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METHODOLOGY FOR SELECTION OF ENVIRONMENTALLY SOUND AND APPROPRIATE TECHNOLOGIES

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Environmentally sound and appropriate technologies can be defined as those technologies which are consistent with an environmentally sustainable development, i.e., a development which can be sustained over the long run by being, among other things,

(a) in harmony with the environment (environmental soundness)

(b) directed towards the satisfaction of basic human needs and the reduction of inequalities between and within countries (economic appropriateness);

(c) based on endogenous self-reliance through an increase in social participation and control over the activities of society (social appropriateness).

The environmental and social concerns in this definition are based on the value-judgements that the environment is the sole irreplaceable habitat for man and that, in the ultimate analysis, it is a basic need of human beings to participate in the decisions and processes concerning their destiny and to exercise control over these decisions and processes. The economic concerns are derived from two value-judgements of the international community, viz.,

(1) that development is an urgent objective of the highest priority; and

(2) that a New International Economic Order, including particularly a new relationship between developed and developing countries, is essential.

It is these social and economic concerns which imbue the concept of "appropriateness" with semantic content and make it inseparable from socio-economic objectives. But, the result of all these concerns is a <u>normative</u> definition of environmental soundness and appropriateness.

Such a definition makes the deliberate <u>choice and selection</u> of environmentally sound and appropriate technologies an issue of paramount importance to all countries. Indeed, neither development nor a new international economic order is achievable without a satisfactory methodology and process of choice and selection.

This methodology and process must have - like development and the New International Economic Order - environmental, economic and social dimensions.

The environmental dimension must be concerned with the rational sustained use, rather than indiscriminate rapid devastation, of the resource-bestowing and life-supporting biogeophysical environment. Hence, this dimension must involve, the exercise of several preferences* in the choice of technologies, for example,

(1) A preference for energy-production technologies based on renewable, rather than depletable, energy sources (e.g., sun, wind and biogas, rather than oil or coal);

(2) A preference for resource- and energy-saving, rather than resource- and energy-intensive, technologies;

(3) A preference for technologies which produce goods that can be re-cycled and re-used, rather than used once and thrown away, and that are designed for durability, rather than obsolescence;

(4) A preference for production technologies based on raw materials which are replenishable (e.g., wood and cotton), rather than exhaustible (e.g., steel or petroleum-based synthetic fibres);

(5) A preference for technologies of production and consumption which inherently minimize noxious or dangerous emissions and wastes, rather than those which require 'fixes' to curb their intrinsically polluting tendencies;

(6) A preference for technologies of production and consumption which incorporate waste minimization and utilization procedures as integral components, rather than those which require them as appendages;

(7) A preference for technologies which blend into natural ecosystems by causing them minimal disturbance, rather than those which threaten the biosphere with major perturbations.

The economic dimension involves the exercise of preferences for technologies which are need-based, rather than demand-oriented, and which reduce, rather than amplify, inequalities between and within countries, for example,

(1) A preference for technologies which are consistent, rather than incompatible, with the basic factor proportions of particular countries, which means, for most developing countries, a preference for energy-conserving, capital-saving and employment-generating, rather than energy-extravagant, capital-intensive and labour-saving, technologies;

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* What is preferred need not necessarily be chosen - as discussed later. In that sense, preferences operate when other things, e.g., productivity, unit costs, etc. are equal.

(2) A preference for the technologies of goods and services relevant to mass consumption, rather than to individual luxuries;

(3) A preference for technologies based on local materials, rather than materials, which have to be imported from abroad or transported from distant parts of the country;

(4) A preference for technologies which generate employment for underprivileged masses, rather than for privileged elites;

(5) A preference for technologies which produce for local consumption, rather than for remote markets;

(6) A preference for technologies which promote a symbiotic and mutually reinforcing, rather than parasitic and destructive, dependence of, on the one hand, the metropolises of developing countries on their rural hinterlands, and on the other hand, of the developed countries on the developing countries.

The social dimension involves preferences for technologies which promote endogenous self-reliance by increasing social participation and control, for example,

(1) A preference for technologies which lead to an enhancement of the quality of life, rather than merely to an increase in the consumption of goods;

(2) A preference for production technologies which require satisfying creative work, rather than boring routine labour, i.e., for technologies which relate men to work, rather than alienate them from it;

(3) A preference for production technologies in which machines are subordinated to, rather than dominate, the lives of people;

(4) A preference for technologies which lead to human settlements being designed to suit the collective and individual lives of people, rather than the requirements of agglomerations of productive units;

(5) A preference for technologies which promote ease, rather than sophistication, of operation;

(6) A preferences for technologies which blend with, rather than disrupt, traditional technologies and the fabric of social life;

(7) A preference for technologies developed endogenously from the local context, rather than transferred from alien settings;

(8) A preference for technologies which facilitate the devolution of power to the people, rather than its concentration the hands of elites.

These preferences* only indicate a recommended poise of the intellect and a bias of the emotions for a decision maker. They introduce a normative content into the process of judgement on technologies. But, the technologies that must be finally chosen and selected are not necessarily those which are preferred - preferences only influence or guide choices, they do not determine them. Between the preferences for certain types or patterns of technologies and the final choice and selection of technologies, lies the whole process of decision-making. And, it is the procedure and methodology intended to underlie this decision-making process, that constitute the subject matter of this discussion.

The general problem can be stated simply. Given the imperative necessity of achieving development and a New International Economic Order, and the consequent prescription of preferences (not necessarily those outlined above) for certain types of technologies, what actual procedure and methodology must be followed in the process of choosing and selecting technologies for particular environmental, economic and social contexts (localities, sub-regions, countries, regions)? If no current or conceivable technologies satisfy all the prescribable preferences (and this is almost certainly to be the case), then the different preferences must be given different emphases. In other words, one is confronted with a weighting problem. To complicate matters, this weighting need not be the same in all contexts.

The most popular, though controversial, approach to the general problem of selection of technologies is that of cost-benefit analysis. When this technique is used by private enterprise, the result may turn out to be a minimization of internal costs and a disregarding of external costs. To avoid such a result, the advance to social cost-benefit analysis has been urged upon decision-makers. Instead of evaluating costs and benefits in terms of market prices, the technique of shadow pricing is adopted in which one uses prices more accurately reflecting the intentions of decision-makers.

How can this approach incorporate environmental factors? Environmental impacts usually take a long time (say, decades) to manifest themselves, and some of the manifestations result in increased economic and social costs, for example, of extracting or using a natural resource (minerals, energy, water, soils, etc.).

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* Each of which involves a criterion.

Thus, there might be a contradiction between economic objectives, on the one hand, which may seek to maximize short-run benefits, and environmental concerns, on the other hand, which aim at minimizing long-term costs. But, cannot the same time-span be used for both considerations? Approached thus, would not a sufficiently long discounting period (say, decades) transform the environmental impacts (at least, the serious ones) into economic costs and benefits, and thereby be brought within the scope of the cost-benefit analysis?

Then, there is the question of how social factors can be quantified with shadow prices? Can, for example, self-reliance or social participation be shadow priced? If not, will not the cost-benefit technique miss out on one of the most critical factors in development? And, if a social factor like social participation can indeed be shadow priced, will the arbitrariness in the pricing be so large that the analyst is likely to produce any result that his sponsor/patron (usually the politician) wants, or that his own social conditioning and/or vested interests bias him towards? Is it, therefore, a question of social cost-benefit analysis being so attracted by numbers that in order to reach the mirage of quantitative results, it excludes from analysis all or most non-quantifiable factors, even though these latter factors may be far more relevant than the quantifiable ones?

The larger question, therefore, is to define the precise extent to which social cost-benefit analysis can help in the selection of environmentally sound and appropriate technologies. In the limited case of alternative scales of production for the same product, is this approach of quantifying the cost-benefit analysis as much as possible, and clearly listing and delineating the non-quantifiable factors, quite adequate for decision-making? But, for the more general case, can one carry the quantitative analysis as far forward as possible making explicit all value-judgements and assumptions, identify and describe sociological impacts, and then leave the assessment of these latter impacts to the decision-makers? If this "upper limit" of cost-benefit analysis is insufficient, what alternatives are there?

One such alternative approach to the problem of selecting environmentally sound and appropriate technologies would involve the use of a sequence of decision filters (of the go/no go type?) as shown in Figure 1.

The process starts with a definition of the basic needs, and the first decision filter (DF 1) is intended to reject those technologies which are not specifically addressed to those needs. In effect, such a first step determines the nature of goods and services to be produced in the economy.

The next question to be considered is that of growth rate. To consider this question is not a submission to growthmania since the content of growth has already been determined in the prior step and since what is under consideration is not the maximization of the growth rate but a fixation of its value. Unless the aim is deliberately to lower consumption standards (which may well be the decision of certain developed countries), it is obvious that the growth rate must not be less than the population growth rate - thus, a lower limit to the growth rate of goods and services can be defined. The upper limit to the growth rate is likely to be determined by the availability of capital and resources. These upper and lower limits to the growth rate define the function of the second decision filter (DF 2) - the function is to reject out technologies unable to sustain the desired growth rate as well as technologies requiring far more resources than are available. In other words, only those technologies which have a low enough capital-output ratio consistent with resource availability will pass this filter.

The third decision filter (DF 3) is particularly important for developing countries because it concerns employment which must be considered a basic human need. The question is whether the various technologies arriving at the decision filter generate sufficient employment. Those that have too high a capital-labour ratio would have to be rejected, for to accept them would be to permit growing unemployment and an undermining of development objectives.

Thus, the whole operation of filters DF 2 and DF 3 is designed to match technologies to the capital, resource and manpower endowments of the locality, sub-region, country and region.

The social decision filter (DF 4) is intended to ensure that the selected technologies enhance the quality of life of those operating the technology, instead of reducing employment into alienating drudgery. Not only will such technologies promote motivated productivity, but they must form the basis of a socially sustainable development based on participation.

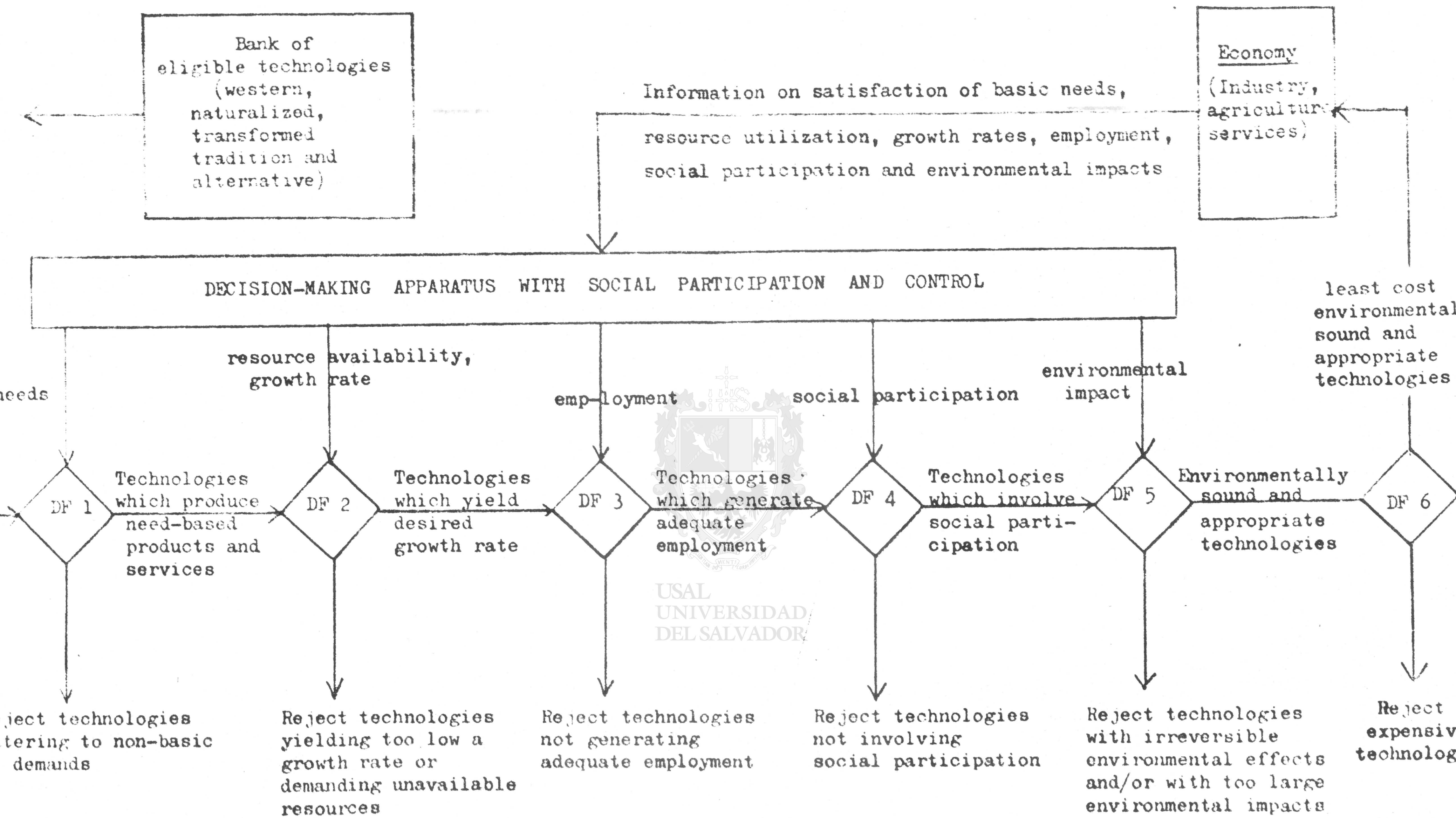

Figure 1: Design Filter approach to the selection of environmentally sound and appropriate technologies

If no mention has been made here about the relation between a technology and the quality of life of those outside its operation who consume its products and services, it is because the first decision filter (DF 1) is presumed to ensure products and services which are acceptable and to promote individual and collective well-being.

The fifth filter (DF 5) is planned to introduce environmental concerns. Since every technology is an open system insofar as it consumes inputs and produces outputs (apart from the intended goods and services), it is inevitable that there are always environmental impacts arising through these inputs and outputs. The question is about the magnitude and nature of these impacts. If impacts cannot be avoided, the continuous escalation of these impacts must be prevented so that a steady-state situation is established within natural ecosystems. If this prevention is not possible, then at least irreversible damages to life-support systems must be avoided. Thus DF 5 can be operated in two stages:- firstly, to reject technologies which can lead to irreversible environmental damages even in the remote future, and secondly, to select out from the technologies which pass the irreversibility test those that have the least environmental impact.

The last filter (DF 6) is intended to ensure that goods and services are obtained at the least cost. Thus, of the various possible technologies for a particular product or service, the filter will select out that technology which provides this product or service at the lowest unit cost.

One cannot just assume that the technologies that pass through the whole sequence of decision filters are environmentally sound and appropriate. Strictly speaking, there must be some sort of empirical test. One must be able to evaluate such a decision-filter methodology, i.e., to determine whether the selected technologies are indeed in harmony with the environment and advancing the objectives of development.

Apart from this evaluation problem, there is another problem. This stems from the fact that the sequence of decision filters can operate only if judgements on basic needs, desired growth rates, unemployment, social participation and permissible environmental impacts are introduced into the sequence from outside the sequence. Hence, the selection may not be optimal.

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How are the evaluation and optimality problems to be approached? One possibility is to link outputs and inputs through a feedback loop. This can be done by considering what effect tentatively selected technologies have on the economy (industry, agriculture, services). The idea is to secure information on what is happening to such aspects of the economy as basic needs, growth rate, employment, participatory and environmental as a result of the introduction of technologies which have been tentatively selected, and then to feed back this information into the sequence of decision filters via the decision-making apparatus.

Thus, the selection of environmentally sound and appropriate technologies becomes an iterative process of: trial selection → introduction into economy → monitoring of effect → improved decision filters → improved selection → ..... But, should this iteration be done in real time or on a simulation model of the economy?

Real-time results may well be more acceptable, but they are also associated with several problems:-

(a) technologies have a gestation time before they reach full effectiveness, and the larger the scale of technology, the larger the gestation time, which means that real-time iteration may be an agonizingly long process;

(b) technologies have a momentum of their own, for instance because of the capital investments made in them, and the larger these investments, the more painful and unlikely the process of withdrawing technologies however environmentally unsound and inappropriate they may prove to be;

(c) some impacts of technology require such long times to manifest themselves - e.g., environmental impacts may take decades - that, unless ingenious techniques of monitoring incipient trends are devised, it would be too late and futile to wait for real-time manifestations before taking corrective action;

(d) if the pace of technological advance is faster than the pace of the iterative selection process, then real-time iteration becomes virtually endless.

If, on the other hand, the iterative selection of technologies is done on simulation models of the economy, then the validity of the selection depends almost wholly on the validity of the model. But, does the state-of-the-art in model-building justify confidence in this approach? Cannot such a simulation approach to technology selection be combined with real-time testing of short-gestation, low-momentum, small-scale technologies? Or, would this lead to in-built biases against large-scale technologies?

In principle, however, a sequence of decision filters incorporating a feedback loop permits both evaluation of the selection methodology and optimization of the selection process. It also facilitates the introduction of social participation and control into the decision-making apparatus, as well as the long-term social sustainability of the whole development process. It has other attractive features, such as

(1) its recognition of the integration of the technology sub-system into the larger system of society (with its economic and political sub-systems) and the biogeophysical environment;

(2) its cybernetic goal-seeking character in which the system (and its components) advances towards development objectives in harmony with the environment;

(3) its firm links with the values of human beings.

On the other hand, its schematic nature and deliberate simplicity (hopefully, not naiveté) begs a host of questions.

(1) What sanctity is there to the particular sequence of decision filters? Can the sequence be sanctioned by an accepted/acceptable hierarchy of basic needs, so that food, shelter, clothing, health, education and employment have precedence over social needs and environmental concerns? Further, will the outcome of the selection process depend upon the order in which the decision filters are sequenced, i.e., are the decision filters commutative? For instance, suppose the environmental decision filter (DF 5) is placed first in order to transmit only those technologies with the least environmental impact - will this lead to an undermining of development objectives? Will such an overriding emphasis on environmental concerns eliminate the opportunity of pursuing development goals whilst buying time to tackle environmental problems later? Or, suppose that the least cost filter (DF 6) is placed immediately after the product-mix filter (DF 1) - will this lead inevitably to highly automated,

capital-intensive and labour-saving technologies which will frustrate other development objectives such as employment, social participation, etc.? In short, does the unquestionable priority and urgency of development tasks necessarily imply a particular sequence of decision filters? Or, does one have to try out various sequences of economic, social and environmental filters to see whether the same technologies emerge irrespective of the sequence? And, if the outcome of the selection process varies with different sequences, can these outcomes be scrutinized to determine which development objectives are subordinated in each outcome, so that a value judgement can then be made on which sequence is consistent with development?

(2) Can the same decision filter sequence be used for the selection of a technology for a single project as well for the selection of a package of technologies for an economy? If not, what changes must be made?

(3) Another question along the same lines is whether the same decision filter sequence can be used at the macrolevel (region, country), the mesolevel (sub-region, province/country/district) or the microlevel (town, village), and for developed and developing countries.

(4) Can the sequence be used for problem areas, e.g., transport or food, and if so, should it be restricted to such an application?

(5) Is this whole sequence issue a "red herring" which is automatically taken care of by iteration?

(6) Would there be significant advantages in using transmission decision filters, rather than rejection filters, i.e., should the decision criteria be designed to pass as many technologies as possible rather than reject as many as possible thus avoiding a situation where no technology succeeds in getting through the sequence? One obvious advantage would arise when the difference between technologies is of degree, rather than of kind, in which case *go/no go* filters are necessarily arbitrary and cut off too sharply.

(7) What should be the detailed structure and content of each filter (i.e., what criteria should be used), and how should these be altered, if necessary, when the use of the technology selection process is changed from projects to a problem area to a whole economy, from the microlevel to the macrolevel, from a developing country to a developed country? Further, can elements of input-output analysis and cost-benefit analysis be incorporated into some of the decision filters?

(8) Even if the idea of a sequence of decision filters is useful, what institutional framework and structure is necessary to make it implementable?

Apart from these questions, the real issue is whether there are other approaches to the problem of selection of technologies? If so (for instance, generalized forms of programming), how do they compare with the cost-benefit and cybernetic approaches?