approach. This approach is often called the *systems science approach* where the word *system* denotes the functional set-up consisting of hardware, men and knowledge based information.

2.2 Societal Forms, Technology and Development Paradigms

It will be instructive to compare societal forms of very old societies with those of the modern societies. This is done in Figure 1 both diagrammatically and in terms of bare essential distinguishing features. The very old societies lived

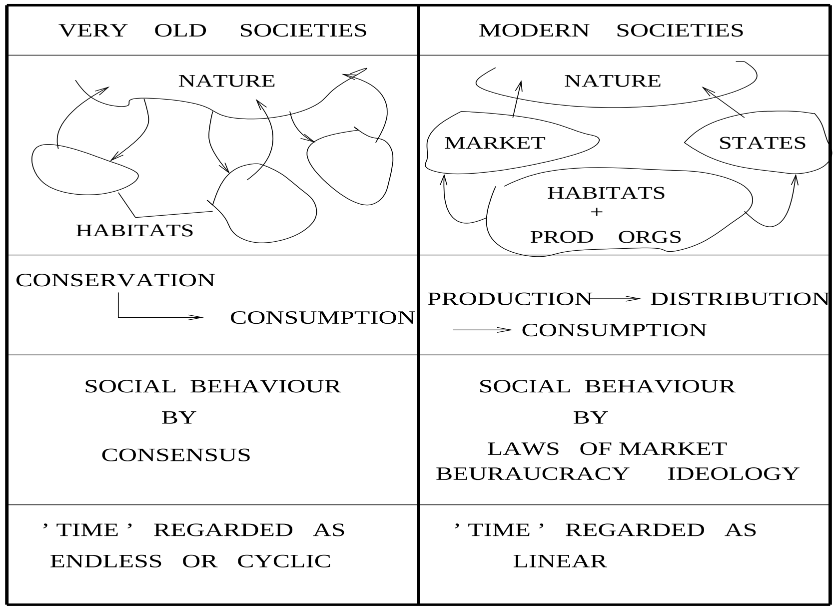


Figure 1: Change in Societal Forms

in small clusters and each individual survived through strong interaction with nature. The people obtained means of sustenance from renewable sources and they engaged in conservation for sustainability. In contract, modern societies are considerably more homogenized and the society comprises of human habitats as well as productive organizations (agriculture, industry and service). The essential distinguishing feature is that people engage in conscious production followed by distribution of surplus which is then consumed. The task of interacting with nature for obtaining means of sustenance is handed over to the productive organizations which may be private or publicly owned. Individuals have little control over interactions with nature. Further, this interaction between productive organizations and between people and organizations is again mediated by the laws of the market or by the national governments with their laws and bureaucracies. Different modern societies permit different proportions in which the market and the national governments may exercise their control over the productive organizations. This contrasts with the behaviour of the very old societies which are governed by customs evolved out of consensus. Finally, in very old societies time is regarded as endless or cyclic whereas in modern societies it is regarded as linear and the world view as well as social behaviour are governed by *the moment gone is gone for ever* syndrome. No doubt, the above manner of characterizing and distinguishing old and modern societies must be considered sketchy. None-the-less, to the extent that Technology is often defined as *technique + structure* [2], the above sketch provides an important backdrop for discussion of issues such as technology innovation, transfer and organization.

Changes in societal forms have taken place throughout history. In early times, the changes were mainly in response to natural disasters or calamities or natural environmental changes to ensure survival. In modern times, besides these causes, social changes are effected in response to conscious choices or goals that are either democratically or autocratically arrived at. In fact, these changes have been extremely rapid in the last few decades with some societies even readopting the goals abandoned at earlier times. Social change is thus considered an essential characteristic of all societies.

The term *technology* is often identified with the hardware of production and distribution in the form of machines, factories, roads, storage facilities, telephones etc. Technology, however, also includes software aspects such as knowledge, knowhow, experience, education, organizational forms and management techniques [4]. Societies that are technologically advanced owe their development not only to inventions and widespread application of new types of machinery but also to major innovations and gradual improvements in organizational forms and institutional structures. One of the major innovations in organizational forms in the first half of the last century was a legal invention, that of a *public limited company*. This new form of association allowed entrepreneur to escape from stifling restrictions of the professional guilds inherited from the middle ages. Formation of *co-operatives* in the socialist world and the creation of *production brigades* at the commune level in China are other examples of innovations in the software aspects of technology. Similar changes in work organization have also been effected to achieve higher productivities of both capital and labour within industrial firms. The introduction of *assembly-line* principle and the recent innovation of the JIT (Just in Time) philosophy in Japan [21] which aims to emphasise non-price factors in production with highest priority to quality through extensive use of modern information technology are prime examples. Similarly, as regards inter-firm dependence, whereas the Fordist model promoted horizontal and vertical integration leading to *ancillarization*, the modern JIT philosophy emphasizes *network mode of interaction* between firms so as to form a non-hierarchical and cellular structure of productive organizations.

Another definition of technology which in many ways is complementary to the one above is that technology is *skills, knowledge and procedures for making, using and doing things*. This simple definition in its broadest context includes all activities geared to social production and distribution. It thus includes methods used in non-market as well as marketed ones. To put it in another way, it includes activities for exchange as well as for use.

While these definitions (and there are many variants) take us much further than earlier, generally understood definitions such as *Technology is application of Science* and discard identification of technology primarily with industry, the definitions by themselves do not explain the role of technology in the dynamics of social change. Another important observation is that the underlying assumption in most definitions is that Technology is only for satisfaction of consumer needs/demand of the people. However, other notions are also possible. For exam-

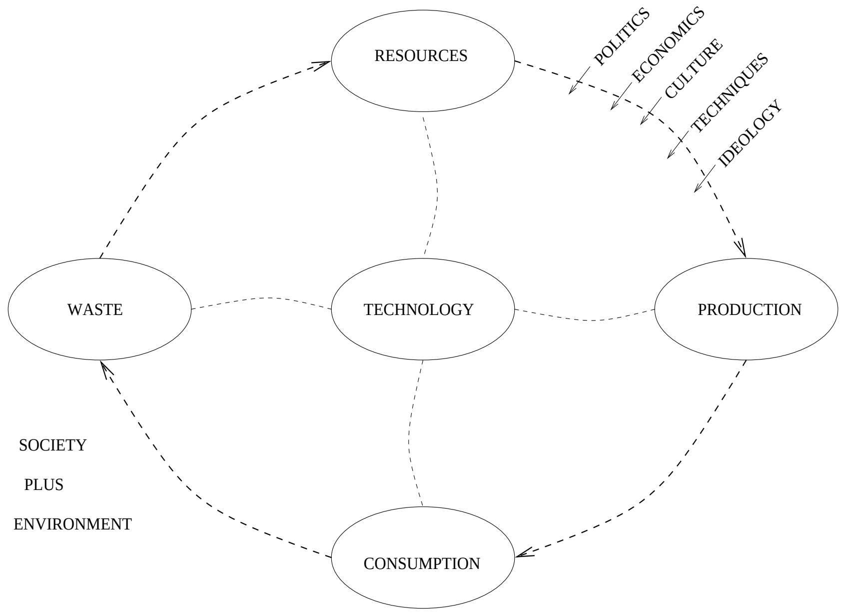


Figure 2: Technology-Society Relationship

ple, instead of viewing majority of people as mere consumers, they can be viewed as creators and technology can be seen as a social learning process feeding and enlarging creative talents of human beings.

It would be pertinent, therefore, to examine the nature of the technology-society relationship and the determinants of changes in it. A conceptual representation [5] is shown in figure 2 where Technology is viewed as a *social activity* in which men and women act for sustenance and maintenance within a cycle of the four main attributes of technology.

While these four attributes are a quite understandable in a material-technical sense, they need to be viewed in a much broader perspective. A successful technological society should continuously find ways of maintaining the cycle between *resources, production, consumption and waste.* This must be achieved on the basis of environmental stability and least adverse impact on the manner in which people can best relate to the means of production and products of their work. It is important to recognize, however, that both technology and society change simultaneously (as they must) and that the linkage between the four attributes are continuously influenced by elements internal to technology (the laws of physics or biology, for example, and their new innovative applications), by political environment as shaped by such factors as ideology, bureaucracy, ownership patterns etc., by economics and, by culture. As such, whenever a reference is made to the idea of an alternative technology, it does not merely refer to changes in techniques but also to a change in the factors which variously influence the linkages between the four main attributes of technology.

In an operational sense, this of course implies appropriate responses from the

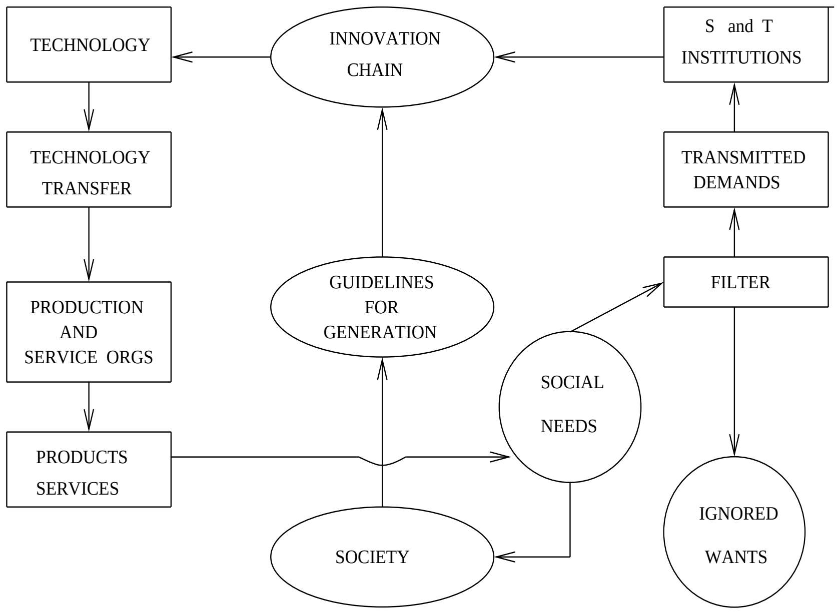


Figure 3: Operation of Technology - Society Relationship

institutions engaged in science and technology as can be discerned from figure 3 [6]. A society with its culture, economic structure and political priorities provides guidelines for generation of new technologies and also provides criteria for choice of technology. These guidelines can emerge from planning exercises, from various protest movements, from organized trade unions or, from surveys of consumer preferences. The criteria embodied in the guidelines feed into the innovation chain to result in a technology which is then transferred. The mechanisms for transfer will be discussed shortly. The technology is transferred to the organizations which produce products and services to satisfy social need and wants. Often this satisfaction itself results in emergence of new needs (often called *latent needs*). Not all needs (new or existing) are in fact transferred to S and T institutions because of the operation of a *filter*. For example, in capitalist societies where market forces dominate, needs not backed by purchasing power are filtered out. Similarly, in planned economies, bureaucracies and institutions are often staffed by elites whose priorities differ from those of the society at large and certain needs enjoy greater prominence over others. This selective filtration results in ignored wants. The needs that pass the filter are transmitted to the S and T institutions who provide the necessary input to the innovation chain.

It is matters such as these that have led to the development of certain theoretical postulates. Thus, many analyses of technology-society relationships are based on *deterministic models* in which one factor (technology, economics, politics or ideology) is picked out as determining everything else [20]. For example, technological determinism suggests that social development is solely a function of the technological changes that a society invents or adopts. Societies are thus classified according to the stage of technological development and sophistication they have reached e.g. Stone age, Iron age, Atomic age, Computer age, etc. Specifically, emergence of technologies such as the internal combustion engines in the latter half of the 19th century or, more recently, the microchip based information technologies are singled out because of their widespread penetration into the various sectors of the economy and because of their impact on the social life in general. It follows from this model that all societies with similar stages of technological development will be similar in all other respects and the lag between the underdeveloped and developed societies can be immediately bridged by adoption of the technology of the latter societies by the former; cultural specificities, it is assumed, will not hinder this process. The model, however, fails to explain why many societies with comparable technological developments exhibit marked differences in the context of social development. This model none-the-less has attracted attention from policy makers and forms an important component of educational curricula in technology and its management.

Economic determinism, by contrast, is based on the idea that technological changes are primarily controlled by economic and commercial forces rather than solely technological ones. According to this view, the state of technology at a given place and time is solely governed by economic factors (like land, labour, capital and markets). The model also suggests that there is always a range of techniques (exhibiting different factor proportions) available to satisfy a given need. In capitalist societies, where economic criteria are dominant and the price mechanism greatly influences the activities people undertake, the model goes a long way in explaining the choice of technology and the direction of technological change.

The political determinism suggests that technological and economic considerations are themselves manifestations of the prevailing political forces in a society. Techniques and organizations (and, their integration) developed and adopted by a society reflect the interests and values of the more powerful and influential individuals, groups and institutions of that society. Finally, ideological determinants of technical change are often the least obvious, being governed by hidden sets of beliefs and premises which taken together make up an ideology.

It will be futile to think that all technologies are developed or all technological change occurs under the influence of only one of the determinants. More often than not, technologies indeed evolve and change under the influence of all determinants, although the hierarchical influence of the latter may not always be clearly discernible. In spite of this ambiguity, technological change in recent times has indeed appeared as both a reform over old ways of doing things as well as radical departure of revolutionary proportions. Thus, for example, whether the micro-electronics will achieve the desirable goal of full employment equilibrium (even in the long run) without dislocation of traditional communities and their values or whether it will merely increase output per worker leading to skewed income distribution in developing countries is still a matter of debate. Economic

Table 1: Development Paradigms

Trickle Down	**Human Resource Development** [6]
Central Planning and Control as a top-down process	Satisfaction of Basic Human needs starting from the needs of the neediest in order to reduce inequalities
Industrialisation and expansion of modern sector as a means of rapid economic growth	Social participation and control in order to strengthen self-reliance that grows from within and to prevent concentration of economic and political power
Aid from developed countries and transfer of international technology	Ecological soundness to make development sustainable over the long run

determinism alone will not suffice to steer social change implied by introduction of microelectronics in the desirable direction and hence result in development.

For historical reasons, developing countries have had to resort to what the development analysts [7, 8, 9] call a *trickle-down* paradigm of development (see Table 1). It is based on the percolation theory of distribution of benefits of rapid economic growth. It is scarcely disputed, however, that this paradigm has promoted dependency culture and has led to the continued exploitation of peripheral areas by the metropolitan core, both internally and externally. There are many other well known effects such as mounting unemployment, environmental degradation, regional imbalances leading to mass migration, increased vulnerability to policies of other nations and lack of social control over immediate environment even for small communities in remote areas.

It is in response to such effects that there has been a calling from social thinkers and activists for adoption of alternative paradigms of development. The ideas embodied in phrases such as self-reliance, eco-development, sustainable development or appropriate technology are described in Table 1 under the heading *Human resource development*. For many developing countries, this paradigm will inevitably connote change in political economy with considerable restructuring in several spheres of activity. The traditional division of agriculture and industry must become blurred. The cottage, small, medium and, large industries may loose their significance as the main organizing principles. Instead, self reliance of village communities, water-shed zones, districts and states with their regional specificities may prove to be more appropriate organizing principles for both technology and economy. Thus, globalization *per se* must be seen to be counter-productive, whereas technical mixes of the new information technology and micro-electronics may require creative adaptations not found in countries of their origin.

How to bring about this transformation is a matter that is debated by both the reformists as well as radicals. The strategies proposed by them differ in their ideological content and in the manner in which the transformation is to be implemented. Without discussing this issue at great length, it will be pertinent to note that the reformists propose *policy incentives* or promotion of successful demonstrations of model-transformations and, oddly enough, sometimes even recommend *authoritarian coercion* in the hope that a clear demonstration of the latter action will itself be a propellent for change. The radicals, on the other hand, see the implementation process as a struggle game since the transformations suggested would hurt certain sections of society and would naturally be resisted. None-the-less, creative technological transformation must remain central to either strategies. What the content and the methodology of this transformation should be is really the Design problem that is of interest in the context of this paper.

3 Technology Design - Main Tasks

3.1 Mechanisms for Innovation Chain

The main tasks for Technology Design for development are:

1. Identification of needs/demands/opportunities
2. Conversion of needs into specification of a technical problem, a product or a service
3. Technology choice among available alternatives and /or new ones
4. Technology generation through R and D, innovation or adaptation
5. Technology transfer

The above five tasks constitute what is commonly called the innovation chain. The most common method or mechanism for executing the chain is the one shown in the left hand column of Table 2. The mechanism begins with survey of those needs (including latent needs) or wants that can be backed by purchasing power or, of those opportunities created by relatively autonomous developments in science and technology. In the context of developing countries, conversion of these wants and opportunities in conceptualization of new forms of products and services is less frequently attempted since such conceptions have often already taken

Table 2: Competing Innovation Chain Mechanisms

Commercial Mechanism	**Social Mechanism**
Survey of needs backed by purchasing power/opportunities	Survey of basic needs and local resources accessible to a community
↓	↓
Scanning technology alternatives ans choice based on commercial criteria	Specification of surrounding conditions to determine appropriate level of collectivity of people
↓	↓
Often R & D and engineering design	Conscientisation and organisation building
↓	↓
Industrial organisations within legal frameworks	Conversion of need into solvable technical problems through dialogue
↓	↓
Contracting for construction and installation	Survey of technology alternatives or innovation through R & D
↓	↓
Training of workers and managing operations	Learning technology by doing and role swapping
↓	↓
Selling products and services supported by advertising	Micro-diffusion for acceptability and participation in technology modifications
↓	↓
Modifications for market segments and reduction of cash-flow related uncertainties	Wider diffusion through education and training, creation of people's movements and other voluntary mechanisms

place in other developed countries and their success in the market place established. This is particularly so in large scale manufactures where flexibility for change is both structurally difficult and commercially risky. The new information technology, however, now offers significant opportunities in this regard both in hardware aspects as well as software aspects of production. The next step is to survey existing methods of production to meet the product or service specifications. Often R and D and engineering design are carried out to meet the local conditions. The final choice among the alternatives is based on commercial (that is, cash flow related) rather than overall economic criteria. Subsequently, industrial organizations are conceived and their location determined by requirements of commercial criteria and the legal frameworks provided by national governments. Typical organizations are cottage or small scale industries with single or partnership based entrepreneurship, private or public limited companies or cooperatives. Once the technology is chosen, the industry is installed, workers hired and trained and operations managed by cultivating suppliers of raw materials and sales distributors. Where necessary, products and services are sold through advertising. The entire mechanism views majority of people as mere consumers. The production and consumption are greatly distanced both in space and time. The spatial distancing calls for enormous transportation and extremely high productivities in manufacture which in turn warrants automation. This has often resulted into both seasonal and permanent migration of people and alienation of workers from products of their wok and from their communities. The distancing in time can often span more than a generation with insufficient concerns for sustainable development.

The mechanism advocated in the right hand column of Table 2 may be called a social mechanism. It involves surveying of all needs (with special emphasis on basic needs) and resources accessible to a reasonably homogeneous community that spans a specific agro-climatic region. Such surveying is to be carried out by adopting an anthropological approach to arrive at specification of surrounding conditions to determine an appropriate level of collectivity of people whose need is to be satisfied. Once the surrounding conditions (in terms of accessibility to resources, cultural traditions, social aspirations etc.) are identified, the next task is to engage in conscientization and organization building through different forms of communications. One-to-one, many-to-one and many-to-many forms are to be preferred over the one-to-many forms of communication. Existing technology alternatives are then surveyed to make a choice or even an innovation is carried out so that the chosen technology internally meets the requirements of scientific principles and externally able to meet requirements of culture, ecological soundness, self-reliance etc. When communities are large and when the technological project has very wide ramifications in space and time, it may be necessary to resort to a form of *referendum* for choice of technology. In most situations, micro-diffusion is to be practiced for acceptability and for involvement in technology modification, if found necessary. Finally, wider diffusion is attempted through education and training, through organization of people's movements and through other voluntary mechanisms. In recent history, some societies at least are reported to have institutionalized and practiced [10] such a mechanism particularly in the context of rural development. The initiatives at Raleganj-Siddhi and of the Narmada-Bachao-Andolan, though differing in scale, are typical examples of practice of such a mechanism in India.

3.2 Approaches for Linkage

The two mechanisms for innovation chain described above can in principle be operationalised through the following four approaches so as to consciously link technology to the process of development. These are:

1. Factor endowment approach (Economic)
2. Resource endowment approach (Ecological)
3. Area approach (Geo-Cultural)
4. Target group approach (Socio-Anthropological)

The factor-endowment approach in which capital, labour and markets are considered to be the major factors, looms large over the commercial mechanism. Not too long ago, labour and capital were quantified from the endowments of a nation state and it was argued that a country with scarce capital and abundant labour should choose a technology-mix which will maximize employment per unit capital used and thus increase both employment and output simultaneously rather than one at the expense of the other. The notion of Intermediate-Technology [1] was, in fact, derived from such an argument. Several examples of these can be found in products and processes such as stationary and wrapping paper, soap manufacture, leather tanning, garment manufacture, weaving and printing, oil expelling, cement production, brick manufacture, plywood etc. (see, for example, [11, 12, 13]). Today, however, globalisation of economies is the accepted norm which means that it is perfectly legitimate, for example, to import large diameter wood from Vietnam, bring machines from Europe, bring experienced workers from over a distance of 1000 kms and bring even water from a distance of over 50 km to produce plywood in a small scale industry in a tribal region of Konkan in Maharashtra since the requirements of commercial and legal criteria are met. The factor endowment approach thus can contradict the main thrust of the other approaches.

The resource endowment approach, on the other hand, insists on use of local materials in generation of technologies. This is to avoid negative effects of dependence on raw materials obtained from elsewhere as well as to avoid excessive transportation. This approach believes that if it is not possible to achieve a certain need physically then, it is certainly not possible economically (unless some costs are externalized); and if it is economically possible, it is not necessarily socially, environmentally and culturally desirable. Thus, what is given is of paramount importance and the given defines the resources with their accessible boundaries. In this way, the approach instills the notion of *physical resource accounting* for generation and selection of technologies. For example, if supplying biogas for cooking or water pumping needs is under consideration, one would not only evaluate the money costs of constructing the gas plant but also the energy costs and further the extent of water and land required to generate the biomass to be fed to animals. Thus, the extent of demands placed on nature are directly assessed resulting in sustainable resource usage.

The area approach recognises the legitimacy of geographic regions with their agro-climatic and cultural specificities. In this approach, the proponents of decentralized development [17] see several in-built prescriptions of a desirable society. The approach has strong affinity to the resource-endowment approach and to notions embodied in watershed development, eco-development, sustainable-development and appropriate technology development. Thus, technologies developed for house construction, food production and processing, infrastructure and communications etc. can be strongly region-specific. The approach emphasises the importance of preservation of plurality and diversity of cultural traditions.

In greatly stratified societies with large populations living below the poverty line, the target group approach is most essential. The primacy of satisfaction of basic needs of the poor, which the other approaches can often overlook or only indirectly attend to, is firmly built into this approach. The main task of the technology design is to convert the labour of the poor into tangible assets with the use of which confidence in change can be generated. Thus, conservation of rain water through various means, construction of houses with local materials and simple skills, development of simple tools for drudgery reduction are areas that require technological intervention. The very poor live under great uncertainties and thus concientization for understanding of bottle-necks to development is of paramount importance not only for the poor themselves but also for the change agents. Anthropological techniques of participant observation, analysis and action-research need to be adopted.

Although the four approaches are discussed separately, it will be appreciated that they can rarely be mutually exclusive particularly in a large stratified society. How to merge these approaches in a symbiotic relationship is a task that must require considerable analytical and empirical support for policy formulation. The approaches express major preferences and requirements for linking technology to development on the basis of which development of specially designed policies, institutional arrangements and management practices can emerge. The quest for demand-side management, JIT philosophy for managing technological change, techniques based on renewable energy and material resources, micro-electronics based information technologies and, for the future bio-technologies has to respond to constraints of the preferences indicated in the different approaches.

4 Case Studies

The theoretical propositions of the foregoing sections can be examined and supported by several case studies relating to choice, generation, management, planning and transfer of technology. The examination can be undertaken through both verbal narratives as well as through more quantitative techniques. The issues at hand are such that they require simultaneous invoking of common-sense or human sensibilities, experiential learning as well as analytical deductions. Opinion forming and decision making environments have to be alive to all the three requirements. Case studies thus can never capture every detail of the argument; never-the-less the message conveyed by them is greater than the sum of their individual specificities. By way of illustration, four case studies are described: two concerning choice of technology and two concerning innovative technology generation.

4.1 Alternatives in Toilet-Soap Manufacture

In 1978, India's soap consumption was estimated at 1.79 kg /capita/year whereas the world average was 7.5 kg/capita/year. The total production of toilet soap in India was 1.66 lakh tons/year and that of laundry soap was 7.7 lakh tons/year. The large scale sector enjoyed almost total monopoly over toilet-soap whereas nearly 70 % laundry-soap production was in the small-scale sector. This production structure resulted largely from two constraints: (a) Government's ban on using edible oils in soap manufacture and (b) Need for recovering *Glycerine* from non-edible oils. The latter is a process that is strongly influenced by economies of scale and hence, only large-scale sector could have the capability. Glycerine is used in the manufacture of drugs, explosives, paints, dyestuffs and other chemicals.

The small-scale sector employed nearly 38,000 people and the large scale sector about 12,000 people. In addition, seasonal employment was possible for nearly 1 lakh tribals who collect non-edible-oil seeds from the forests. The small-scale sector could not process non-edible oils economically to engage in toilet-soap production and the large-scale sector was unwilling to surrender processed (hardened) non-edible oils for saponification to the small-scale sector. The government, therefore, assisted the small-scale sector by importing mutton-tallow which was used by this sector mainly to produce laundry soap. But, this meant that scarce foreign exchange was used to maintain employment in the small-scale sector. The KVIC, on the other hand, developed the full-boiled process for manufacture of toilet soap using largely Neem oil. Of course, this process, because of its small

Table 3: Alternatives in Toilet-Soap Manufacture

Item	Semi-Boil Process	Full-Boil Process	High pressure splitting	Twitchell's Process	Full-Boil Process
Type of Unit	KVIC	medium	medium	medium	large
Capacity/day kg	126	10,000	18,000	10,000	540,000
No of workers	9	56	70	194	-
Capital cost Rs	60,000	100 lakh	225 lakh	130 lakh	-
Output/worker /day kg	14	180	257	51.7	-
Capital/output /day	475	1,000	1,250	1,330	-
Capital/worker	6,700	1,80,000	3,20,000	80,000	-
Int & Dep/ton /day	157	810	1,200	1,080	
Price/kg	16.6	10 to 25	12 to 25	10 to 18	-
Time to set-up (months)	2	12	24	12	-
Raw material + Rosin and silicate	Neem,palm, coconut oil	fatty-acids, byproducts of groundnut oil refining	fatty-acids	fatty-acids	Non-edible oils
Energy (KWH) / ton	16,000 (heat)	4,100 (heat) 450 (elec)	2,740 (heat) 360 (elec)	5100 (heat) 550 (elec)	-
Energy source	Firewood	Furnace oil	Furnace oil	Furnace oil	Furnace oil
Location	village	city	city	town	city
Skills	Learning by doing	Science based	Science based	Science based	Science based
Glycerine kg / ton	nil	40	90	80	42
Mechanisation of operation	hand operated	mechanised except wrapping	mechanised	partial	mechanised
Design & fabrication	Indigenous	Imported	Imported	Indigenous	Imported
Water (l / kg)	19	10	66	17	-
Transport	tricycle tempo	Truck	Truck Rail	Truck	Truck Rail
Waste	Spent lye	wash water chemicals	Treatment plant	wash water chemicals	- -
RANKING1	3rd	2nd	1st	4th	-
RANKING2	1st	4th	2nd	3rd	-

scale, did not recover Glycerine. KVIC also scrupulously avoided use of mutton-tallow.

The foregoing discussion is only a snap-shot view of the status of the soap industry. To meet the requirements of use of non-edible oils (including mutton-tallow) and that of Glycerine recovery, the Indian soap industry demonstrated varied adaptations in scales of production as well as in process-alternatives. Further details of these adaptations are described in Date [11]. Table 3 provides the main characteristics of five alternatives.

The data shown in the table were obtained through a questionnaire and personal interview with senior functionaries of the companies. In most cases, the product-lines are diverse (manufacturers engage in oil-refining, toilet and laundry soap manufacture and Glycerine recovery in pre- or post-saponification stages) and the costs had to be trimmed to reflect the costs attributed to toilet-soap manufacture with Glycerine recovery. In this sense, the data presented in the table are indicative rather than conclusive. The last alternative (5,40,000 kg/day) is a multinational company that produces toilet and laundry soap using non-edible oils. Unlike other manufacturers, the company was unwilling to share its production cost structure with the author. Although soap is a chemical product, there are Indian standard specifications (For example, soap must contain 76 % Total Fatty Matter, TFM). But, few manufacturers strictly adhere to them arguing that

> ... *Soap sells not because of its fatty matter but because of its color, fragrance, freshness and shape. In a democratic society, different classes of people need soaps of different sophistication.* ... *You cannot preach hygiene and sell toilet soap. That is the job of the government and welfare agencies. On our part, we depend on upper-middle classes for acceptability. The lower classes join to acquire status.*

The data from the table can be subjected to Analytical Hierarchy Process (AHP), a technique that permits multi-criteria comparison amongst alternatives to arrive at Rankings among them. This has been done by Raju et al [14]. The data were subjected to the two development paradigms mentioned in Table 1. In Table 3, these Rankings are shown at the bottom. The last alternative is ignored because of lack of data. RANKING1 corresponds to *Trickle Down* paradigm whereas RANKING2 corresponds to *Human Resource Development* paradigm. In each case, the *attitudes* of the two paradigms towards each criterion shown in the table were assessed and weights assigned to arrive at the rankings. It is interesting to note that the rankings do indeed change substantially under the two paradigms. The Trickle-down paradigm favours the largest scale unit whereas the Human Resource Development paradigm favours the KVIC type cottage scale unit.

Table 4: Societal Characteristics

Bureaucratic Society	**Participative Society**
People wait for government or higher authority to take initiative	Individual and group initiatives
Elite proposes while the rest contribute to organisational strength through dedicated work	Venting of creative urges and enjoyment in experiencing struggles of change
Large, indifferent and hierarchical organisations - Disinterest in small projects	Voluntary organisations with shared shared responsibilities - Active interest in small projects
Monologue or one-to-many forms of communications dominate	Dialogue or one-to-one, many-to-many and many-to-one forms of communications dominate

4.2 Communications Technology for a District

In order to facilitate choice of technology in communications, it is necessary to examine characteristics of a bureaucratic society and a participative one. This is done in Table 4. The message of the table is self-evident and it would be instructive to consider a communications plan for a typical district of say, 2 million people. For every Rs. 1 crore available for spending , the possible technological alternatives as deduced by Krishnayya [18] are shown in Table 5. All prices relate to those prevailing in 1975.

It is obvious that the de-centralised system will provide for a large number of jobs at skill levels feasible in rural areas. It will also lead to creation of a local problem solving capability and will facilitate much greater participation in local decision making. A local radio station with a 5 kW transmitter will result in radio programmes that will provide more opportunities for local talents. Availability of at least one telephone at relevant nerve-centres throughout the district will ensure quick transmission of emergency related messages and will assist local business carried out from villages far away from district headquarters. Production of pamphlets, booklets, posters, newspapers etc. will provide information on local needs and priorities. Finally, the technologies involved will require no import

Table 5: Alternatives in Communications Technology

Centralised System		De-centralised System	
2,000 T. V. sets at Rs 5000 each	1 crore	20,000 FM radio sets at Rs 200 each	0.4 crore
		District co-operative Offset printing plant	0.5 crore
		2,000 Village Telephones at Rs 500 each	0.1 crore
Total Investment	1 crore	Total Investment	1 crore

of technology from foreign countries. The ability of the system to respond to local cultures and local aspirations will also be greater. On the other hand, the centralised T.V. broadcast system will serve very few individuals within the district. The information transmitted will not always be of relevance to regional priorities. In fact, there is a danger that in a highly stratified society, the medium will perpetuate and reinforce monologue forms of communication.

4.3 Sludge Gas Aero Engine

Sludge gas from a city sewage waste is a valuable by-product containing a high proportion of methane (53 to 68 % with a calorific value 19 to 25 MJ / m^3). While the use of reciprocating gas engines for operation on sewage gas is well known, a technology has been developed at NAL, Bangalore (Pai [15]) that uses Gas-Turbines derived from out-of-service Aero-engines. Such discarded and idle engines are available from Indian Airlines and Indian Air Force. The engines are available in the power-range 1 MW to 2.5 MW. They represent a total idle capacity of about 250 MW. To realise this potential, it is required to modify the combustion chambers of these engines to burn sludge-gas instead of the aviation fuel.

In particular, the fuel injection (see Figure 4) and the control systems have to be modified. Such a modification was undertaken at NAL which resulted in a suitable injector nozzle for the sludge gas. The existing nozzle was retrofitted in such a way that the injector was introducible into the existing swirler hub. Since the calorific value of the gas is about half that of kerosene (on mass basis) and since the density of the gas is nearly 800 times lower than that of the liquid fuel, it was necessary to optimise the nozzle pipe diameter to obtain the same thermal output from combustion. Further, in order to achieve almost uniform temperature distribution at the exit from the combustor, three types of injectors

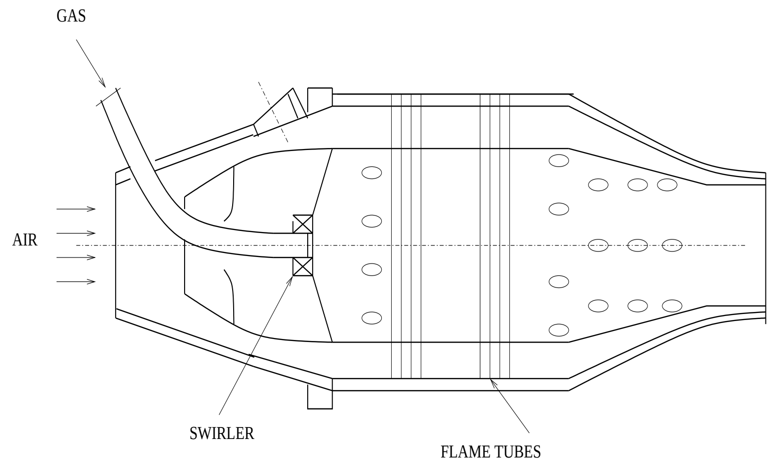


Figure 4: DART Combustion Chamber with Slit Injector

were tested: (a) injector with multiple radial holes (b) a single axial hole and (c) variable radial slit injector. The last mentioned was found most suitable.

With these modifications, the engines were tested on sludge gas. The large power output was measured by lighting a bank of nearly one thousand 1 KW light bulbs. The tests showed that the engine ran with nearly equal efficiency as would be obtained with liquid fuel. Such an R & D effort was crucial to realise the innovation.

It is worth noting that the effort required to make large amount of city sludge-gas turned out to be a far more demanding task than the innovation in engine retrofit. This is because, the gas generated in existing digesters had a concrete dome and the hair-line cracks in them resulted in leakage of the gas. Repairs to these domes at Bangalore proved unsuccessful and hence a 2266 m^3 capacity metal gas holder had to be erected into which the gas generated in the concrete dome was continuously evacuated. The city sewage plants at Bangalore provided gas at the rate of 9,500 m^3/day/million population. It is known, however, that an optimised plant could provide nearly 20,000 m^3/day/million population. In fact, from an optimised plant with secondary treatment, gas generation rate of 34,000 m^3/day/million population is achieved in USA.

With the technical feasibility of power generation through engine modification and of availability of gas through erection of a metal gas holder thus established, a techno-economic feasibility study was under taken. In this study, the entire system consisted of the gas-generation unit, the power generation unit and a steam-generation unit. The latter was incorporated to utilize the hot exhaust gases from the engine at nearly 500 C (a characteristic of gas-turbine engine) and to provide process steam for further industrial use. The results of the study made under three assumptions of the gas-generation rate are shown in Table 6. The table is self-explanatory and suffice it to mention that an MOU

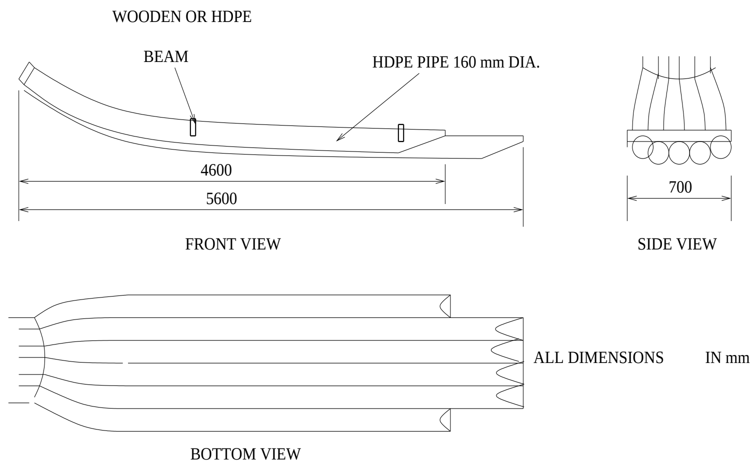
Table 6: Sludge-gas Aero-Gas-Turbine with Steam Co-generation

Item	Units	Low Rate	Medium Rate	High Rate
Generation Rate/ 10^6 Pop	m^3/day	9600	20,000	34,000
Methane	% volume	53.4	62.5	66.7
L Cal Value	MJ/m^3	19.18	22.45	24.53
Thermal Energy / 10^6 Pop				
Energy Available	GJ/day	182.1	449.2	833.9
Diesel Equivalent	kL/year	1831	4517	8366
Value of Diesel	lakhs/year	65.4	161.6	299.0
Price Rs 3.75/l				
Therm to Elect Conversion				
Gas Turbine Efficiency	%	15	16.9	22.0
Conversion Efficiency	%	13.7	15.4	20.0
Power Rating	MW	0.75	1.0	2.0
Daily Operation	hours/day	9.2	19.2	23.7
Economics				
Capital Cost	Rs/kW	3.244	2.52	2.175
Generation cost (gas free)	Rs/kWh	0.4	0.18	0.18
Generation cost	Rs/kWh	0.72	0.42	0.33
(gas Rs 0.23/Nm^3)				
Pay-back Period	months	5.5	2.6	2.5
Waste Heat Recovery				
Heat Recovery/day/10^6 Pop	MWh	27.76	76.11	127.97
Steam Generation	tons/hr	4.1	4.53	7.5
Overall System Efficiency	%	68.6	78.9	75.3
Pay-back Period	months	18	8.1	8.1

has been signed between NAL and Lotus Energy Systems, Bangalore to provide 1 MW (Elec) power and 4.5 tons/hr of steam at the cost of Rs 1.35 crores [16]. When the entire 250 MW capacity is harnessed in this way, the country can save approximately Rs 100 Crores in foreign exchange.

4.4 HDPE Kuttamaram

The target group approach can be a very powerful tool for linking technology to development problems. Here a novel design of a catamaran (Kuttamaram in Tamil) is considered. The catamaran developed by Murugappa Chettiar Research Centre (MCRC), Madras is made from High Density Polyethylene (HDPE) pipes [6]. The MCRC views *conservation of resources and the environment as preconditions that are built into technology rather than a rectifying process adopted once the damage is done.* Much of its work on edible algae and on phototrophic



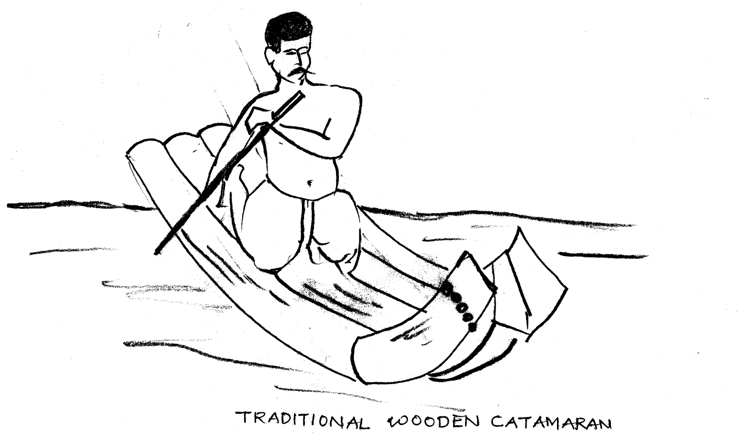


Figure 5: Design of HDPE Kuttamaram (Top), Traditional Wooden Kuttamaram (bottom)

bacteria has resulted from the above principle.

The idea of an HDPE catamaran was born after the centre started interacting with the fishing communities in the Coromandal littoral by designing and introducing a low cost solar dryer to help them dry fish. The interaction drew attention to the plight of the artisanal fishermen. The traditional Kuttuamaram (see Figure 5) used by them was becoming more expensive as the availability of specific species (obtained from forests in Orissa, Madhya Pradesh and Kerala) of wood suited for fabricating fishing crafts was decreasing. Through surveys, the magnitude of the problem was assessed as follows: A traditional Kuttamaram has five logs of wood tied together by rope. It weighs 250 kg (or 3.5 cubic meters). It has a separately attached bow-piece to face the surf and it can be paddled or poled. Once at sea, it is driven by wind through a latin-rig sail. It usually carries 2 or 3 fishermen and permits productivity of 2.54 tons of fish/fisherman/year or 4 tons/Kuttamaram/year. It has a life of 5 to 7 years. The survey showed that in Tamilnadu alone, nearly 5,000 boats (out of 26,000) are replaced every year. This means 17,500 cubic meters of wood is necessary every year. In other words, with a 30 year harvest (or regeneration time), 75 hectares of forest need to be cut every year to provide 5,000 boats. It is through such resource accounting that concerns about conservation of resources and the environment take a concrete shape.

The MCRC decided to build Kuttamarams from 6 inch dia HDPE pipes instead of the wooden logs. The HDPE is one of the cheapest and widely available polymers with a density lower (sp. gr. 0.91-0.96) than that of water. The material is extremely easy to bend and fuse. It is chemically inert in that it is not prone to marine fouling and corrosion by salt water. When mixed with carbon additive, degradation of the material by Ultra-Violet component in the solar radiation is also prevented. Polythylene is a highly compacted polymer of the simple gas ethylene which can be made from alcohol or ethanol. Since ethanol is a product that, in principle, can be made from any cellulosic biomass (especially as an alternate fuel), polyethylene may be looked upon as a renewable resource. When the technique of resource accounting is applied to HDPE boat (which weighs only 100 kg), following estimates emerge. Tamilnadu cultivates 150,000 hectares of sugarcane which has the property of very high photosynthetic efficiency of conversion of solar energy into biomass. The ethylene budget will show that:

Sugarcane yield (18 month season)	70 tons/ha/year
Molasses yield	1.8 %
Ethanol/ton of molasses	180 kg
Ethylene/ton of ethanol	610 kg
Polyethylene/ton of ethylene	1 ton

From the above, and assuming 50 % overall efficiency, it follows that from only 7,000 hectares (out of 150,000 ha planted with sugarcane in Tamilnadu),

Table 7: Comparison of Wooden and HDPE Catamarans

	5-log wooden	**HDPE**
People to launch	2 or 3	1
People for beaching	2 or 3	1
People for Righting after capsize at sea	3 or 4	2
Weight	250 kg	100 kg
Buoyancy at sea	High on outward and low on inward journey	Equal at all times
Bow-piece	Separately attached	Integral
Skill for fabrication	Special-traditional	Simple
Days to fabricate	10 to 15	3 to 4
Tools	Carpenter's	Blow-torch, manual jig
Cost	Rs 6000-8000	Rs 6000
Time for decay	5-7 years	25 years
Wastage in logs	up to 40 %	Nil
Rope used	Yes, needs replacement	Eliminated
Time to regenerate	30 years	1.5 years

one can obtain $7000 \times 70 \times 0.018 \times 0.18 \times 0.61 \times 0.5 = 485$ tons of Polyethylene and can provide for nearly 5000 boats per year. Thus, 7,000 ha of land would be required for one year whereas the wooden Kuttamarams would have required 75 hectares of forests over 30 year period. Such regional resource accounting offers opportunity to combine resource endowment, area and target group approaches discussed earlier. Whether the proposed method of winning HDPE will meet the requirements of factor endowment approach, however, needs further exploration. A more relevant question in the context of development planning is: Should the proposed method be abandoned if it does not meet the requirements of commercial criteria ? How should the costs and benefits be assessed ? Does the present cost of HDPE won from petroleum reflect its true cost ?

The actual design and the method of fabrication were evolved after several trials and dialogues with the prospective beneficiaries, the fishermen (see Figure 5). The boat is made from 6 inch HDPE pipe, 6 meters long (pressure rating 4 kg/sq. cm.). The two ends are squashed and sealed in planes perpendicular to each other by using a stove-torch and a specially designed simple jig that can be manually operated. Each pipe is bent by heating to form the bow-piece which is now integral and not separately attached as in a wooden Kuttamaram. The bending is accomplished by first filling the pipe by beach sand and inserting the pipe in a dug hole in the sand on the beach. The heating by blow torch softens the pipe were it is bent by manual pushing from above the the surface of the sand on the beach. This method prevents buckling of the pipe during bending and represents a fine adaptation of simple principles besides using local materials to achieve the desired objective. The two outermost pipes are shorter to allow rowing when sitting at the back. The pipes are shorter to allow rowing when sitting at the back. The pipes are held together by a specially designed curved solid HDPE blocks that are force-fitted and subsequently welded by heating.

The overall comparison of the 5-log Kuttamaram and the HDPE boat is shown in Table 7

5 Concluding Remarks

In this paper, the problematique of linking technology to development process is presented together with suggestions for possible approaches and mechanisms for this linking. The case studies illustrate the theoretical propositions as well as the mechanisms. The paper is written for readership by both working scientists and engineers as well as social scientists. While most propositions are not new, they are presented (nay, simplistically narrated) here to serve as a reminder for a professional who is occupied with day-to-day responsibilities and immediate concerns of his profession. It is hoped that the paper provides the necessary framework for self-evaluation of his/her work and of his/her working environments.

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