NATIONAL DEVELOPMENT OBJECTIVES AND SCIENCE AND TECHNOLOGY POLICY*

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(Editor's Note: What follows is the balance of Ratna Rana's article which commenced in Chapter 4. There he was talking about the national organization for S&T policy. Here he demonstrates how criteria for many S&T policies flow out of national development goals)

The major objectives laid down in Nepal's Sixth Five Year Plan constitute the basis for identification of priority areas for science and technology. There are three objectives in the plan:

1. To meet the basic minimum needs of the people
2. To increase the rate of national production
3. To increase the opportunities of productive employment in the country

At sectoral levels, objectives have been laid down to achieve these broad national goals. In the agricultural sector, efforts are geared towards increasing food production, especially in the hills, so that food deficient areas are made more self-sufficient. Food being one of the basic needs, full priority is given to its production. Thus technologies relevant to the improvement of food production become important from the viewpoint of science and technology policy. The emphasis on food as a basic need gives importance to various sub-sectors such as irrigation, chemical and biological fertilizers (biogas plants), pesticides, manure and fodder plants, and pasture and livestock. The technologies related to these sub-sectors, therefore, need to be improved or developed.

The energy sector is also to be reckoned with in this regard. Food production must be cooked. This draws attention to the problems associated with firewood demand. In the hills, firewood demand has resulted in continued deforestation and excessive erosion. The impending ecological disaster can only be averted through afforestation schemes and

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increased production of firewood. Science and technology can solve this problem by providing more efficient stoves and identifying appropriate species of fast-growing trees. Identification and cultivation of multi-purpose firewood-fodder trees is a matter of utmost importance.

The second basic need is the clothing requirement of the people. In the industrial sector priority is, therefore, given to cottage and small-scale industry development. The textile sector, both large and small scale manufacturing, becomes important in this context. The present raw material requirements of cotton and wool industry are not being met from within the country. In view of large future demands, it appears necessary to improve the supply base of cotton and wool through enlarged production. In this respect, in addition to the expansion of cultivated cotton, it becomes necessary to look into the cellulose-based synthetic yarn technology. The technology of hand-looms, pedal looms and other indigenous manufacturing techniques needs to be improved. This implies that production of cotton, wool and artificial yarn has to be expanded along with the extension of existing weaving and spinning technology at the cottage industry level. The fulfillment of the basic food and clothing needs requires cash income to be generated at village level. The role of cash crops, horticulture, poultry, etc., is also quite important. Thus the promotion of these sectors is another priority area for science and technology application.

The third basic need is for shelter and protection from harsh environment. In the housing and construction sector priority must go to low-cost housing for urban areas and improved shelters for rural areas. House cost is determined mostly by the cost of construction materials. Therefore, construction materials technology needs to be exploited to reduce the cost of shelters. Science and technology may be applied to produce better building materials from available resources, resulting in cheaper shelters for the people. There is also a need to ensure supplies of basic raw materials and spare parts required for various small and medium scale technologies. So emphasis must also be placed on the development of technologies related to basic industrial raw materials and spare parts supply.

The achievement of all the broad national goals, however, requires that the application of science and technology be made broader than is possible when it is focused exclusively on basic needs. The national goals are strongly interlinked with one another. These linkages indicate, among other things, the necessity to evolve a comprehensive and coherent set of science and technology policies. In evolving such policies, interdependence among the various sectors of the economy must be borne in mind.

To achieve a broader application of science and technology (than is dictated by the basic needs approach), especially in the medium term, it becomes necessary to exploit interdependencies existing between basic science and applied science. From an operational standpoint, it becomes hard to distinguish between basic and applied science. Though, at least in the context of research activities, queries in "applied" science are quickly relegated towards "basic" science. If and when answers are found, these answers find their way back towards useful applications. It is in this sense that basic science research may be looked upon as a derived demand for research--the demand being derived from the demand for technology, which has been established either through the basic needs approach or through some other developmental approach (e.g. industrial growth based on abundant hydropower).

SCIENCE AND TECHNOLOGY POLICY

The formulation of science and technology policy requires the identification of broad areas of application. The next step in policy formulation thus involves a set of criteria based on which different priorities can be given to the broad application areas identified. The set of criteria used in fixing priorities must be complementary to the overall development goals even if they cannot be directly derived from these goals.

Policy formulation (in the science and technology sphere) can also be looked upon as a process of evaluating alternative investments in research, development and diffusion activities in various areas of science and technology application. The process of prioritization may be looked upon as a process of selecting a few areas of application of science and technology which yield maximum social returns on investment.

A broad area of science and technology application should be further analyzed to determine the composition of research, development and diffusion activities required. It is clear that in some areas, basic research and dissemination are more important. The policy formulation process should be able to assess the relative importance to be given to research, development and diffusion activities.

Planning basic research necessarily entails the fulfillment of only the broad objectives of generating basic knowledge and potentially useful knowledge. Hence, only broad areas and directives can be programmed. Results depend on the capacity of researchers in teams, or working individually, to generate new ideas. Hence, uncertainties are generally inherent in basic research. The scope of basic research activities is universal and these activities and results have worldwide validity. An evaluation of such activities is based mainly on scientific merit as judged by the scientific community and, in a few cases, on possible applications. Short-term basic research planning is rather uncertain and the dominant time horizon is generally medium and long-term. Against this backdrop, it calls for due care in the exercise of planning basic research, particularly in a country like Nepal where such activities are still a new phenomenon.

Just as endogenous technological capability is a prerequisite for identification and transfer of technology, endogenous capability in science is similarly essential to assimilate new technology and to make science and technology take roots in the country. Research in basic science plays a very crucial role in such development of endogenous capability in science.

Development of endogenous capability in science is essential from two major considerations. One is the need to maintain the capability to assimilate new technology as it becomes available elsewhere. The other consideration may be termed "derived demand"--a demand for science emanating from the internal demand for technology may initiate more basic science research within the country. The resource endowments of a country and the "development path" chosen by it dictate the type of technology it needs and acquires. To this extent, basic science research may be largely dominated by the need to evolve a certain type of technology. However, the manifold developments in science on the one hand, and limited availability of resources on the other, give rise to a need to determine priorities along the wide spectrum of scientific developments. In the past, not much attention was paid to linking such developments with national development efforts.

For increasing the S&T input in the development effort, it is useful to adopt a strategic approach. A clear choice of priority sectors and strategic science and technology inputs would permit infusion of the requisite critical mass of science and technology for generating the desired impact in the priority areas. Priority ranking among the sectors, and appropriate weight given to them, would further help to consolidate efforts in areas of top priority.

The above approach would necessarily imply temporary sacrifice of some of the objectives of S&T development. Such strategic choices should, by definition, be transient, changing with the requirements and conditions of time, but conforming to a broad perspective. A major consideration would be to ensure that strategic choices made at any point of time do not restrict the future options of scientific advance.

At present, the identified strategic sectors in the country needing immediate S&T inputs are agriculture, forest, water and mineral resources, energy and industry. The nature of basic science research and the specific areas of basic science research within these strategic sectors, must be determined through the consideration of two factors:

1. The existing and potential capabilities for conducting basic science research within the country

2. The necessity or demand for basic science research to evolve and/or develop a specifically beneficial type of technology. (For example, due to great potential for applicability, small-scale hydroelectric plant-based chemical fertilizer technology is going to warrant specific basic science research in areas of electrochemistry and catalytic synthesis, etc.)

Even though basic science research is not geared towards creating the whole gamut of specific technological knowhow incorporated within a given technology, some basic science research can open up the possibility of transfer and adaptation of relevant technology. The following long, medium, and short-term objectives of basic science research and development have been identified keeping in mind the above mentioned determinants of basic science research.

The long term objectives of basic science research should be:

1. To generate basic and potentially useful scientific knowledge which may eventually be fed into social and economic use for national development, and which may promote requisite understanding to keep up with the evolution of science elsewhere

2. To develop a base of scientific activities linked to growth of knowledge at world level

3. To ensure that the creative talent of mankind is encouraged and finds full scope in scientific activity, and thus to encourage individual or team initiative for the discovery of new scientific knowledge

The medium/short-term objectives should be:

1. To raise the present standard of science research in the country

2. To ensure an increased supply of scientific research personnel who are capable and competent to work on development problems of the country

A set of criteria to be used in giving relative weights to various research, adaptation and diffusion activities should be in hand for purposes of policy formulation. The following section outlines such a set of criteria.

Criteria for Evaluating Science and Technology Policy

One way of determining priority is the deductive approach of first identifying the problems, needs and priorities of the country and then expressing them in terms of questions and problems amenable to scientific treatment, and thus, eventually leading to an appropriate R&D plan. This sectoral approach can, however, have potential limitations for the all-round development of capability in science. It can, for instance, completely overlook the influence of S&T considerations in socio-economic objectives, particularly in terms of creating new opportunities for the development process. An integrated approach that deals concurrently with both S&T planning and development can alleviate such problems. Similarly, discipline-based S&T planning also runs the risk of introducing too much academic bias. Proper focus on problems rather than on disciplines can, however, minimize such bias.

As the above mentioned two methods are not mutually exclusive, simultaneous use of the two methods can help in avoiding (to a great extent) their respective limitations. A fruitful way of approaching the integration of S&T with the development planning process would involve selecting an initial group or a sequence of problem areas in which the development of indigenous S&T capabilities would be attempted. For the identification of such problem areas on which to focus efforts, the fulfillment of the following criteria has to be examined.

1. The first criterion is the need to secure a critical mass of scientists, technologists and managers to undertake research activities. This critical mass should be examined from the point of view of quantity, quality and its links to related fields. Considering the quantitative aspect, the question is to ensure the availability of human, physical and financial resources above the minimum level required to generate scientific knowledge of direct relevance to the problem area. From the qualitative point of view, the resources available should have the characteristics which make them suitable for sectoral activities (trained and experienced scientists, sets of equipment satisfying certain specifications and standards, etc.). It is necessary to gather a base of resources, not only in the scientific field of immediate relevance to the problem area, but also in those neighbouring fields which interact strongly with the main axis, since advances in science arise frequently from the combination of knowledge generated in contiguous fields.

   This criterion focuses on the demands of science and technology activities on infrastructure, human and financial resources and the existing knowledge in science and technology. It can clearly indicate areas where critical mass can be secured through five kinds of investments:

   a. Building up the laboratory and other infrastructures

   b. Creating the institutional mechanisms necessary to facilitate exchange of know - how and information amongst various S&T units

   c. Creating new R&D institutions, when necessary, to back up other S&T activities

   d. Providing incentives to the S&T community to produce results

   e. Creating an environment conducive to S&T development

2. The second criterion derives from the fact that scientific advances from research should enhance the technological capabilities of the country to use the existing (or highly possible) resources within the country. The problems should be closely

linked to the national development plan and programs both on the medium-term and long-term time horizon.

3. The third criterion to be considered should be the possibility and the opportunity (e.g. by taking advantage of topography or geo-physical position) of exercising leadership, so that the country would become an internationally recognized centre of scientific excellence in a particular problem area. This would be achieved through a concentration of effort, and this could eventually pave the way for a more balanced exchange of scientific knowledge and technologies with other countries.

4. The fourth criterion would lead to the selection of problem areas based on the possibility of obtaining concrete results within a reasonable period of time, expressed in terms of producing and utilizing technologies related to scientific findings, and serving as a starting point to undertake similar activities in other areas, thus generating a cumulative sequence which would facilitate the growth of an endogenous scientific and technological base.

The selection of major problem areas to which application of S&T is envisaged is merely the starting point. These problem areas would indicate the necessary S&T activities to follow. The mix of S&T activities required can vary from one problem area to another. In the case of application of a less sophisticated technology, basic research activity will be minimum. In the case of a complex technology, application will demand greater efforts in basic research along with adaptive research activities. The selection of major problem areas (priority areas) thus should eventually lead one towards specifying a set of S&T policies geared towards finding a reasonable set of solutions to the selected problem area. The formulation of S&T policies also requires a set of criteria specifically designed to evaluate S&T policies.

Evaluation of science and technology policy must be conducted *ex ante* on the basis of the stipulated impact such policies generate on the welfare of the country. The economic impact--income, employment, and equity considerations in particular--constitute the most important effect to be considered. Though science and technology policy may have other long-term impacts, the importance given to economic impact reflects the application-oriented strategy adopted in the country. Its sociological and environmental impact will also need to be evaluated later on.

Impact evaluation is to be conducted in terms of a set of existing and potential technologies which a particular policy will bring into the production arena. The effectiveness of a particular policy will depend upon the effectiveness of various research, development and diffusion activities undertaken under a particular policy implementation. Thus the criteria for policy evaluation may be directly translated into criteria for evaluating research, development and diffusion activities themselves. The following discussion outlines the criteria for evaluation of research, development and diffusion activities.

EVALUATION CRITERIA FOR RESEARCH, DEVELOPMENT AND DIFFUSION ACTIVITIES

Application of science and technology generally involves promotion and coordination of the following broadly categorized activities:

1. Basic research and technology development
2. Adaptive research and technology transfer
3. Technology promotion and dissemination

Basic research and development of technology are after all inseparable from one another, and so these activities are put together as shown in (1). In situations where basic research is not necessary on account of the existence of the technology elsewhere, adaptive research and/or transfer of technology becomes necessary as indicated by activity (2). Finally, when suitable technologies are available within the country, the impact of such technologies may be optimized through diffusion activities, involving technology promotion and technology dissemination.

Evaluation criteria for basic research and technology development activities would consists of the following:

1. Basic research activity to be undertaken in a given area should have a high potential for giving rise to suitable technologies of high economic significance (low risk area with large potential benefits)

2. The potential technology which may be generated from basic research must use existing (or highly possible) resources within the country (technology of comparatively large advantage conducive to self-sufficiency goals)

3. Basic research activity should draw from the existing core of scientific and technical manpower and should help towards the improvement of their quality and skills (indigenous manpower base)

4. Basic research activity should not be prohibitively expensive from the standpoint of imported raw materials and equipment (foreign exchange components and foreign dependence)

Evaluation criteria for technology development activities would include the following:

1. Technology development activities should be undertaken only when a high potential exists for the success of such endeavours (low risk area)

2. The developed technology should have large potential benefits associated with it (large potential benefit)

3. The potential technology should have a good prospect for being drawn into the production processes (good adoption potential)

4. The potential technology must be able to provide comparative advantages to the user (cost effectiveness)

5. The cost of technology development should not be excessively high, i.e. the development costs should not exceed potential benefits (low development costs)

6. Manpower required for the development of technology should exist in the country (indigenous technical expertise)

7. Skill requirements and the resource base for the potential technology should be met indigenously when in operation (based on indigenous resources)

8. The potential technology should not lead to excessive dependence on a few specific countries (less foreign dependence)

Evaluation criteria for adaptive research and technology transfer activities would include the following:

1. Adaptive research or technology transfer activities must relate to these technologies which have proven potential benefits (large proven benefits)

2. The technology to be adapted must also use existing or potential resources locally available (high backward linkages)

3. Technology transfer costs and licence fees should be low (low transfer costs)

4. Adaptive research should have good potential for reducing operational costs associated with the technology under consideration, so that products are competitive (high forward linkages)

5. Adaptive research or technology transfer should be possible using existing skills and manpower (indigenous research capability)

6. The technology transferred should have no manpower and skill constraints (indigenous manpower base)

7. The technology should have high industrial and social acceptability (high comparative advantage and high acceptability)

Evaluation criteria for technology production and dissemination activities would include the following:

1. Technology promotion and dissemination activities should relate to those technologies which have been proven after field trials within the country and show good promise (field-tested technologies)

2. Promotion activities should also be oriented towards technologies which are experimentally a success and provide good potential benefits if they can be extensively diffused (large social benefits)

3. Promotion and diffusion activities should be geared towards those technologies which show good prospects of social and/or commercial acceptability (high social acceptability and/or high commercial acceptability)

4. Technologies with low diffusion activity costs should be diffused (low dissemination costs)

5. The technology to be promoted should preferably have indigenous resource base, good forward and backward linkages and be comparatively advantageous

The above criteria (although relative weights are yet to be devised for them) are adequate for the evaluation of any science and technology policy that may be adopted by RONAST

There are, however, some evaluation difficulties even if these criteria are well developed unless the policies can be related to specific technologies. In program formulation, it becomes necessary to select the most promising technologies from among a set of technologies meeting these criteria. The programming process involves a kind of optimization exercise, where the returns from investments are maximized against the given constraints (of manpower availability, knowledge and other resources). In what follows, technology assessment will be discussed as a means of further screening potential technologies.

EX-ANTE TECHNOLOGY ASSESSMENT

Adoption of science and technology (S&T) policies can draw a set of specific technologies into the production process. Such technologies (or sets of techniques) must have two major characteristics:

1. Technical feasibility

2. Socio-economic acceptability

The notion of technical feasibility requires no elaboration. Socio-economic acceptability, however, goes beyond the notion of simple financial profitability. The techniques must have no social stigma attached to them either on account of their by-product or of their side effect (e.g. environmental effects). It is important to note that socio-economic viability looks at both the forward and backward linkages generated by specific technologies and/or their products. Generally speaking, backward linkages of technology draw our attention to resource endowment and the potential comparative advantage this can generate. Similarly, forward linkages relate to the ability of technology to cater to the intermediate demands of other productive sectors, and therefore, this has strong bearing upon aims of import substitution and export promotion. The assessment of these technologies vis-a-vis the linkages forms the basis for technology assessment.

At this stage of discussion, it is obvious that specific S&T policies implicitly envisage a certain type of structural change in the economy. Structural change implies that intersectoral interdependence undergoes change, and if the structural change is deep, there is a significant modification in sub-sectoral interdependence. Presumably, if planning strategies and S&T policies are harmoniously integrated, the envisaged structural change would bring into productive use more of the abundant natural resources to overcome the constraints imposed by scarce resources. Thus technology assessment involves the determination of "appropriateness" in the broadest meaning of the term.

An *ex-ante* assessment of technology thus requires the evaluation of (1) technical feasibility, (2) socio-economic feasibility, (3) social acceptability, and (4) environmental impact of the technology under consideration. The process of evaluating research, development and diffusion activities must be done through *ex-ante* technology assessment. There is a good possibility of formulating qualitative as well as quantitative sets of criteria in the assessment of technical and socio-economic feasibilities of technologies under consideration. Social acceptability and environmental impact assessment would, however, tend to be based on the criterion of qualitative decision.

TECHNOLOGY TRANSFER POLICY

Transfer of technology is an important area where S&T policies need to be carefully spelled out. Transfer of technology will take place between Nepal and other less developed countries (LDCs), and also between Nepal and developed countries (DCs). The areas of technology transfer are bound to differ between LDCs and DCs. Though the criteria for adaptive research activities and for technology transfer and dissemination activities have already been pointed out, it would be appropriate to spell out a broad policy for technology transfer.

Technology transfer policies need to be differentiated in regard to two factors:

1. Technology areas where self-sufficiency goals are vital

2. Technology areas where technologies will be imported in the immediately fore - seeable future

Technology transfer in areas where self-sufficiency is desirable must be broad as well as deep. Such transfers should be multilateral and diversified in terms of countries. Technology transfer in areas where self-sufficiency is not necessary and/or economically desirable can be on a bilateral basis. Or it can be through collaboration with a few countries. These broad issues have to be borne in mind while conducting technology assessment for transfer purposes.