Technology assessment methodology

The experience of India’s TIFAC

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Technology Assessment is a systematic attempt to foresee the consequences in all spheres of introducing a particular technology. This article attempts to explain the concept of TA and its role in technology development at national, sectoral and firm levels. In particular, it describes the approach and methodology adopted for TA studies by Technology Information, Forecasting and Assessment Council (TIFAC), which works under the Government of India’s Department of Science and Technology (DST).

Introduction

Technology has become a vital part of the lives not only of commercial and industrial firms, but also of individuals and societies. Whether we speak of a materialist society or of an information society, it is technology that lies at the heart of producing material wealth, and we use technology to handle, store and transmit information.

The greater the knowledge obtained before a decision is made on the development or deployment of a technology, the fewer the chances of mistakes and unpleasant surprises. In particular, a technology should be viewed in its widest context, in all its impacts on society, the natural environment, and the organization it is deployed in. This kind of information gathering is known as Technology Assessment (TA). Its purpose is to look beyond the immediately obvious by analyzing the ramifications of a given technology in as wide-ranging and far-sighted a manner as possible. It is only by gathering the best possible information can one make the best possible decision. TA is a systematic attempt to remove all blinkers and to cure myopia.

Global competitiveness

Before we consider the role of TA in the context of the post-WTO global village, let us have a closer look at the meaning of the word ‘technology’. We imagine we know what technology is, but when we think about it more closely, the term becomes elusive; because it is so difficult to distinguish technology from other types of human activity. In its simplest form, we can define technology as the ‘ways and means by which humans produce purposeful material artifacts and effects’. Essentially, in this
definition, technology always consists of material artifacts (hardware, means), and of the software (knowledge, ways) necessarily and immediately associated with it.

Technology has now become one of the principal weapons in the competitive struggle between firms, especially because of the worldwide playing field (referred to as domoii, i.e. economic reform, in Viet Nam). It can be used both tactically and strategically. How well a firm performs depends to a considerable extent on how well it understands, masters and uses a technology. The competitive success of today’s business clearly depends on the use of technology. Modern organizations face the dual challenge of keeping up with a rapidly changing technology and making sense of it.

TA is the tool, or the frame of mind, that allows firms to examine technologies in depth and with foresight in the context of the firm’s interests and capabilities, as well as in the context of the society the firm lives in. The objective of TA, in order to gain full competitive advantage, is to consider technology in its full context, and with all its opportunities, possibilities and ramifications for the firm and the environment in which it operates.

We therefore define TA in the context of technology management - as a systematic attempt to foresee the consequences of introducing a particular technology in all the spheres it is likely to interact with.

General principles
The assessment of technologies involves two major dimensions. The first of these is the characterization of a technology’s economic aspects that demonstrate its influence on business success. For this purpose the following criteria, among others, should be considered:

- The competitive advantage that can be achieved with a particular technology with respect to performance, costs and quality;
- The potential growth rates of sales, earnings and market share (‘lever-age effect’) due to the technology;
- The potential for development of new products;
- The economic risks involved; and
- The R&D resources required.

The second dimension of assessment analyzes the significance of a technology with respect to:

- Its maturity and foreseeable performance limits;
- Competing technologies;
- The scope of potential applications and potential synergy;
- Compatibility with existing systems; and
- The technical risks involved.

Technology forecasting
It is not enough for an enterprise to catch up with a technology; it must also be in a position to continually upgrade it. In other words, it should not only look at solving today’s problems but also consciously aim to lay the foundation for the future course of technologies. Criteria for relevance of listed technologies do include an assessment about the future.

Looking at the possible future technological scene in a systematic manner is called technology forecasting. It is a necessary step while making a technology assessment for an enterprise. It is therefore highly useful to build elements of both assessment and forecasting while looking closely at a particular set of technologies. This combination is popularly known as technology foresight. An example of this concept and term has been used extensively in a Foresight exercise carried out during the last few years in the UK.

Life cycle assessment (LCA)
There is a growing need to move away from narrow definitions and concepts in environmental system management. Life cycle assessment (LCA) is a technique for assessing the environmental performance of a product, process and policy or activity “from cradle to grave”, i.e. from exploration/mining of raw materials to their extraction, use and final disposal. It may be noted that emissions and wastes arise because of inefficiencies, causing losses in both material and energy uses. LCA has the potential to take on a broader, life cycle approach, which can be incorporated into corporate strategic planning and policy development.

The life cycle of a product (Figure 1) starts from the extraction and refining of raw materials. These are then transported to a manufacturing site to produce a product. The product is then transported to the user and, at the end of its useful life, is either recycled and returned for re-processing or disposed of in a landfill. In all of these steps, materials and energy are consumed, and wastes and emissions are produced. This is the ‘cradle to grave’ concept.

The question in the future, however, will be whether it will become necessary to adopt a ‘cradle to cradle’ approach: that is, whether some materials that we landfill will become a source of primary materials in the future (indicated by the question mark in this figure). This is already happening with some metals in North America which are being dug up from landfills, because they are richer in their metal content than the primary repositories. In India, many such initiatives have been undertaken. TIFAC, under the Fly Ash Mission (FAM), has taken up projects on extracting important and scarce minerals from fly ash.

The potential of LCA in TA to understand and solve problems of environmental impacts cannot be underestimated. First, an LCA of the technology is carried out to identify the main stages in the life cycle that most contribute to environmental impacts. These ‘hot spots’ in the system are then targeted for improvements. Once the main environmental impacts of the technology have been quantified, the potential for improvement is identified through a selection of materials and process routes for a particular technology. This helps to minimize the environmental impacts, while still satisfying other parameters, such as technical performance, costs, legislations and society as a whole. When all of these parameters are met, an LCA is performed again to identify and quantify the improvement made. The whole process is iterative, with a continuous exchange of information among stakeholders, and yields a number of possibilities for improvement.
India’s TA experience
Elements of TA have been built into the national planning process, and an approach more suited to the complex socio-economic milieu of the country has been used. India has already made substantial investments in various industries, as well as in scientific and technological infrastructure over several decades; so it is often difficult not to realize the full benefits of investment from them. Often the approach is to build around the existing investment to go forward. Also it is often difficult to change various organizational patterns beyond a certain speed.

Well researched studies on several of these aspects would have been welcome, but, in fact, the country lacks data or informed studies on organizational behaviour through changes. Given all these constraints, one has to resort to the intuitive forms of TF/TA such as scenario writing, brainstorming, Delphi methods, and interviews, backing them up with quantitative technologies.

The TIFAC approach
While several agencies of the Government of India, like the Planning Commission and the Ministry of Science and Technology, as well as major players from the industry sector have carried out an assessment of technology needs, this article will confine itself to the TA studies carried out by Technology Information, Forecasting and Assessment Council (TIFAC), a registered society set-up under the aegis of the Ministry of Science and Technology in 1988. One of the main objectives of TIFAC was to generate well-researched reports on several sectors of social and economic relevance, in which elements of both TF and TA are built in as an integrated and constructive, action-oriented exercise.

TIFAC started work on forecasting and assessment relevant to Indian ground realities, while looking at world trends and practices. Its attempt has not always been to promote a few indigenous developments alone, but to look at technology as a whole for the benefit of Indian economy, business, trade or social need. It looks at technology, not merely as a process of innovation or invention of a laboratory process, but as a whole process going through the entire chain; which means operationalization and commercialization plus subsequent service, maintenance and continual upgradation.

TIFAC’s approach to forecasting and assessment has been with practical goals in mind, namely, to create alternative technology trajectories for various important sectors with broad acceptance from stakeholders, ranging from scientists to industrial and technical personnel, to business leaders and government. The TF aspects take into account the world status and trends pertaining to the concerned technologies for the selected sector. This is done mainly through secondary data of reports from many advanced countries. Thus TIFAC has consulted reports of the Office of Technology Assessment (OTA) of USA, reports of Forecasting and Assessment of Science and Technology (FAST) of Europe, publications from MITI, Japan, and so on.

In the following section, the TA methodology is explained on the basis of work carried out by TIFAC.

Methodology
Step 1: This is, in fact, the ‘zero’ step because it involves preliminary work that needs to be carried out while approaching the assessment of any technology. The first issue to be resolved before embarking upon a TA is the top-
ic to be treated. The topic is usually a technology, but it may be a social problem that might be ameliorated by the application of technology. For this, TIFAC conducts brainstorming sessions with people from different walks of life, i.e. industries, researchers, government, etc. These interactions with a large number of intellectuals having different perspectives help to narrow down the areas for conducting TA exercises at a national level.

The next issue to be resolved is the scope of the assessment. The TA studies conducted by TIFAC look at both the perspectives, i.e. a narrowly defined technology and its immediate rivals, as well as the major bundle of technologies serving related purposes. For example, in an assessment made of glass fibre optics, its role in the overall context of IT was also considered.

The third issue is to decide on the time horizon to be covered. A long time horizon brings with it very great uncertainties while a short horizon may be insufficient to reveal truly important aspects of the problem. These decisions about the topic, scope and time horizon are extremely important and must be taken in consultation between assessor and decision maker. At every stage of the assessment, therefore, TIFAC involves experts representing key stakeholders.

Step 2: This consists of a description of a technology under scrutiny, or of the technologies relevant to the solution of a problem under discussion. In addition to merely describing the main technology, a description of alternative, complementary and rival technologies is included, with a discussion on likely development paths of all of these.

Step 3: This concentrates on the core questions: what benefits are to be expected from the technology, what needs does it satisfy, and why is it superior to present or rival technologies?

The benefits may be purely economic and commercial, or they may be expressible in terms of environmental improvement, health benefits or, on a more subtle level, improvements in the social or political fabric of society. By speaking of benefits we do, in a sense, apply a value judgement, though there is a pretty universal agreement about some of the ‘good things’ that technology has to offer.

Step 4: This must address the question of what unwanted effects or hazards the technology might cause. When such undesirable impacts or dangers are identified, the associated problem of who or what might be adversely affected needs to be addressed.

In any case, close attention must be given to all possible side effects, which might prove destructive of the natural environment, dangerous to human health, or disruptive of society, or otherwise trigger a chain of events which appear unpredictable and risky. As far as possible, the risks and impacts ought to be described in quantitative terms, though very often these are artificial and meaningless and it is wiser to stick to qualitative statements.

Step 5: The final step consists of an analysis of policy options. If a technology is likely to require supportive measures for its development and diffusion, the analysis should recommend what measures need to be adopted in terms of fiscal benefits, regulatory measures, training programmes, and so on.

In the case of a technology assessment carried out for a commercial firm, the policy measures will be rather different. It is then not a matter of public policy (although the firm might be able to take advantage of public policy support, or might have to take action to comply with control measures) but a matter of management policy.

TA reports from TIFAC

The steps mentioned in the preceding section are used as general guidelines to prepare TIFAC’s “knowledge-based business opportunity reports”, a fountainhead of useful information for policy planners and industry alike. During the past decade or so, TIFAC has brought out over 250 specialized reports, well researched both in breadth of technologies covered (agriculture to advanced sensors!) as well as in depth. The TA reports usually cover:

- An overview of the technology and its relevance to industry and society;
- The status of the technology in India and abroad;
- Technology gaps;
- The choice of appropriate technology for India, in both the economic and social/environmental contexts;
- Business opportunities;
- Major stakeholders in the country;
- The policy framework, which may act as a driving force or an impediment; and
- Recommendations for action - by industry, researchers and government.

TIFAC reports have been widely consulted by industry, as well as for policy forming by different ministries of the Government of India (Box 1). Some examples of the findings are mentioned below:

**Steering industry to face global competition**

With rapid industrialization and increasing market demand, both domestic and export, for products and technologies, a need was felt to make a realistic assessment of technology status in India vis-a-vis the global scenario, existing and potential markets, directions for R&D, etc. TIFAC is perhaps the pioneer in fulfilling this need of a burgeoning Indian industry by preparing technomarket survey reports on a wide range of subjects.

For example, India being primarily an agricultural country, the use of appropriate fertilizers is imperative. Keeping this in view, TIFAC prepared an assessment report on potassium fertilizer salts from sea bittern. Potash is one of the three major soil nutrients. The total potash requirement in the country is about two million tonnes and is growing at the rate of 8.5 per cent. Most of this quantity is being used in fertilizers. India has no known land sources of potash, and the entire requirement is currently being met through imports to the tune of Rs.15 billion (say, US$ 300 million).

Potash can be extracted on a commercial scale from sea water, where its concentration is about 0.07 gm/100 ml in the form of potassium chloride. During the manufacture of common salt, the potassium chloride becomes concentrated to about 2.5 gm/100 ml in the mother liquor, called bittern, which can be used as a source of potash. For example, Israel and Jordan each extract around 2 million tonnes of potash from the Dead Sea.
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Box 1: TIFAC TA reports - an illustrative list

A. Focus on capacity-building and global competitiveness
- Biotechnology application in floriculture (TMS: 126)
- Biotechnology: Tissue culture (TMS: 045)
- Cryogenics with special reference to food/fish/milk (TMS: 016)
- Packaging of horticultural agri-products for exports, extending shelf life to avoid waste of products during peak of the season (TMS: 081)
- Process automation in the chemical industry (TMS: 107)
- High purity materials (TMS: 119)
- Status of select high value chemicals (TMS: 003)
- Technology and systems to make photovoltatic economical (TMS: 092)
- Sensors, transducers, actuators (TMS: 082)
- Advanced technology for conversion of raw materials into components (TMS: 131)
- Membrane separation systems (TMS: 106)
- Design and competitiveness:
  - Future technology trends and imperatives for India (TMS: 056)

B. Towards promoting sustainable development
- Technologies for use of rice husk as a source or for energy in rural areas (TMS: 065)
- Energy - biomass production/utilization for power/gas generation (TMS: 012)
- Technologies for gainful utilization of sugar industry waste (TMS: 132)
- Use of bagasse for the paper and pulp industry (TMS: 086)
- Flyash - high value-added application (TMS: 101)
- Industrial raw and wastewater treatment (TMS: 116)
- Economic reduction of ash in coal, while conserving scarce coking coal resources (S: 037)

C. Futuristic technologies
- Recycling of nickel from electroplating, electrolysis and electroforming waste (TMS: 047)
- Recycling plastic waste (TMS: 074)
- Geothermal energy - an alternate source of energy (TMS: 153)
- Bio-sensors (TMS: 129)
- Technology for futuristic pesticides (TMS: 051)
- Monoclonal antibodies (TMS: 029)
- Tissue culture - horticulture, floriculture (TMS: 030)
- Advanced sensors: Technology Vision 2020 TIFAC:V:01:ESDR
- Recombinant DNA therapeutic products (TMS: 167)
- Regulations governing genetic engineering products and drugs (TR: 110)

Note: This is just an illustrative list. For a comprehensive list of TIFAC TA reports, visit us at: http://www.tifac.org.in or at www.tifac.org.in, or write to TIFAC.

TIFAC’s TA report has led to commercial initiatives in this direction, paving the way for Indian fertilizer companies becoming globally competitive.

Another interesting TA study on the manufacture of chlorpyriphos led to an Indian company challenging a world leader, DOW of the USA by producing a product of global standards. Chlorpyriphos is the largest selling insecticide in the world due to its low mammalian toxicity. Spurred on by the global success of its product, the Indian company has increased its capacity from 300 to 1,000 tpa. This company made their own assessment of technology available at a national R&D laboratory and upgraded it with the help of TIFAC to match international quality levels.

Sustainable development

Often TIFAC’s TA studies have not only focussed on the economic benefits, but also addressed social and environmental issues. Any analysis of environmental and social consequences of technological choices is difficult and uncertain. A few examples of TA studies carried out by TIFAC in this direction are given here (Box 1).

Nicotine from tobacco waste

India is the second largest producer of tobacco (587,000 tonnes) after China and the third largest consumer after China and the USA. The tobacco industry in India employs a manpower of 7.5 million.

During processing, about 80,000 tonnes of scrap are generated in the form of dust, broken leaves and stalks. Of this, only 25,000 tonnes are used in manufacturing cigarettes and manure. The rest of the scrap is dumped as waste, polluting the environment. This scrap can be used viably to produce nicotine sulphate and other chemicals that have very useful applications. The assessment report gives details of technologies for producing valuable nicotine sulphate and other chemicals that have useful applications and have an export market.

Utilization of construction waste

The essential function of the construction industry is to cater to domestic and public building requirements. However, at the end of each construction activity, a large amount of materials remain as leftovers. Of this, 50 per cent comprise bricks, tiles, metal and wood, which are recycled. The other half, mostly consisting of masonry and concrete chips, are dumped as waste, polluting the environment. The total waste thus generated runs to 12 million tonnes per year, comprising 25 per cent of all solid waste generated in India.

Elsewhere in the world, almost all the left-over materials are recycled. TIFAC’s TA report on this subject details the current status and technologies and the necessary steps to be taken to convert the solid waste generat-
ed by the construction industry into useful products, like aggregates for con-
struction, which are in short supply.

Animal feed
In India, the large population of ani-
mals (horses, cows, poultry, etc.) serv-
ing the people annually requires 37
million tonnes of feed, which is met
mostly by the use of grain. Out of this
requirement, 13 million tonnes can be
partly derived from processing of what
is at present considered slaughter-
house waste.

TIFAC’s TA report gives details of
the feed needed by different animals,
technologies available for processing
slaughterhouse by-products, cost esti-
mates for total carcass utilization, and
so on. The report has been widely used
by entrepreneurs and industries en-
gaged in producing animal feed.

Future areas
TIFAC has recently embarked upon TA
studies on some futuristic areas, like
genetic engineering, recombinant
DNA therapeutic products, and nano-
technology. In order to bring aware-
ness among stakeholders about the
conflicting issues being raised by so-
cial activists, such TA reports help in
well-informed decision-making by pol-
icy planners and industry in the Indian
context. For example, a study on tran-
genic seeds, estimated that, before
1996 about 4 million acres the world
over were used for genetically engi-
neered crops and over 75 per cent of
the land used for transgenes was in
the USA alone, followed by Canada
(20 per cent), and other countries (5
per cent). In 1997, about 25 million
acres were used for transgenic crops
with about 80 per cent usage in the USA.

Transgenic plants may contribute
to the global economy to the tune of
US$ 2-6 billion by 2005 AD. A few Indi-
an seed companies have already
team up with foreign companies and
are conducting trials for obtaining ap-
proval of their products for commercial
use in the country. Several research
institutes are also involved actively in
development of transgenic crops. The
TIFAC TA study reviews the work done
so far worldwide and the direction of
efforts in India.

Conclusion
At the core of TA lies the art and sci-
ence of foreseeing the effects of tech-
nological change. Even more impor-
tant, however, is an attitude of mind that
attempts to take a broad and far-sight-
ed view of introducing a new technol-
yogy. Technology assessment demands
not only that we should look before we
leap, but that we should look beyond
the obvious, that our horizon in time
and space should stretch as far as is
humanly possible.

While conducting TA studies,
TIFAC has extensively used the knowl-
dge network available with institu-
tions, organizations and professionals.
The focus of all TA studies has been to
‘make technology work for the people’
in all sectors of economy.

For practical tips to the new entre-
preneur for carrying out TA before em-
bering on a new venture, the ap-
proach and methodology mentioned in
this article would be a useful starting
point. However, it is essential for the
entrepreneur himself to be educated
through technology information sour-
ces and technology reports (such as
those prepared by TIFAC and others).
It should also be borne in mind that
nowhere will the entrepreneur find all
answers - there will always be infor-
mation gaps. No database or a con-
sultant can provide all the answers.
Also, data search is a costly process
in terms of money and time; therefore
the entrepreneur should develop instincts
about when to cut research and study!

This logical approach for the per-
son making an assessment of a tech-
nology before actually venturing into it
is expressed beautifully by the Buddha:

Be ye lamps unto yourselves,
Be your own reliance,
Hold to the truth within yourselves,
At the only lamp!

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Integrated Technology Upgradation and Management Programme

The Office of the Development Commissioner (Small Scale Industries), India, has launched a scheme called
the "Integrated Technology Upgradation and Management Programme" or UPTECH. The scheme applies to
any cluster of industries where there is similarity among the units of the cluster, perhaps in the method of
production, or quality control and testing, or energy conservation, or pollution control, or something else. The
scheme aims to take care of the modernization and technology needs of the cluster. It covers a comprehensive
range of issues, such as technology upgradation, improvement of productivity, energy conservation, pollution
control, product diversification and marketing, and training needs.

For more information on, and submission of proposals to UPTECH, contact:
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