TECHNOLOGY GENERATION AND UTILISATION

Many phases, Changing Paradigms.

PATHWAYS FOR AN INNOVATIVE INDIA

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INTRODUCTION:

It is much more common and fashionable now to use the word 'knowledge' so much so that many persons hyping on innovation totally leave out the word 'technology'. But truth of the matter is that modern economy, military, security, innovation, healthcare, entertainment, many social functions including culture, etc heavily rely on use of modern technologies. Even while some persons may accuse technologies of spoiling the environment, many real solutions to ecological sustainability, protection of biodiversity, natural disaster management and mitigation, addressing issues of arresting climate changes etc need more and more smarter use of right technologies. Some of these technologies may result from a revisit of the traditional technological heritage of human beings and adapting them in the modern forms.

Hence generation and utilization of technologies will continue to be a major critical activity of human beings of all societies and nations.

However the processes governing uses of and generation of technologies and introducing new innovative products, processes and services, have gone through many major changes. The simplified assumptions of linear processes like idea – invent – experiment – limited production – commercial launch – standardization – imitation of the leaders by others – new processes of technology cycles etc are no longer valid.

The 1960's and the following decades have introduced many new complex paradigms and totally different legal and commercial practices for technologies. Therefore institutions specialization in generation of new technologies need to understand the new forces that are prevalent now in order so as to be relevant to the modern economy, society, military, etc. as well as to serve the people.

This talk (paper) is an attempt to provide a holistic picture of the historical perspectives and the current forces at play. Also it will attempt to provide pointers to the options and directions that can be attempted by technology professionals and institutions.

This talk (paper) is based on the actual field (executive and programme management) experiences of the speaker (author) as well as the knowledge derived through study of books which are the result of scholarly studies of various country / company performances by many experts around the world. Some of the references will be given here.

LAND – LABOUR – CAPITAL – TECHNOLOGY

Persons familiar with economics and technology management would be aware of such a description of the paradigm shift over a few millennia. A few millennia ago possession of land determined the political, economic and military strengths. Hence we had great emperors attempting to win over vast stretches of land areas and their nobles possessing lands in many villages. With the growth of agriculture diversifying to many different crops, animal husbandry, fisheries and with the spread of early industries with artisanal products, labour (possession of or command of labour) became important. Labour created more wealth out of the land. Then the societies grow from the mere self – sufficient low subsistence levels of existence to larger trading. Till about the early 19th century China and India dominated the world trade and created most of the wealth (capital). Later with the industrial revolution science and technology (engineering) with automotive machines became a stronger force. During the later half twentieth century technology became the major force for economic, military and business strengths. The process is still continuing.

While the shift as described above is broadly correct, popular myth (even in elite circles in India) is that these factors were displacing each other. As such many persons thought (and think) that mastering of technology alone is adequate to grow the economy.

As a sub – set, those who were the protagonists of newer technologies like Information Technology (IT), Biotechnology (BT) etc started claiming that IT & BT alone can revolutionize the societies and economies.

Just as life is a continuum and is a complex adaptive system, the other factors like LAND - LABOUR – CAPITAL – TECHNOLOGY are also a continuum.

While the (historically) later entrants have their importance, the needs for the earlier factors do not disappear.

The current ‘fights’ in India over land acquisition and scramble for land by industrialists and business persons would show us how important land is even during the 21st century. Modern technologies help to achieve much more useable area from a small piece of land through multistoried building, under ground constructions etc. Also modern agricultural technologies help get much more yield per unit of land. Also newer concerns about environment and ecological balance add new dimensions to taking care of available land and its resources.

Similarly undue chasing of capital (through financial markets) created a ‘fluff’ of an artificial wealth. It led to an economic crisis in several parts of the world. Land price speculation and financial fluff in combination were one of the main reasons.

When it comes to the issue of labour, the attention given to continually educate and skill bulk of the people in pace with emerging technologies and new factors of globalization (new forms of trade and return on capital etc) determines how well countries continue to develop. In India there is a perpetual shortage of skilled labour, as our attention was more around higher education, attracting investment etc. The general belief was that the ‘market forces’ will automatically take care of skilling. …. But actual life is more complex and we have on one side huge huge human resource in number and also simultaneously shortage of skilled workforce on the other hand. USA is also facing problems of unemployment because their assumptions and focus on growth was more around capital and technology and less on continual re - skilling their work force. ‘Markets will decide’ was the slogan. Hence they have a crisis on the employment front.

In the overall as new knowledge (new technology and new scientific knowledge) continues to grow, there is a need to continually fine tune the balance of Land – Labour – Capital – Technology. In India bulk of the govt. policies now is around capital – to attract investment, to facilitate businesses, to raise government capital through taxes etc (which are important but are not sufficient). On the technology front as well as in terms of skilling the workforce, we are severely behind our potentials.

We will address in this paper about where we are on technological front and in what way we as a country, and as institutions, industry etc need to orient ourselves.

SCIENCE AND TECHNOLOGY POLICIES IN INDIA

India, amongst the newly liberating countries around the middle of the 20th century, had already some good base in science and technology institutions and higher educational institutions. Pre independent India had produced excellent world renown scientists based on India itself. It had also produced a few good technologists and technology entrepreneurs.

Post independent India laid a lot of emphasis on the establishment science and technology (S & T) institutions and higher education in S & T. Scientific policy Resolution (SPR) Govt. of India, was enunciated during 1958. (Ref 1) However the word science used therein led to multiple interpretations as it was convenient to various stakeholders. The word ‘scientific’ was originally meant (by Jawaharlal Nehru) to address all activities (and therefore all departments, ministries) of government. The idea was to emphasize scientific approach to decision making as well as to be aware of the scientific and technological developments while promoting industries and a developmental services.

The word ‘science’ was used in its broadest meaning including technological applications and view point of life (‘scientific temper’).

Unfortunately SPR did not become the guiding force for industrial and other socio economic policies of India.

Public sector and private sector industries which grew under the planned economy being administered by the license – permit – quota – inspector raj were dependent heavily on imported equipment and technologies and turn key foreign consultancies. Though the words self reliance and phased manufacturing programme, know how and know why etc were often used in all government statements, repeated imports were accepted as a principle and practice. Even purchase procedures of government departments discouraged indigenously developed products.

For further study of the above, one may refer to the Article section of the website www.ysrajan.com for a three part exhaustive article titled Technology Policies in India. (Ref 2)

Such a ‘safe’ and ‘risk averse’ path suited the govt. administrators and the public and private sector industrialists. They can travel the well beaten path under the guidance of those who made successful world standard products in their countries. Why take a tortuous route of indigenous development? A few exceptional cases were for Indian Space Programme and Atomic Energy. However it is to be noted that these sectors were those in which technologies and even products were denied to developing countries at that time. They were the exclusive preserves of a few countries which were engaged in the Cold War and Arms Race. No doubt the Indian scientists, technologists and engineers made excellent achievements in these select areas. But these are very small in terms of overall contributions to the economy measured in terms of the Gross Domestic Product (GDP) or in terms of employment. But they did give India a stature in the comity of nations.

But in the overall status of technology development and applications, that is, technology generation and utilization for various socio economic sectors be it agriculture, manufacturing or services, India was lagging behind many of the mid 20th century newly liberated countries like Israel, S.Korea, Taiwan, Singapore etc. Japan was making rapid strides in the technology conquest of the world trade to become a second largest economy built on technological strengths (even with extremely poor natural resources available in that country).

Powerful and influential scientists, technologists and academicians in India did not do much to realize the true spirit of SPR, except by giving lip service slogans to the self reliance band wagon and slogans of know why. Some import substitution efforts at the periphery of the core sectors of Indian economy, society and military were touted as successes of self reliance. They were busy in getting more and more money from govt. and building up S & T and academic institutions. Of course the academic institutions fulfilled an important social and economic function of creating excellent human resources in S & T for research and development (R & D) as well as for running the industries and operational services.

Since there was little scope for industrial R & D, many young persons had to join the newly and fast expanding S & T institutions in India DAE, ISRO, DRDO, CSIR, ICAR etc. Many went abroad. Though these institutions had excellent infrastructure and special administrative systems to help flexible operations, opportunities to produce tangible end products and services did not exist for most of the S & T institutions. (except for the 'mission' agencies like ISRO, DAE and to some extent DRDO). This is due to the lack of policy and procedural systems (currently used fashion word is ecosystem) to tie up the laboratories to the needs of operational sectors and industries.

Apparently this situation suited the S & T policy makers (mostly scientists) and S & T administrators (again mostly scientists). They were spared from the rigours of delivery schedules and therefore questioning by the end users. They had their 'freedom' to do what they wanted and what they consider as the best! The situation still continues.

Thus the hiatus between S & T institutions and the end users in the socio economic sectors (agriculture, manufacturing, services, military, security, etc) grew more and more. There were, of course, a very few exceptions; they were often due to struggles of some extraordinary individuals rather than through enabling systems (as there were in Japan, S.Korea, Taiwan, Hongkong, Singapore, Israel etc not to mention the developed nations like USA, UK, France, Germany, Sweden, Norway, Finland, Netherlands etc.)

One of the main reason for such a (sad) situation is because of the confusion caused by the usage of the word 'science'. As mentioned earlier the use of the word 'science' by Jawaharlal Nehru in SPR and in his other speeches was meant to cover a wide area of human endeavor and not just scientific research or basic research. However the power elites of Indian S & T chose to ignore it and conveniently used the word 'science' as the basic research or some form of research not connected with the need to engineer products or services that will feed into the economy or later to the needs of the country. Fortunately ISRO, DAE and part of DRDO had a mandate to focus and deliver actual products and services. But it was not so for other S & T institutions. In some sense, it could not be so. A chemical S & T institution cannot be made to establish big chemical factories to produce fertilizers, pesticides' etc. But they can produce technologies and engineering processes to feed into such factories. There has to be a close link and not a stand off relationship. This process is unlike ISRO designing, developing, making and launching launch vehicles or satellites or DAE building and operating a nuclear reactor or nuclear bomb. When DRDO has to deliver a few missiles for the developmental phase it is in small numbers. But building and supplying tanks or fighter aircrafts or other operational equipment, numbers involved is large and therefore large scale production is involved. This is where manufacturing engineering or manufacturing technology (this word applies to large scale delivery of services as well) comes in. It is an area totally neglected by our S & T institutions as well as academic institutions.

At this stage a reference is made to an article by Y.S.Rajan "What is Science? Who is Scientist?" in the website www.ysrajan.com under the Article section. (Ref 3) and also Role of Engineering in Development of Economy, Society and People, the first Prof.Satish Dhawan commemoration lecture organized by the Institution of Engineers, Karnataka. Delivered on 22nd September, 2010 by Prof.Y.S.Rajan. Also available in the website www.ysrajan.com . (Ref.4)

SCIENCE, TECHNOLOGY AND ENGINEERING

It will be good therefore to recall the definitions of the above terms and how they relate to economy society and people? Also how they are interlinked. It is better to see a few quotes from the address of Sir David Davies ("Engineering as an Innovator of change in Society and the Role of Engineering Academies", address by Sir David Davies, CBE, F Eng. FRS, Chief Adviser to the Ministry of Defence, UK and President, the Royal Academy of Engineering, at the annual function of the Indian National Academy of Engineering (INAE). New Delhi, December 3, 1998). (Ref 5)

Quotes:

About Science: "Science is unquestionably a search for a better understanding of the laws of nature described in the broadest possible sense from astronomy to medicine and from engineering to genetics. Despite massive steps forward in each field, the understanding always remains incomplete…."

About Engineering: "Engineering on the other hand is about innovation, design and the construction of new products and new capabilities. We must take care not to define this solely in terms of physical products since engineering can also often offer new services often without the need for additional hardware….. However, whatever the form of the new innovation its design is inevitably a compromise between many different parameters. The success of the products is therefore bound up with the efficiency of the design process which has the role of matching the design to the requirements in as efficient a way as possible…" .

What is innovation?: "In terms of an engineering product or service an innovation enables it to offer some new advantage in capability or performance (including cost) that there is a strong coupling between engineering and science but this does not necessarily mean that this engineering innovation derives directly from the latest improvements or understanding in scientific theories……..".

An example: "Perhaps the most obvious example here is the steam engine. That innovation arose from experimental observation but is was not based upon any current understanding a theory of heat at the time. Indeed the whole subject of thermodynamics was developed afterwards. It provided better understanding of the performance of heat engines and was further evolved in order to aid the design of improved equipment".

Unquote:

For Sir David Davies the word technology and engineering are synonymous. In the later part of his talk he has discussed the role of Engineering Academies. He points out that for the implementation of most of the government policies for various social and economic sectors the strong link required is engineering. Policies have to link to the engineering aspects in the implementation. He has implied that without such strong links most policy statements may not achieve the stated goals.

You may judge for yourselves what has happened in India over the past six decades and why the Indian performance lags seriously behind the policy and programme statements.

Another quote about the definition of technology and technology policy by Lewis M. Branscomb, Empowering technology: implementing a US strategy edited by L.M.Branscomb, 1993, MIT Press (Ref 6) emphasizes this point again: "A technology is the aggregation of capabilities, facilities, skills, knowledge, and organization required to successfully create a useful service or product. Technology policy concerns the public means for nurturing those capabilities and optimizing their applications in the service of national goals and the public interest".

The word technology here encompasses engineering and the processes of engineering which includes implementation in the field.

The boundaries which distinguish technology (engineering) policy from economic and industrial policy are fuzzy at best. It is therefore necessary for Engineers and Engineering Academies or Institutions not to be quiet spectators or mere implementers of policies done elsewhere but to be proactive shapers of various socio economic, trade and industrial policies. The current author has elaborated in detail the interplay of these policies in his book "Empowering Indians with economic, business, and technology strengths for the 21st century" (2001, revised print 2002). (Ref 7)

There is a wonderful definition of what is expected of technology by Rajiv Gandhi (for easy download see www.ysrajan.com Website - Article Section - "Definition of Technology") (Ref 8)

As it is done in this paper it is good to use the word 'technology' and 'engineering' as more or less synonymous terms.

There are many uninformed or misinformed hypes about Indian capabilities in science and technology. "India as an IT super power", "knowledge power" etc. and as a global science power.

It will be good to study in detail an exhaustive report by National Institute of Science, Technology And Development Studies (NISTADS) : "India Science and Technology 2008". (Ref 9) Full report is available in www.nistads.res.in

Partly based on that report and information from other sources, there is an article by Y.S.Rajan based on the key note address delivered at the Project Management Practioners' Conference 2010 on September 9, 2010 under the title **"GLOBAL POSITION OF INDIAN INDUSTRY AND ROLE OF TECHNOLOGY PROJECT MANAGEMENT"** (see www.ysrajan.com website). (Ref 10) The article will give in some detail on the challenging tasks in India for the technology project management professionals. This paper and the first Professor Satish Dhawan Commemoration lecture organized by The Institution of Engineers (India) (IE) referred to earlier, (Ref 4) together provide a good sample of tasks for technology generation, utilization including through technology transfer (TT).

But these tasks or missions or mega tasks and the subtasks cannot be taken up using the old linear paradigm of idea – invent … etc. as pointed out in the introduction part of this paper. One needs to understand the new paradigms which have emerged and also as to how they apply to developing countries like India. These are addressed in the next section.

TECHNOLOGY TRANSFER AND ECONOMIC DEVELOPMENT – SHIFT OF PARADIGMS during 1960's, 1970's, 1980's to now

This word technology transfer' (TT) was hotly debated in India with several jargons of 'know how' ; know why' etc during the 1960's, 1970's, 1980's and even during the 1990's when the economy was liberalized and globalised. It referred to the whole range of contexts: from the principal supplier of embodied technologies (equipment supplier or turnkey project implementer usual by a foreign company), technical consultancy contracts as well as attempts towards commercialization of laboratory developed technologies to an industry.

As noted earlier, India continues to be a major importer of technologies even now. Currently one more context is being discussed: the acquisition of a foreign company (abroad or in India) by an Indian company with a view to benefit from its technology strengths.

It is good to begin with a detailed look at the evolution of several phases of TT with a quote from a recent article in Current Science Vol 98, No.11, 10 June, 2010 "Fuelling the Indian economic engine by retooling Indian technical education" by Vikramaditya G. Yadav and Ganapati D. Yadav. Pp. 1142 – 1457. (Ref 11)

"As was the case with several formerly developing but now developed countries, imitation was absolute with little deviation from the borrowed policies. Not to be left behind, several of India's development policies too have conformed to those of the bandwagon."

"So why have not most Indians reaped the benefits of development despite several decades of reforms and execution of policies that were seemingly successful in other nations? Tersely stated, the global economic equation today is vastly different from what it was when the United States had just embraced industrialization and a nation now has to look inward as well as outward while charting its economic agendas. This could unforeseeably scramble national development priorities, especially for nations such as India, and wanton imitation by present day India of the executive policies of industrialized nations when they were at a similar stage of development will yield only minor benefit."

In order to understand the new context and how it has evolved during the 20th century, it is recommended that a scholarly book by S.Radosevic (Edward Elgar publishers) "International

Technology Transfer and Catch up in Economic Development" (1999), published by Edward Elgar, is carefully read.

Some important quotes from the book are appropriate here: "The generation of new knowledge embodied in new products and processes and its diffusion throughout the economy is the main source of economic growth. This knowledge is only partly the result of endogenous technical effort. The more a country is lagging behind the technological frontier the more it has to rely on foreign knowledge and the import of technology through equipment, machinery, licenses or through copying ('reverse engineering')."

"Successful latecomers have combined heavy imports of technology with strong expansion of indigenous efforts devoted to technical change. The main locus of these activities were large domestic enterprises. These were complemented by domestic infrastructure and investment in education and training activities. So, the import of foreign technology is a necessary but not a sufficient condition for growth. Imports of technology and autonomous innovative efforts are not alternatives but complements. The historical experience of countries of central and eastern Europe shows what happens in the absence of this complimentarity. The import of technology was not integrated into domestic technological efforts and the link with demanding foreign markets was absent. So, despite intensive endogenous technological efforts and a large pool of scientists and engineers technical change which would lead to long term growth was not generated".

India also with its emphasis on the central planning of everything including science, technology and higher education followed the models of the eastern Europe. Therefore even while there was a major step up in the 1960's such as establishment of IIT's as well as massive expansion of national S & T laboratories, the insulation between the technology importing industries and the indigenous S & T development grew more and more during the subsequent decades. Some examples will be given later.

As Radosevic points out later in his book with several illustrations, most of the technology importing countries (industries) concentrated mainly on the costs of technology transfer. The terms of technology transfer again emphasized more on the financial and administrative aspects, and "virtually ignored the problems associated with the accumulation of technological capability". India was no exception!

Public sector enterprises (PSE) under the control of state or central govts. did very little to create their internal technological capabilities. The S & T policy leaders and those who directed national laboratories or the chiefs of academic technical institutions were mostly from the basic research background in limited narrow fields. Though they may have academic excellence in such fields, technology management or technology policy analysis being complex subject of its own was not recognized by them. It was assumed that it can be "learnt" by doing when they become top administrators at (almost near) the end of their normal careers. Also the centralized planning system never attempted the integration of the industrial / business needs and societal needs with the S & T systems, though volumes of reports and minutes of meetings were written about such a coordination. Most of these "coordinations" were at a macro level, having little connections with ground realities (where real engineering and technology come in!).

Real tangible projects to build up accumulation of technological capabilities in the firms (industrial units) and corresponding further innovations in the S & T / University systems never took a front seat. Individual scientific projects were taken up as decided by the scientific community (read it as the fancies of the scientific power elites). Back up analyses of the economic and social needs before undertaking S & T projects were never seriously considered except for some agencies like ISRO. Most of the S & T leaders / policy makers satisfied themselves by talking about "know why" as a substitute of technological capability and its continued accumulation.

During the 1980's globalization processes around the world started speeding up. Many developing nations who had after their independence, adopted socialist and centralized planning, had started the process of liberalization of their economies. It is to be noted that the People's Republic of China had started such a liberalization during 1978. The combination of liberalization of national economies with the globalization of trade, finance and production especially led by the transnational companies (TNC's) qualitatively changed the modes of technology transfer. To quote Radosevic again:

"The most important change for technology transfer brought by the new stage of globalization is the changing relationship between finance, trade and production. The interaction between financial and trade liberalization ('shallow integration') and production and technology integration at the level of networks ('deep integration') is generating dynamics distinctively different from the situation in the 1960 s/70s. Trade patterns are increasingly determining the distribution of production tasks across national borders."….

"'Deep integration' has been facilitated by the liberalization of the international framework governing the flow of technology (mergers and acquisitions legislatures: joint venture rules; local content regulations; technology transfer controls). Compared to the 1960s and 1970s, developing countries are now much less in a position to control the interaction between finance, trade and production in old ways."…..

"However, the importance of local or national systems of innovation has not been reduced. This generates problems for national technology transfer policy which now has reduced control over its economic space."

There is an extensive discussion in Radosevic's book about the processes of "shallow" and "deep" integration and the modes and terms of technology transfer (TT). Post 1980's contract bargaining in TT strongly depend upon how Foreign Direct Investment (FDI) is used as the sourcing link for domestic technology upgrading. Noting that most developing countries had little of the technological strengths of TNC's this bargain is more difficult and complex. (When Japan built up its technological and business strengths during 1960's and S.Korea during the 1970's and caught up with the developed world there was a much greater control of the TNC's and trade, by the national governments. Also they parallelly built up their innovative strengths over the TT given by TNC's)

During the initial period, FDI bringing TNC's, who also assure trade in export markets, may use the host country only in low value added activities. In this context, Radosevic elaborates the crucial issues facing the developing countries:

"There is also a danger that countries will become 'locked in' to low value added activities by foreign partners. Inward FDI may not only drive out local competitors, but may also restrict the creation of new technology by local suppliers, even if more technology disseminates to them from the TNC's. In short, TNCs may enforce both 'virtuous' and 'vicious' circles of increasing dependency on external sources of technology supply".

"'Catching up' in such a context requires several technological upgradings within international and technology networks. An issue of concern here is how technology transfer is used in the process of improving one's technological position within the international production chains. It seems that in a liberalized trade and investment environment governments in developing countries have fewer opportunities to structure interaction between domestic and foreign enterprises, which has significant effects on technology transfer". ....

"From being a controller of technology transfer governments will have to develop a role of network supporter or organizer. As in the past the formal mechanisms of control in technology transfer or today only access to production networks will not distinguish success from failures. The final results will depend much less on specific policies than on the policy implementation capability of governments and the kind of social organization and governance mechanisms that they build for an economy increasingly dependent on foreign markets, finance, production and technology networks".

Further developments post 1995, due to the formation of World Trade Organisation (WTO) and the successful attempts to unformise IPR (intellectual Property Rights) laws amongst all its members, have created several barriers and challenges for building up of internal technological strengths the of developing countries at least to a level of respectable interdependency from the current levels of near total dependency described above.

That is the challenge facing India as well. Policy making bodies have very little awareness of these realities.

Before discussing India specific issues, it may be good to have a look at different mechanisms of TT (as would apply in the currently existing paradigm). A Table sourced from the book by Radosevic referred to earlier, is very useful.

Types and Dimensions of Technology Transfer

Transfer mechanism	Type of embodiment			Mode of Transfer			Role of seller /partner		
	Capital Embod	Embod	Disembod	Market (explicit)	Network (intermd)	Hierarchies (implicit)	Active	Enabling	Passive
Direct foreign investments	X	X	X			X	X		
Joint ventures	X	X	X			X	X		
Licensing			X	X					X
Imports of goods	X			X					X
Co-operative alliances*		X			X		X		X
Subcontracting		X			X		X	X	X
Export		X		X					X
Transfer by People		X			X			X	
Development assistance	X	X		X	X		X		

***Production sharing agreements, management and marketing contracts, service agreements, R & D consortia and other co-operative alliances, franchising, technical services contracts. (Source : Ref 12)**

We will refer to many of these elements when we discuss India specific examples in the later sections.

Bulk of the Indian economic growth as of now is propelled by direct foreign investment, licensing, import of goods, subcontracting and to a limited extent by joint ventures. Other elements are limited. Since this table is about TT, internal R & D and its utilization by the firms is not indicated, though they are implicit in other elements if "deeper" globalization takes place; one explicit form of this will be through cooperative alliances.

Let us now have a quick survey as to what happened in India in different sectors and where we are now.

WHAT DID INDIA DO, DURING 1960's, 1970's, 1980's 1990's and WHAT DOES IT DO NOW?

AGRICULTURE

When India became independent, its GDP was dominated by agriculture. A few years before independence the country suffered a major disastrous famine. During the fifties agriculture contributed more than half of GDP. Even during the 1960's and early 1970's its share was more than

40 per cent. Naturally the first five year plan which began during 1951 laid emphasis on agriculture.

Agriculture has received the attention of govt. of India even during the pre independent period. Some of the presently excellent agricultural research and education institutions were set up during the colonial period.

National commission on Agriculture 1976 in its report published by Ministry of Agriculture, Govt. of India, during 1977 (Ref 13) traces many of these developments and elaborately deals with research, development and education aspects. It has gone into the details of adaptive research, agro intelligence as well as the requirements of allied industries.

An interesting extract from the report is appropriate even in the current context:

"A major development of this period was the first ever elaboration in January, 1946, of an all-India policy on agriculture known as 'Statement of Agriculture and Food Policy in India." According to the Statement, "The All India policy is to promote the welfare of the people and to secure a progressive improvement in their standard of living. This includes the responsibility of providing enough food for all, sufficient in quantity and of requisite quality. For the achievement of these objectives high priority will be given to measures for increasing food resources of the country to the fullest extent and in particular to measures designed to increase the output per acre and to diminish dependence on the vagaries of nature. Their aim will be not only to remove the threat of famine but also to increase the prosperity of the cultivator, raise levels of consumption and create a healthy and vigorous population." The ten objectives of the policy included: "increase in production of food grains and protective foods; improvement in methods of agricultural production and marketing; stimulating production of raw materials for industry and exports; securing remunerative prices for the producer and fair wages to the agricultural labour; ensuring fair distribution of the food produced and promoting nutritional research and education."

Post independent India had special problems due to the partition: distribution of irrigation and other resources between India and Pakistan. Various traditionally established supply chains especially for cotton and jute were severely disturbed.

It is not intended to cover fully the history of agricultural development in India. During the later part of 1960's stress was laid on greater adoption of S & T for raising productivity, in terms of irrigation facilities, spread of high yielding varieties, use of fertilizers and adoption of plant protection measures. Agricultural extension services were also done through various state level institutions and local agricultural universities.

When the report of 1977 is revisited, one would find that number of measures to build technological strengths in the farming sector have not been fully achieved, though there has been remarkable progress since 1950's. Also new methods brought in newer problems – partly technical and partly due to the raising expectations and other socio economic factors.

A recent report entitled "State of the Indian Farmer, A millennium study", 27 volumes + CD ROM has been published by Academic Foundation, New Delhi in association with Ministry of Agriculture Govt of India (2004) (Ref 14). It is an extensive recent update about differentiation in markets, the experience with earlier S & T inputs, the lessons learnt therefrom and also the newer technological requirements and challenges. Issues of commercialization of agriculture, IPR issues etc are discussed at length.

There are a whole gamut of science, technology and engineering challenges for the Indian S & T system from the critical and important problems of present day agriculture. These are not for the Indian Council of Agriculture research (ICAR) alone. Every discipline of science and engineering need to be deployed including advanced technologies from chemistry and biology. Select import of foreign technologies through various forms indicated in the table in the last section especially cooperative alliances can accelerate technological capabilities of Indian agriculture to truly fulfill many objectives given in the January 1946 Statement of Agriculture policy of India quoted earlier in this section.

It is sad that Indian S & T system and its apex bodies do not work on specific projects and missions resulting from such reports. This is because of the hangover of the past which grew the S & T institutions through Five Years Plan **of their own and annual budgetting.** The apex policy makers think that ICAR will take care of agricultural research and extensions. Since Govt. does not involve Industry for S & T generation and utilization activities, they do not bother about these issues either. Also various govt. policies and procedures inhibit industry and businesses in venturing into agriculture. So on one side the economy and society especially farmer and agricultural labourers are awaiting for solutions to their problems; Farmers are ready to experiment to get better incomes. There is a good and comprehensive set of reports giving a clear picture of issues (including policy support systems). On the other side many capable S & T personnel plod along with routine research suiting their narrow tunnels of approved projects. Potential of India which is blessed with a large percentage of arable land and other biodiverse resources is yet awaiting to be realized.

The author is personally aware of a situation during 1990, when a Secretary in the central department of science and technology was ready to get approval of a total proposal from the then Prime Minister under his self – reliance programme, a project of Indian design, system engineering and establishing an advanced fertilizer factory which can become a forerunner of Indian Industry in fertilizer to be followed by other agro – chemicals. This would have led to a huge step up technological capability of Indian industry and S & T institutions. India could have been a global leader. He approached many top scientists / technologists to take up the challenge. None was ready!

Many Indian scientists are willing to take up piecemeal research projects. But are not ready to bring them up to a production level working with an industry (firm) or creating a new firm. This is one severe lacuna of Indian S & T institutions whose bits and pieces of technologies generated, howsoever good they are, do not find their destination in the market place. Such a situation in turn leads to a vicious circle which leads the hiatus into a total isolation.

While the current mode of having agro related firms in India continuing repeated acquisition technologies (embodied and disembodied) as well as import of needed chemicals, mechanical equipment, electronic / electrical equipment for agricultural operations could also be continued, the author is of the firm belief that India should also require a few home grown firms as well, which can meet domestic demands and also meet global demands (exports, establishment of firms abroad with Indian home grown technologies etc). The reason for this need can be understood especially when one studies in detail the 27 volume State of the Indian Farmer reports. Agriculture (which word includes in wide and comprehensive sense crop production together with land and water management, animal husbandry, fishery and forestry) deals with life in the biosphere. As we learn to increase productivity and destroy insects, pests etc, the other organisms also learn. For example it has been found that pests become resistant to newer pesticides over a period of 7 to 10 years. Similarly soils offer new challenges, when we increase productivity. Also people's demands change….. Therefore a continuing innovation is required in all these aspects. For a country as big as India (geography and population) there needs to be continuing R & D, application, production, extension services with home grown technologies. This will help in maximizing the benefits and profits from agriculture – which will continue to be an engine of growth of India though its share in overall GDP may remain around 20 to 25%. Status of agriculture will continue to affect other sectors of economy.

Also in the coming years there will be increasing demand for cleaner technologies, better phytosanitary conditions (which are partly due to agricultural residues), and better management of agricultural wastes (solid, liquid and emissions). Also challenges from the need to preserve biodiversity will require scientific, technological and engineering solutions. In the coming years agricultural IPR's would be very strict by applied. One cannot expect a Norman Borlaug willing giving away his technologies as was the case for Green Revolution.

Without a robust and technologically strong home grown system in place meeting at least 25% of the total domestic demand and also with a noticeable global presence (more to challenge oneself to raise quality and also to make profits as well as to have a geopolitical influence) – from S & T to final deliveries and services of agriculture and agricultural industries – India may lag behind economically. While interdependence can be an accepted solution, a total dependence on foreign technologies also far agriculture and agro related industries will lead to serious current account deficits in Indian economy.

Reading again now the National Commission Report on Agriculture (1977), one can find how much of the past S & T / industrial opportunities in agriculture and related industries have been missed.

The 2004, 27 volume State of Indian Farmer Report (2004) is still current.

It is a challenge for Indian S & T, industrial, business and policy making community to rise up to meet the challenges of Indian technology generation and its utilization on a massive scale as suggested above.

The current Indian policy discussions about Agriculture is more around the financial aspects, subsidies, delivery of free food, free electric supply etc. **There is no attempt for systematic understanding as to how to make it all economically_ecologically and socially sustainable.** The key is with the orchestrated use of science, technology, engineering by firms, businesses and delivery systems (public and private). And also there need to be a massive training of skilled workers, all through the supply chain (including experts) and other professionals including researchers. There is a need to increase the Indian IPR's on various aspects of agriculture to enable global competitiveness. Under the regime of WTO, no country can afford to relax IPR constraints on the premise that the efforts are only to meet the domestic demands. Since Indian demand is very high, it will surely attract global suppliers who would demand market access and a level playing field. So the challenges before industry, institutions and farmers are really very daunting.

Let us now have a brief look at the industrial sector.

INDUSTRIAL SECTOR:

This sector is vast covering many areas of manufacturing. These include chemicals, pharmaceuticals, agro food processing etc.

At the time of independence India was importing almost all the manufactured products. Geo-economic strategy of the colonial power was to use India's raw materials exported to UK and have the manufactured products exported to the world (including India). That is how wealth was created by the colonial power. In economic terms value addition was done in U K. The technology or engineering enabled such a value addition. In India (and in China as well then) around 1950's such industries were nearly non existent but for a few chemical and metallurgical industries in India.

Bulk of the manufacturing that existed in India was artisanal in nature.

Post independent India thanks to the emphasis of central planning, built up many industries in the public sector. Invariably they were established through total import of technologies from different countries. This was a good option as endogenous capabilities and knowledge did not exist then. During the 1960's and 1970's, India had many elements of the manufacturing sector as it existed elsewhere nearly in the same level of sophistication; the gap was low. Most of these industries, set up with foreign technology, know how and equipment, catered to the domestic demands (again fixed up by the central planning machinery). Imports for consumption were either curbed or attracted very high levels of customs duty. Thus it was the world of manufacturers who managed to get a license if it was in private sector. The public sector enjoyed a near total monopoly in that product line, as a part of the policy of the "commanding heights of public sector." Many capital goods were produced by PSU's.

A classic example of such a monopoly situation by the licensed private sector, was the Ambassador car, which became almost a national symbol. President, Prime Minister, Chief Ministers, Ministers and every govt. official had to travel by it. Fiat was a poor second. Both were in private sector. A poor third Standard disappeared. Even private sector persons followed the pattern!

In the field of chemicals it was better because many private sector units in small and medium sectors manufacturing a wide range of chemicals came up in the post independent India. This was partly so because the consumers were highly dispersed. Fertilizer companies were highly protected and were subsidized to meet the lower sale price to the farmers; in the later decades this practice caused technological lethargy in the sector, lagging behind the world standards of material or energy efficiency.

1960's and 1970's were also periods of severe foreign currency shortage. Foreign exchange earnings were mostly through the primary sector and through export of raw materials such as ores. Industrial sector needed huge foreign exchange to meet the demands of equipment, technology know how and license fee to the principals abroad. The only place they could attempt savings (in the short term) in foreign exchange was through use of some local materials in the manufacture. Thus came the practice of "import substitution" which became the main focus of industrial R & D; it was touted however as self reliance. Since the tax structures for imported goods were very high (ironically much more for imported raw materials as against much lesser tax for purchase of a total system!) such import substitution R & D efforts did not have the pressure of cost effectiveness: somehow do it with indigenous materials was the aim.

Such efforts though useful in a short term then, it took away the main focus of mastering technologies of the total system as was done by Japan, S.Korea, Israel, Taiwan etc. When the total systems became outmoded (maintenance costs became very high), new systems were imported; some private sector companies purchased reconditioned equipment from abroad to cut costs.

So was the Indian industrial growth. But there were bright spots. Rourkela steel plant at the time of its establishment was one of the best technological and cost effective plant by world standards. But slipped in position later due to complete neglect of continual industrial R & D to upgrade it. The plant's profits became a part of all earnings of PSE's and got lost! National laboratories hardly did any system level R & D and were not even aware of it. Some research at the periphery sufficed to produce papers by the laboratories. Publishing in an international journal was the peak they aspired for! No wonder India at 2010 has to import or have joint venture with foreign companies to establish steel plants in India or abroad. Such a situation is due to the decades of missed opportunities to upgrade the Indian Industry, over these decades the gap of sophistication between Indian industrial technology and those of other developed ones in the world, has increased manyfold.

As regards the electronics industry which was emerging as a major industry world wide, during 1970's, India had a unique opportunity then. India had an electronics manufacturing base better than S.Korea during the late 1960's and early 1970's. India had made a valve based electronic computer called TIFRAC during later 1950's. There was a huge article on it in the series of books entitled Advances in Electronics during 1970's.

But overcentralised scientobureaucracy virtually killed the growth of Indian electronics industry under the false (perhaps well intended!) slogans of self reliance by the Govt. of India's Department of Electronics. It is ironical that the Department came out of the HomiBhabha report as a vision for Indian Electronics and which was passionately advocated by Dr.Vikram Sarabhai (he passed away in December 1971)

Hongkong etc were gearing up for the manufacture of microchips (not to mention the emerging Japan in 1970's and other countries). India was then struggling under a severe licensing regime. India lost a unique opportunity to have become a technological giant in electronics in terms of industry, R & D and innovation. Such a centralized control regime by the Department of Electronics did not even result in giant R & D centres nor original software creators and producers. As a result, the telecommunication industry totally stagnated. The India's symbol in electronics was the huge and heavy black telephone set produced by the only telephone maker in the public sector.

Even during the 1980's the fledgling software companies like TCS, Infosys, WIPRO etc struggled for a decade till economic liberalization of 1991 gave them some oxygen to survive and later to grow well using the world wide IT wave and outsourcing.

In the chemical sector oil exploration with govt. efforts and resultant petrochemical plants gave a fillip to chemical engineering. Enactment of 1970 Indian Patent Act gave the opportunity for many Indian Pharmaceutical companies to grow using the provisions for the process patent.

Relative to other sectors of Indian chemical industry had a closer relations with industry (not to the optimum level though!). This was partly due to the nature of the chemical technology R & D and also due to fairly spread out nature of the industry. Still there were no breakthroughs that came in R & D or in industry as the relationship was mainly focused on import substation, pollution mitigation, process changes etc. Agricultural related chemical industry (input side like fertilizer, pesticides, micronutrients etc and at the output side alcoholic beverages, industrial alcohol, textiles etc) was another growth sector during the 1960's and 1970's.

Electric power sector started with hydro electricity and then grew with thermal plants. But coal mining industry which was a public sector monopoly, never attempted gradual value addition like beneficiation etc; nor addressed the special problems of Indian coal. A national laboratory concerned with coal during late 1960's took a bold step to import a pilot plant for coal gasification. But those scientists had to struggle to go forward as the central administration of the laboratory did not fund them adequately, as perhaps they did not understand the significance. The user industry, ministry of coal and the central headquarters of that national laboratory had little interest. Had that been pursued India would have been a world leader in clean coal technologies. See for more details "Technology and Power Perspectives" – Seminar 414, February 1994, special issue on Managing Energy. (Ref 15)

During mid 1980's partial liberalization of Indian industry began with a few areas. As foreign exchange problems were acute as foreign direct investment (FDI) was severely curtailed, it led to a major foreign exchange crisis for India during 1990's. Fortunately that crisis also led to globalization and liberalization in the Indian economy, mainly to tide over the crisis in foreign exchange reserves. It helped FDI flows and along with it some embedded technology flows. Also it helped the (low end) outsourcing IT tasks to be taken up by Indian Industry. There was a massive growth. Foreign exchange reserves crisis became a thing of the past.

However 1990's liberalization by the Govt of India, never had the technological capability upgradation as a part of the national objective. Entire dialogue was terms of macroeconomics, financial markets, structural reforms for easing the access, tax reforms etc. No doubt they were all essential. Equally essential was the need to build technological capabilities of linking science, technology, engineering and businesses to use the global markets. Indian industry which emerged out of an oppressive licensing regime needed special support mechanisms to quickly complete the evolutionary processes needed to become technological leaders; these processes were absent or stymied in most of them.

Govt. of India nor industry groups attempted to build up these processes. The only attempt by the post independent Govt. of India (GOI) earlier was through the National Commission on S & T (NCST) which had profiled several important tasks in this direction (1971). They were forgotten and the only action taken by the Govt. was the establishment of Department of Science and Technology (DST). Not fully appreciating (or being aware of) the processes of technological growth processes in industry as explained in the quotes by Radosevic earlier, or the important differences between science and engineering (& technology) or the definition of technology Branscomb etc, the entire funding was left at the hands of scientists. Soon DST and its offshoots primarily turned out to be funding of scientific research "of the scientists, by the scientists and for the scientists". No doubt a few attempts were made to develop relevant technologies.

By the time of economic liberalization 1991, DST and its off shoot "scientific departments" turned out to be funding mechanisms for building more and more infrastructure for science laboratories. Of course some of these efforts were useful in providing human resources to the new industries; for example Dept of Biotechnology's (DBT) massive investments in many universities for establishing post graduate courses.

The establishment of Technology Information Forecasting and Assessment Council (TIFAC –approved 1986 and established 1988) was a feeble attempt. A number of its forecasting and assessment reports, technomarket survey reports were useful to identify technological needs of Indian industry – in the short, medium and long term in the global context. The Home grown Technology (HGT) programmes (started 1991) helped to build the gap between industries and labs; it became a forerunner in terms of various procedures for the Technology Development Board (TDB) established during 1996. Notable amongst TIFAC's outputs were the three major Technology Mission programme in Sugar industry, Advanced Composites and FlyAsh Utilization (1993). To a reasonable extent they helped Industry to taste the benefits of technology adoption and also helped many academic technologists and national laboratory scientists / technologists a unique opportunity to work with actual industry and business related projects.

TIFAC's experience of Mission REACH was the result of unique experiments for inducing industry to invest in colleges / universities (non – IIT, non IISc) for establishment of Centres of Relevance and Excellence (TIFAC CORE). A recent paper quoted below (Ref 16) may be referred to. It was Government mediated programme to intensify industry academia linkages for human resource development, relevant R & D and commercialization and working closely with the fund contributing industry and others. See "Experiences of an innovative model from TIFAC" by Jancy Ayyaswamy, Neeraj Saxena & Antaryami Parida Technology Information, Forecasting & Assessment Council (TIFAC), New Delhi. Presented at the International Conference on: Science, Technology and Economy: Human Capital and Development. (Annual Conference of IASSI and Knowledge Forum Hosted by IIT Bombay)(venue: Institute Auditorium, IIT Bombay, Mumbai, November 11 – 12, 2010) (Ref 16) Can be viewed at the social sciences website. http://esocialsciences.com/KF conference/index.html and also www.fgks.in

Another important output of TIFAC was through major national exercise of Technology Vision for India 2020. It was a joint exercise of scientists, technologists, industrialists, administrators, NGO's and other public persons. The exercise involved use of various technology forecasting, assessment and foresight models. It used the questionnaire methods as well to capture the ideas and insights of several practicing professionals.

A glimpse of the outcome was bought out as 25 volumes dedicated to the nation on 2nd August, 1996. A popular book "India Vision 2020 A Vision for a new Millennium" A.P.J. Abdul Kalam and Y.S.Rajan (Ref 17) gives a good summary of all these documents and also additionally describes linkages between various sectors, economy, society and national security.

TDB became a good source of funds to industry projects but was not large enough. It also spurred other such funding mechanisms in specific sectors like pharmaceuticals, biotechnology etc. While a number of them grew, they continued to be small in size. Neither did they cater to fresh new technology entrepreneurs as venture capital agencies did in other developed countries. (Due to many govt. procedural inhibitions which are totally risk averse and also because there was a constant lurking fear of danger of attracting criminal investigations against a bold but honest funding official. Indian public accountability systems are yet to graduate to support industrial and S & T innovations!). Most of these funds therefore focused on funding an industry which took up technologies from a national laboratory as TT rather than working on the tasks needed to position the industries in the global value chains as described in Radosevic's quotes given earlier. Also most of them were unaware of the new emerging phases of TT, technology generation and utilization and new IPR regimes. They believed in the old linear models of technology development.

India 2020 documents had many details giving excellent indicators for actions in the short – medium – and long term, in the global value chain. The report covered all vital sectors: Agriculture, Agro food processing, Materials, Engineering, Chemicals, Services, Advanced sensor etc. These documents which had broad acceptance of industry as well covered a whole range of items to cover all aspects of technology acquisition by Industries (Refer to the Table quoted before from Ref 12). That would have meant special GOI's orchestrated efforts ranging from provision of conditionalities for FDI (negotiated with foreign investors with mutual agreement) to supporting special joint ventures to promoting cooperative ventures to forming industry – lab – university consortia for developing newer technologies (medium and long term) to support the global competitiveness of Indian Industry. Even some of DST's and DBT's funding of basic research could be oriented towards these overall goals.

Development, orchestration and execution of such a systematic market driven plan (with some govt. oversight) over a period of two decades require a special type of leadership of S & T agencies, academic institutions and govt. (state and central) departments and their agencies. An attempt to create such a mechanism through the Office of Principal Scientific Adviser to Govt of India (2000) with a cabinet rank did not yield any tangible action. Office of PSA as well as Scientific Advisory Council to the Prime Minister still exist. It is perhaps too much to expect from the Indian system which has over five decades grown up in cosy and narrow silos with individualistic orientations!

It is also to be noted that TIFAC had built up since 1995 an excellent Patent Facilitating Centre (PFC) noting the importance of IPR's in the globally interconnected world. It has a global recognition from the developed world and has helped many Indian Universities, Labs and industries. If an Indian industry becomes big (be it in domestic sector or outside) it is bound to attract various forms of IPR and other technology based litigations. In this context the problems which our major pharmaceutical industries go through now in USA or Europe, are not all surprising. If Indian exports grow in the coming years to a reasonable size (as of now it is still small as can be seen from the information given in the article referred to earlier (Ref 9)), they will face problems ranging from challenges to IPR to adherence to global good laboratory practices to phytosanitary conditions (for agriculture and food related products) etc. These issues and challenges require good internal technological strengths to face and tackle.

Coming now to Micro Small and Medium Enterprises, let us look at a table derived by the author from the NISTADS report referred to earlier (Ref 8) and explained in Ref 9.

<u>Table: MSME Salient Features</u>

- 10.5 million enterprises (2001)
  (new definition 13 million)
  of which 5.8 million in rural areas and rest in town mostly non-metropolitan / peri-urban areas.
- 40% of total MSME in manufacturing sectors
  16% in repairing and maintenance.
- Gross output of all MSME's (2001-2002) Rs.2,822 billion and export Rs.141.79 billion
  Share of GDP 8 to 9%;
  40% total export; 30 million employed

- ❖ About 98% of MSME units in India have almost no relation to big industries or channel partners. (Thus ancilliarisation is very small).
- ❖ About 85% of MSME's use traditional knowledge in production units; domestic R&D have a meager share in provisioning knowledge – only about 5 – 7% of the technical knowledge transactions are with public R&D.

(Source: NISTADS Report Ref.8)

As can be seen from the above there is a great need to mount a large nation wide effort (not just New Delhi driven!) to infuse technological strengths in to the MSME's. It will require a whole set of actions ranging from FDI policies to govt. procurement policies. A book specially addressing these aspects may be referred to "Global Business Technology and Knowledge Sharing : lessons for Developing Country Enterprises" by N S Siddharthan and Y S Rajan (Ref.18). There is a chapter on Technology Intermediation in the book. This is particularly required for MSME's. Scientists, technologists, engineers and management professionals have a great role to play for technology intermediation for Indian MSME's to graduate to contemporary levels to meet global competition. This idea was further developed by Y.S.Rajan as "Knowledge Intermediation" to include the fact that in addition to 'technology' other factors would also need to be included. This idea was already imbedded in Ref 18. However an explicit use of 'knowledge' may bring it to the attention of more persons See for details Article Section of www.ysrajan.com website under the title "Knowledge Intermediation" (Ref 19)

We will close this section with further two references. One gives the micro level details of the processes involved. "New Product Development " Challenges of Globalization". (Y.S.Rajan and Kalpana J. Chaturvedi). Appeared in the international Journal of Technology Management (IJTM), Vol.X, No. Y, pp.000-000. (2000) (Ref 20).

Another article is the chapter – 5 of the book Empowering Indians. (Ref 6 pp.91 – 112). It is worth referring to it here as a specific item. It is titled "Policies for Science and Technology in the Era of Liberalization" (Ref 21). It covers all crucial elements needed for Indian Industry to position itself globally and the role of S & T by policies and contributions for the same. The ideas and the specific recommendations covered therein are valid even now during 2010 and beyond. The officially stated govt. policies on technology and science are too general and do not cover the whole eco system of science, technology, engineering, innovation, and business, society and national security. Ref 21 has described the **five basic elements** of S & T policy as: Need for Employment;

Improving the Quality of Life of People, Vitality of the Economy: Wealth creation, Trade and Technology; National security; and the Human Resources for S & T. In addition the chapter briefly described the complex interconnections between the five elements. All these five elements are on the top of the agenda even for the most developed country USA, as can be seen by explicit statements by the US President Barrack Obama.

WHAT NEXT FOR INDIA?

We have so far covered a wide terrain: the crucial differences between science, technology (engineering), innovation etc; changing paradigms in TT during 1960's, 1970's, 1980's and beyond. We have also touched upon briefly what happened to India during that period in Agriculture and Manufacturing, with a few examples.

While India has achieved well in a number of ways in terms of agricultural output, diversity of industries, presence of its goods and services in the international markets, human resources in diverse fields some excelling in global standards, an large S & T infrastructure, strong armed forces, etc they are yet small when one looks at the true potentials of India. A lot more needs to be done especially in terms of building up technological strengths and global standing in terms of share, position etc. But it cannot be done using the assumptions of earlier paradigms. We need to look at the future based on current day realities.

The reason for covering the recent history of India's performance especially in terms of missed opportunities is to ensure that actions for the future are not clouded by the same ideas of the past being regurgitated again. Experiences of the author during the past decades have shown that S & T and other administrative systems in India, tend to do so (that is to regurgitated old failed ideas, very often only changing the jargons over a period suiting the then current fashions).

There needs to be a clear departure in the outlook, attitude and methods of selecting and executing S & T based or related projects in order to build up technological capability within Indian enterprises and to make Indian products and services globally innovative and competitive.

It is yet possible to do so. This section will address the approach to such actions.

First and foremost, the economic growth machine has to be kept going. That will mean attracting investment (foreign and domestic investors) and enabling them to be profitable Investors in addition to various forms of legal, administrative, and financial support systems (not necessarily subsidies) will also require right types of human resources. It is only in rare cases they try to invest on training human resources; at best they may do the final touches, the "finishing" touches. The State has to enable creation of right skills; often times in India the parents invest on their children till they get good jobs. They even take loans. That is why there is a huge distortion in India in the higher education and the school education that feeds it: most of these are "self financing". Bulk Govt. resources go to a few select elite S & T and academic institutions. There will be a need to drive the elite institutions to earn more from the end users. It is to be done not by mere speeches or policy statements. There has to be an economic pressure (incentives and disincentives) to make them work on problems needed for the Indian firms to graduate from the follower mode of technological acquisition to leadership mode.

These tasks may not be the usual mode of academic research as it takes place in India nor the current forms industry academia linkages. The real tasks may range from those elements which will add strengths to the firms or enterprises from their current levels of technological capabilities be it in their own production lines for domestic or export markets or from their current levels of capability with which they execute jobs outsourced by foreign firms from abroad or operating in India. This is not in an import substitution mode of the past. **It is a process of upgradation of these firms in the global value chain through various forms of technological strengths:** embodied technologies (adding some equipment or software); upgrading the tacit knowledge (special on the job training or some incremental development projects which will develop insights for workers, middle managers, top managers etc); etc. Such upgradation processes should encompass all firms: big ones to MSME's. For MSME's especially the vast network of engineering, pharma, science etc colleges can be deployed, not just the elite institutions like IIT's, IISc or other govt. supported ones like NIT. Involve all colleges including the self financing ones: it has a double effect; one to spread to all firms in India; another to upgrade India human resources base.

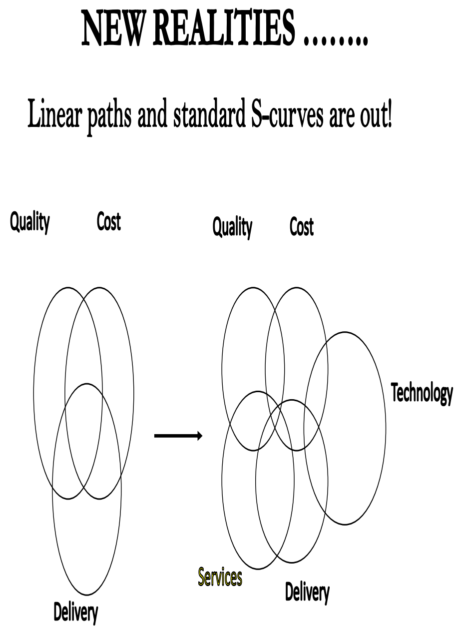
Outsourcing which is really the core of globalization process helps the Developed Country Firm (DCF) and also the Outsourced Country Firms (OCF). Though it has become a "dirty" word in some developed countries which were the advocates of free trade and free global access, it has helped global economic and technological growth. The DCF firm gets not only a good cost competitive option to do some of the subsystems / elements of the total product (be it a car or consumer product or a software enabled service) thus making it globally competitive and thus helping it to earn more profits **but it also provides time – space and managerial space for DCF to concentrate on further higher value R & D** activities which will help them to create more innovative products. Regular **standardized work packages** are being taken care of by OCF firms; so DCF firms have some free space. This aspect is missed in many economic or econometric studies which take into account only macro elements like productivity; profit etc.

For the OCF firms such a process of outsourcing provides a new and more profitable **market space**. They earn more profits that too by an assured sale (by contract) to a customer abroad. Also the volumes are large than what they (OCF) can imagine in their domestic markets because the foreign customer DCF firm has global access to market.

It should be noted here that in this relationship between DCF and OCF, DCF is in a stronger position. It can have many OCF's in the same country or different countries. It can dictate terms as it has the core strengths in the technologies for the products (technology as defined by Branscomb Ref.5) for the global market.

But OCF firm need not be and should not be in the same static position in which they were selected by the DCF firm and provide outsourced services as the "most obedient and loyal server". That would have been a virtue in the 1980's. Not any more. Because the DCF firm in the global market is not a monopoly "emperor". It is under continuous "attack" by its other competitors who may be number 2, 3, 4 even 10. That is the power of the modern technologies and innovation. A number 10 may spring surprises through its innovative and technological efforts (even incremental ones) and capture much of the market segment enjoyed by 1 to 9! Therefore DCF firm will look for not just a loyal and trusted OCF firm but also a firm which has S & T capabilities, which can think ahead and which can innovate **within the framework** of the product of DCF. It is like the Panchatantra story of Prince and the Monkey!

At this point let us look at a figure sourced from Radosevic's book Ref. 5



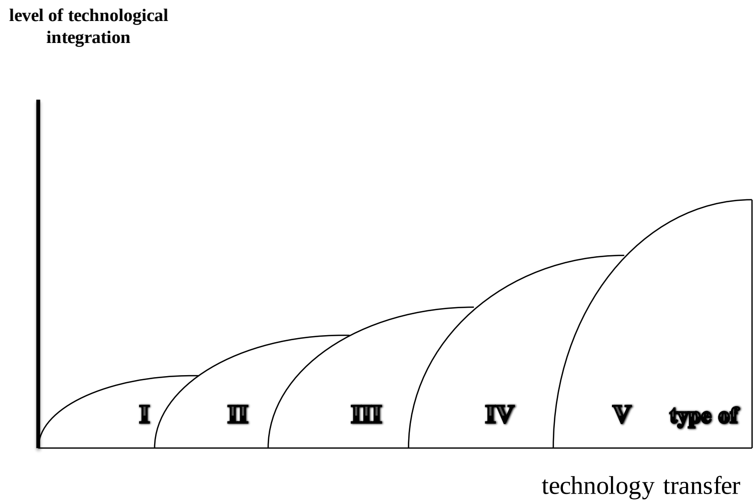
With the detailed discussions we have had before it is easy to understand this figure. Earlier requirements of quality, cost, and schedule remain. But two more crucial elements are added.

Those are elements which add to the technological capabilities to the OCF firms. Instead of leaving them at an individual firm level to the “market forces” **as it happens in India today** due to faulty policies and poor implementation of even good policies, it is necessary to orchestrate the whole process in India with all the willing firms and all the willing colleges. Basic knowledge inputs for such a “technology intermediation effort” (See Ref. 18) has to be done by the State with sophisticated modern methods and flexible governance systems. Such actions will create the necessary innovation system, though at a bottom level to begin with.

But one cannot be satisfied with such a state of capability. One has to go forward.

Again to source a figure from Radosevic (Ref 12), it describes the evolutionary process of transformation of IT from mere outsourcing (intelligent though) to higher levels of capabilities.

Discontinuous character of technology learning within alliances



I	II	III	IV	V
Cost reductions; Standard quality	Quality improvements; Flexibility and response time	Product customization; Process improvements	Minor joint product developments	R & D co – operation; Major joint product developments
Cost cutting alliances		Process and product development alliances		Pre-competitive and product development alliances
First threshold level		Second threshold level		Third threshold level
Standard quality processor or contractor		Specialty subcontractor		Technologically integrated; Strong learning-by-exporting inputs

If the figure is read along with the table with the background of the discussions so far (earlier), one can be clear about the various (more) challenging steps for the firms and therefore for the participating academic and S & T institutions. All these steps have great challenges and opportunities for the elite, medium and private institutions / colleges. Govt. has a role to play as a facilitator – also through incentive / disincentive systems to make the better institutions to focus on these processes rather than being lost in so called "blue sky research" agenda set up by developed countries for themselves.

With the size of Indian human resource and domestic market, Indian firms and institutions have a great opportunity before them for creative challenges, more wealth and profit, as well as the excitement of achieving leadership position in the global markets in several areas.

But this cannot be done by hypes and hyperbolic policy statements.

Can be achieved only through orchestrated and sustained policies and implementation by Govt., firms, institutions, media and others over a period of 15 – 20 years (minimum gestation period).

Let me quote:

Observe calmly; secure our position; cope with affairs calmly; hide our capabilities and bide our time; be good at maintaining a low profile; and never claim leadership.

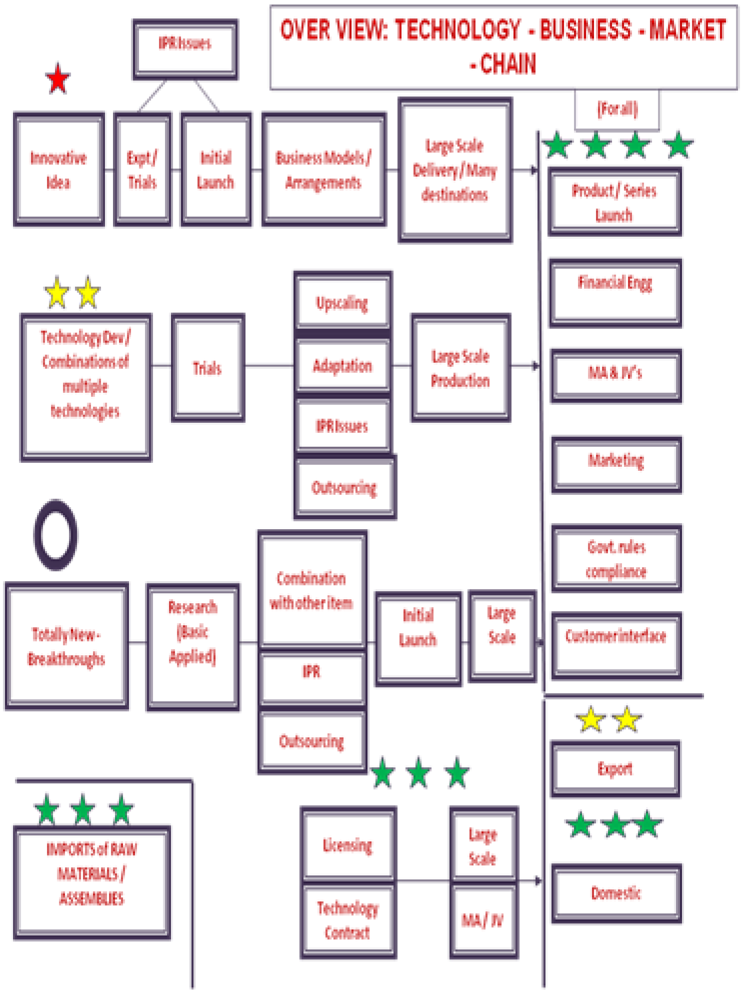
AN OVERVIEW

So far we have covered as to how we need to orient policies and procedures such as to acquire technological capabilities in the firms, academic and S & T institutions, governance systems etc. If the orientation is not suiting the demands of the globalization processes under way as well as the rapid growth of multiple technologies which are increasingly customer options oriented, the firms and institutions of that country will be left behind with serious implications in terms of denying better incomes, prosperity and well being of the bulk of the people.

Since many countries are in the race there is a need to catch up faster and be agile to changing situations.

As explained earlier there are no single point solutions, such as more of R & D or basic research means innovation and leadership; outsourcing or continual imports or continual merger and acquisitions abroad will do etc., will not suffice either. It is a multipronged attack depending upon the context along with, agile mid course corrections but having a clear overall strategic view of arriving at a leadership position in order to achieve a respectable stature for interdependence in the world.

In the context of such a multipronged approach, an overview flow diagram of technology to market and customer as applicable to 2010 period is given in this text. This diagram is true for any country and has to be adapted sector by sector or even for sub sectors in order to derive practical insights. It can be used at a firm level too if it is big or a group of firms. It will require lots of inputs in terms assessment of current global situation and the context of firm / group / sector etc; technology foresight relevant to the sector; potentials for the firm / group / institution etc. It will be a knowledge intensive exercise. It can take several weeks to several months depending on the magnitude of the scope covered. For a country as a whole (like say India), it will take at least a year.



In that diagram, only a very broad brush impressionistic / intuitive (derived from experience) indicator is given in terms of rating as stars. For a particular sector or sub sector it may vary. But by and large for a macro view of the country's position in terms of capabilities at the various levels of the value chain from an idea to actual customer service, the star rating is reasonably correct.

On the right side of the figure is clubbed all tasks relating to reaching the market / customer service / meeting special regulations, if any, in the country of market (foreign for exports or domestic) etc.

Post liberalization in 1991, the Indian private sector has progressed remarkably well in terms of achieving various targets for the elements in the right hand side in the competitive global market (i.e. export as well as domestic competition by imported goods or with foreign entities operating in India). They have done it despite the fact that governmental enabling systems are poor compared to their counterparts in the world. PSE's performance is not to their full potential because of the various constraints posed by the promoter owner that is, Govt. They are still under various bureaucratic and political controls. Once freed PSE's will also do well. Therefore all the elements in the right hand side except the bottom two elements is four star (out of five) for Indian companies. Bottom two elements of the right hand side are shown as EXPORT and DOMESTIC.

In EXPORTS India is still a small player. Indian Pharma firms, chemical firms etc do better, but most others are small. (See Ref 9 for a brief glimpse of global position of Indian Industry) Of course the issues are not merely that of science, technology and engineering. But they can also help to achieve better competitiveness. Our assessment overall for Indian industry is two star out of five. Lot of work is needed.

Performance in meeting the domestic sector market is better. Indian domestic demand in high and is growing. Still the performance of the Indian companies in reaching the vast domestic market is still not very high; hence it gets three stars. Lot needs to be done, be it reaching IT and IT enabled systems to rural areas or doing special and quality products for rural and small town markets etc. They are yet to reach the real bulky base. Of course there are various constraints such as absence of electricity, other infrastructural inadequacies, poor governance leading to delays and corruption etc. But still there is a scope to improve.

For the right hand side elements there is very little interactions with Indian academic and S & T institutions. Even MBA institutions including elite ones do not participate and are mostly being happy with foreign case studies. Of course the academic institutions turn out the rich human resources of young qualified men and women who learn and adapt while in job.

We suggest that upscaling to five star status will require several endogenous knowledge inputs and knowledge intermediation. Close partnership with academic and S & T institutions, of all types, not just elite ones, will broaden the gene pool of innovative ideas which will in turn help the companies doing business.

For example, good practicing technologists from the academic and S & T institutions along with experts from industries can visit many exports markets in which the Indian companies have entered. If planning and follow up exercises are done well each big company and a group of MSME's could have their own well informed 'think tanks' which can help the company to chart out new innovative paths to increase their market presence or to improve profits etc.

Now the question is who will make the first move given decades of respected (or suspicious) hiatus between the academia and corporate sector in India?

It is hoped that some of the listeners of the talk or readers of this paper will attempt: One is aware that it is not an easy task. But it is in the interest of all Indian people and also the main stake holders – the companies and the academia.

In the export sector, to graduate from two star to say four star and in the domestic sector to graduate from three star to five star are great challenges. For the domestic sector the colleges spread all over India can do a great job, if companies / firms include them in partnership. The experience from TIFAC – CORE and other TIFAC projects mentioned earlier are good examples and forerunners for such partnerships. For the export sector, young persons now working in India having had a study or work experience abroad will be of great help.

Of course if State / Central governments take active interest – not for a central planning nor for supervisory control – but as a facilitator for technology and knowledge intermediation, the process will be accelerated. But such facilitating agencies should keep in mind the diversity, complexity and fast moving nature of globalization and technologies, so that they avoid single point guidelines – one shoe fit all type – which will appear excellent on paper and in air conditioned meeting rooms, but will fail in practice. This is the experience of the past several attempts by various central government departments including S & T departments. If such a mindset continues it is better not to do a facilitatory process!

Now moving leftward of the figure let us look at the bottom of the chain. They involve various tasks like licensing arrangements with principals abroad for manufacture and other aspects or having long term contract with the outsourcing DCF firms, technology contracts of various forms including consultancy accreditations, project management of these elements etc and using these to start large scale production in India. Most companies in automobile sector, chemical sector, electronics etc use these processes. Since Central govt. controls have become minimal since the period of liberalization (post – 1991) PSE's also do well despite their governance constraints. As a part of large scale operations and depending on the needs of specific technologies or market access, mergers and acquisitions as well as joint ventures are done. Mostly Indian companies are very good in the process. Hence there is a three star.

Here again there is a good scope for partnership between academic / companies / firms and S & T institutions on the lines suggested above. Technology foresight, IPR searches, technology assessment and identifying areas of incremental improvements in the short and medium term and organizing technology acquisition or development of the same etc could be the tasks.

In the extreme left hand end one would notice the input elements for most of the companies – imports of raw materials / assemblies. Indian companies in the overall cannot be considered to be excellent but are very good. Better technological knowledge coupled with market / business aspects can help them in competitiveness in terms of cost, quality and performance. This again is an excellent area for academic / S & T institutions to partner with industries. Each S & T institution or a group of them may specialize in select sectors. Many such groups in turn can network themselves as Knowledge / Technology Intermediation groups. There is a plenty of scope for knowledge / experience sharing between industries as well as partner institutions.

Let us go up in the chain second from the bottom. This is indicative of a line of technology development, production and marketing starting with new break through ideas for technology. Though there are occasional media hypes and misinformation from some S & T institutions, there are no such break through ideas coming from an Indian firm or institution which has tried to move rightward. We are still followers and everybody is conditioned to think whether it has been done elsewhere, even for basic science research! The review committees at most laboratories or at the funding agencies will ensure nothing break through can be proposed!

We leave this chain for a moment hoping for a better future. Hence shown as a big zero.

Third chain (upwards) from the bottom left hand extreme indicates some technology development mostly as adaptive or with some incremental value addition or combination of several existing technologies in a different configuration or process to derive a better product.

Firstly they go through various trials and then go through further steps. Since WTO regimes are in operation, IPR issues are critical. Some elements of the work may be outsourced by the Indian firm to others in India or abroad (eg getting a design for a high value leather good from France or Italy etc). Then the firm can enter into large scale production and go further right.

Indian companies have started making some presence in this chain: examples are in automobile sector – full systems and auto components, also in pharma; chemical etc. Still the total number of such companies are small. Most of companies prefer to adopt the bottom line of licensing, technology contract discussed earlier. Thus for this chain, we give two stars out of five.

Though currently the number of firms / companies involved in venturing into this chain even for same of their product lines, is small now, it is a huge area of opportunity for academic and S & T institutions to partner with industries. Many more Indian firms / companies will venture when they see the initial adventures benefit the industries / firms, in terms of new markets, increased profits etc. Knowledge intensity required for this chain will provide new challenges for the academic and S & T institutions especially the ones which are already better equipped. But S & T / academic institutions under govt sector try to shun this chain, as they get substantial funds from Govt. which they can use for research of their own choice without the necessity of having pressures to meet targets and schedules. **With the slogan of investing more in S & T to increase the share of expenditure in S & T as percentage of GDP, merely to show the macro level statistics, will lead to a situation where most S & T / academic institutions which are already well funded by Govt. will shy away from taking the <u>real</u> challenges required to build <u>technological capabilities of the Indian firms.</u> If such a situation continues, even if our S & T / academic institutions invent some new technologies there would be no takers from the Indian firms / companies.** Then the inventors have to try to find foreign companies who may take them but it is not going to be an easy process.

Therefore concentrating on this chain for various sectors and sub sectors by our academic / S & T institutions and working with Indian firms in their real problems and challenges will not only be profitable for India but also build up within the management of Indian firms a trust about the capabilities of Indian S & T / academic institutions. Then they will be ready to go towards the top chain in which they will start with an innovative idea from within their firms and especially from our academia and laboratories. **Today their (firms') trust level on academic national S & T laboratories is very low. Trust can build up only through real life positive examples.**

If the top chain gets populated with several success stories by Indian firms in the domestic and global markets with "Invented in India" brand, then India would have arrived at a respectable interdependence level in the global competitive market. It will then be innovative India.

The top chain as of now only has come epidosical examples, those too being small ones. Most of them are due to the struggles of a few brave men and women in the difficult ecosystem of India. That is why it is shown single star out of five star. India cannot afford to be in the same situation for another decade when she is really growing up her economy and becomes a reasonable size in global terms.

In order to upgrade the top chain, confidence in industry – academia partnership should be built up through the bottom most chain, third from bottom chain and then arrive at the top chain soon. (The break through chain can be in general forgotten or kept in abeyance for a decade or so till other chains function well).

If this chain approach is taken seriously first by academic and S & T institutions (national laboratories), then the firms / companies would respond. Then pressure can be built up on Govt. technologies funding agencies / schemes to modify the current straight jacketed and unrealistic rules.

Then the powerful Industry – Academia lobby which will be wide spread all over India, can then force the governance mechanisms to change in order to create a good national ecosystem for innovation (which is currently rated poor by global standards). India : The uneven innovator by Kirsten Bound, The Atlas of Ideas: Mapping the new geography of science published by DEMOS, first published in the year 2007. ISBN 1 84180 171 2 (Ref 22)

GLOBAL LEVEL INNOVATIVE INDIA

That brings us to the last section of this long paper / talk. It is best to refer to a book titled "Innovation Policy in a Global Economy" edited by Daniel Archibugi, Jenemy Howells, and Jonathan Michie published by Cambridge University Press (1999), Ref 23) transferred to digital printing in 2003. http://www/cup.cam.ac.uk and http://www.cup.org . It comprises twelve chapters by eminent experts. Each of the chapter brilliantly bring out the actual experiences, analyses thereof as well as suggestions for actions for the future. Especially in the context of the latter element it is an unusual book and is therefore useful for practitioners in firms, institutions and policy makers.

Chapter 2 of the book is titled "Technology Policy in the Learning Economy" by Bengt – Ake Lundvall. The author has effectively brought out the idea that world is past mere knowledge economy and in fact through operation of knowledge economy, another equally critical element has started dominating. That is, "learning". In the words of the author "The concept emphasizes that we today find ourselves in an economy in which the competitiveness of individuals, firms and entire systems of innovation reflects the ability to learn." The author elaborates various aspects of the learning economy such as the changes in the structure of labour market and production, and the fact that the increasing proportion of output is knowledge and information. Te author further points out that "learning and especially learning new skills and competences is necessarily a social and interactive process…." And further elaborates the social dimension. Hence the learning economy cannot flourish in pure market economy and the author recalls Nobel prize winner Kenneth Arrow's paradoxical observation "that people will only pay for knowledge they do not have – but that, on the other hand it is difficult to assess how much to pay when you do not know what you are getting for your money".

The chapter -2 further explores the learning process and arrives at the need for TRUST, another difficult item to incorporate in an economic analysis. Again there is an Arrow quote "trust cannot be bought; and if it could, it would have no value whatsoever".

It is good to read the whole book and especially Chapter -2. Other issues discussed are: plan versus market – a dead issue?; competence and social equity; etc. then are given six steps in the formulation of a knowledge – oriented technology policy. They holistically cover many elements referred to in this talk (paper).

In its summary part of the chapter – 2 the author concludes: "….. in the learning economy the primary task of industrial and innovation policies will be to promote learning processes involving a interaction between sub – systems, organizations and individuals. This involves, among other things, ensuring good communication between knowledge producers such as universities and schools on the one had, and firms, on the other. But it is even more important that firms, both on an individual basis and in an interplay with each other, invest in knowledge creation. It is also of crucial importance that the knowledge created in one firm is used to stimulate innovation in other firms. Particularly with respect to organizational renewal, it is imperative that firms are encouraged to learn from each other."

These words emphasize what the current paper reiterates in various sections. They also further strengthen the need to address different chains described earlier in order to build trust between the firms and S & T / academic institutions. In turn they will learn from each other and continue to innovate in the global economy and global knowledge society.

Let us all work for enjoying our participating in such a knowledge society and more importantly bring the benefits to all Indians.

It will, of course, require that we totally change our present mindsets and adjust ourselves to the demands of new paradigms unfolding rapidly in the globalizing world.
Thank you.

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