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A Framework for Technology-Integrated Development Planning

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A FRAMEWORK FOR TECHNOLOGY-INTEGRATED DEVELOPMENT PLANNING

by
Nawaz Sharif

1. Introduction

Throughout the world, people -- at home, at work and at play -- have, over the past millennium, moved away from their sole dependence on only naturally available resources to more increased reliance on many kinds of human-made technological resources. Consequently, at the enterprise level, the technological resource -- as much as capital, labor and natural resource -- has also become one of the essential factors of production. At the national level, technology is now regarded as the engine of economic growth and a strategic variable for sustainable development. Furthermore, in the present world in which international trade is considered to be essential for economic progress, exposing the domestic enterprises to the rigors of global competition is also found to promote technology-based efficiency. Hence, in an increasingly globalized and interdependent world economy, technology has clearly emerged as the driving force behind: the structure of domestic production, the advantage in market competition, the opportunities for across border trade, and the growth of the standard of living of the people of a country. This vital power, however, resides in the productive enterprises, and is derived primarily from their ability to introduce technological innovations faster than other competitors -- to make products and services better, cheaper and greener. Thus, "management of technological innovations" is aptly described as the master key for sustainable socio-economic development in all parts of the world.

Recently, as a result of liberalized regulations for attracting foreign investments and lifting of existing restrictions on foreign exchange flows, the productive enterprises in many developing countries are by deliberate plan experiencing the importance and pervasiveness of technology for achieving global competitiveness. They are forced to realize that the only way to compete globally is to hold an advantage in technology. Therefore, in the present era, the most important consideration for international market competition is the management of technological innovation. However, to improve one's ability to manage technological change for international trade, simple economic analysis is not enough any more. One now needs proper understanding of the technology-based development process and a suitable methodology for considering technology related variables in an integrated way for decision-making at all levels.

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In developing countries, enterprises have to introduce technological innovations through acquisition (technology transfer) and/or self-generation (technology development) to enhance their targeted market competitiveness. Given this widespread recognition that the key competitive advantage in the international marketplace, nowadays, is the ability of a country to manage technological innovations through transfer and development, the need for endogenous technology management capability can, therefore, be hardly overemphasized. Consequently, technology management capability development for effective "technology transfer" and "technology development" have become the two most important concerns. However, technology transfer and technology development can be addressed at the productive enterprise level where various technology components are employed to transform inputs to outputs and upgrade technological capability in the process; at the technology infrastructure level where the needed institutions are developed and the necessary linkages strengthened for innovation to take place; and the national technology climate level which provide the favorable techno- and socio-economic environment for the conduct of technology transfer and technology development.

The general purpose of this paper is to present the rationale and a framework which could be used for technological change management in developing countries. As conventional economic and financial indicators do not adequately describe the strengths and weaknesses regarding the technology aspects of a firm, an industry and a country, the approach taken in this paper is essentially different in terms of its focus. It is proposed that a holistic approach for technology transfer and technology development, linked to the development strategy of the country, should be pursued as a multifaceted and dynamic process which interfaces with several elements. Using a systems approach, the framework presented in this paper attempts to integrate technological considerations at all levels of decision making. Specifically, the framework attempts to establish technology management methodologies in the context of public and private sector enterprises and technology support system development at the sectoral and national levels. Starting with an exposure to the unique characteristics of technology at the firm level, and using a systems view of the market structure, possible strategic mixes are determined by considering available business and technology strategies. Necessary considerations for technological capability enhancement and plausible technology strategy progression path are also discussed for different development conditions. As most of the enterprises in developing countries are of small scale, they need supportive infrastructure and conducive climate to enhance their technological capabilities. Technology infrastructure provides the mechanisms for endogenous capability enhancement; and technology climate determines the rules of the game for technology factor creation and capability advancement.

Besides understanding the unique characteristics of technology as a resource and recognizing the elements of the technological system, the analytical measures presented in this paper are therefore focused on such important aspects as: degree of technology component sophistication, level of technology capability advancement, status of technology infrastructure building and dynamism of technology climate -- some of which could be used the managers of private and public sector enterprises, and others would be useful for investment project review and appraisals undertaken by international and national development planning institutions. These measures taken together provide an integrated framework for establishing a set of technology management methodologies, giving rise to a much desired synergy to the otherwise fragmented attention to management of technology for achieving global competitiveness for sustainable socio-economic development.

2. New World Order of Technological Change

Recent technological and geo-political changes have made all countries of the world more and more outward-looking and more interdependent through international trade. Much of this evergrowing and complex interdependence has come about due to the unprecedented technological advancements in the past few decades, including: modern transportation and communication technologies have made the world smaller (with respect to distance) and closer (with respect to time as well as space); modern production systems enabled simultaneous achievement of both: the "economy of scale" through process standardization; and the "economy of scope" through product differentiation; and modern computer aided activities enabled much quicker responses to the customers' preferences and the market demands. Thus, there is an everincreasing trend of interlocking among all nations of the world due to widespread globalization of many production activities, inputs sourcing and outputs marketing. Interdependence is also growing due to the raised awareness of global consequences, resulting from natural resources depletion and apparently localized environment degradation, caused by various economic production activities in all parts of the world. Moreover, as a consequence of the failure of certain centrally planned economies in the world, there is also an observable undercurrent (in most developing countries) of full-scale deregulation, privatization, and open competition (in international trade) for economic development. Therefore, in many developing countries, which are now introducing trade liberalization policies, both public and private enterprises are under strong pressure to introduce technological change to improve productivity and to become internationally competitive.

At present, the world of industrial production is undergoing a revolution of thought and organization. Recent technological advances are leading to changes in productivity and costs, impacting on global and national structures of production, trade and employment in a revolutionary manner. There is increasing concern with external, market and customer oriented goals, and increasing efforts in reducing uncertainty based on information interventions. Microelectronics, informatics and biotechnology are playing a primary role in the radical shift in the production mode of all economic activities, be it in agriculture, industry or services. The current trend is toward: shorter product life cycle; greater product diversity; more fragmented markets; more rigorous quality standards; more demanding customers and increased environment conscious societies. There is also evidence of profound changes in factory operations from the early-era mass-production to the new-era lean and flexible production in competitive industrialization. New technologies help transnational companies to turn out new products much faster, while at the same time, enable them more flexibility in the manufacture of higher quality and more reliable products at lower costs. And whenever economic considerations dictate, these companies move to developing countries with lower labor costs: lower wages; longer working hours; and lesser worker protection. Furthermore, compounded by the fact that international competition is increasingly intense and there are new market economies (as a result of recent failure of the centrally planned economies) with much lower wages, many newly industrializing countries are being squeezed out of the marketplace and will have to engage in more technology-intensive production activities.

A thorough study on industrial productivity in the United States of America by a Massachusetts Institute of Technology Commission clearly states that "for continued success in world trade, new ideas generated in the United States and elsewhere must be converted into products and processes that world-wide customers want, when they want them, and before competitors can provide them -- and those must be produced efficiently and well." This prescription is equally valid for developing countries as they also nowadays accept the free market concept and aspire to join the global economy. Therefore, in many developing countries which are now introducing trade liberalization policies, their state-owned enterprises are under strong pressure to improve productivity and become internationally competitive. However, for the foreseeable future, those industries will have to attempt free market business on the basis of upgrading their production facilities through imports. Moreover, their people have also realized that, exporting raw-materials and primary goods to pay for imported machinery and process know-how is a losing business, because the purchasing power of these commodities have steadily fallen while that of machinery has continuously risen over the last two decades. Furthermore, state-of-the-art machinery, which can give competitive edge in the international market, is normally not sold but can only be exchanged for something equally valuable. Therefore, consideration of technological capability building for transforming raw-materials to high value-added products is becoming extremely important for both private and public sector enterprises in developing countries ambitious to join the global market.

There is strong evidence to suggest that the industrialized world is now in a technological revolution of enormous scale, entailing significant changes in many production activities and affecting almost all aspects of social and economic development. Therefore, many suggestions can be noted in contemporary writings that the most important consideration for market competition nowadays is the management of technological innovation. In industrialized countries, this quest for technological change in an enterprise is directed towards the acquisition and utilization of: the most advanced physical assets; the most competent human resource; the most valuable knowledge base; and the most effective management practices. Unique combination of these four aspects (machinery, skill, knowledge and management) collectively contribute to the competitive edge of an enterprise. Many have also argued that comparative advantage based on differences in production factor costs (land, labor and capital) alone is not sufficient any more; now competitive advantage based on accumulated technological capability is most essential. However, acquiring technological competitiveness is progressive in nature, and is not a once-and-for-all event. Technological development takes place through costly and purposeful efforts resulting in accumulation of technological capabilities. It is a continuous process of capacity enhancement and never ending innovation. Without capability advancement technological dependence will increase. Indeed, evidence is growing that access to advanced technologies is increasingly constrained by both the complexity and size of technology as well as by the fact that it is increasingly under the control of transnational corporations which have invested heavily in specialized capability accumulation.

Understandably, every country is now interested in increasing value addition (ie. technology content added) by its productive enterprises as a strategic factor for global trade. In the industrialized economies, there is an observable emphasis on innovation and specialization in economic restructuring for boosting international trade as more and more the value of a manufactured product is determined by the technology that goes into it, and not by the raw-material that constitute it. Their recent successes show that, in the international market, the real competitive edge is derived from the efficiency of a production system in adding higher technology content to its outputs. Technology content added depends on the stock of physical resources, quality of human resources, usefulness of knowledge resources, and effectiveness of management resources. Therefore, using higher technology content for international market competition requires the production system to expand and diversify the industrial base of a developing country by following a coherent technology strategy. Also, the technology strategies of enterprises in developing countries should change over time coinciding with different stages of industrialization and for different phases in the technology life cycle as follows:

First Stage - imported and old technology based small and medium scale enterprises for low-value local market;
Second Stage - selective importation of technology mostly through joint ventures by medium-size firms;
Third Stage - creative imitation based on licensed technology enabling large-firms enter international market; and
Fourth Stage - introducing self-developed technologies giving rise to temporary monopoly in emerging areas.

Although the developing countries have, for a long time now, given high priority to the promotion and development of small and medium size industries, the technological aspects have often not received adequate attention. Proper management of technological change, particularly at the productive enterprise level, are important consideration for both private and public sector enterprises. Besides the private sector companies, state owned enterprises will also have to be internationally competitive for sustainable growth of economies. Governments and corporations in the industrialized world are investing billions of dollars in creating the capabilities and institutions necessary to develop and deploy new technologies. Such changes in the industrialized world may undercut the comparative natural resources and wage rate advantages of many developing countries. Therefore, both for public and private sector production enterprises in developing countries there is an urgent need to introduce technological changes to make their outputs competitive in the open market.

In developed countries, government policies are directed to influence the rate and direction of technological change, and they are justified because they correct market failures. Some of the common reasons include: standards for interfaces and networks; flow of information; penalties and restrictions on technological change that damages health, safety and the environment; and protection of intellectual property rights to reinforce the potential temporary monopoly rent afforded to would-be innovators by the natural time-lags and cost of imitation. It may be important to note that the transnational corporations do not need any support for technological innovations, they need to be controlled. But developing countries do not have their own transnational corporations for international competition. Catalytic and supportive institutions can help small enterprises in developing countries become global firms. Small scale enterprises, in both developed and developing countries, do not invest in technological factor creation. On the other hand, in the developed countries, universities, research institutions and the mass media actively supporting the growth of high technology enterprises to become global companies.

3. Review of Existing Situation in Developing Countries

Because of the diversity in the world, it is neither possible nor very useful to list the myriad of problems and issues faced by all developing countries in introducing technology based development planning. Therefore, recognizing the uniqueness of each country situation, the following account only attempts to highlight some of the most common and important aspects only:

All countries now recognize the importance of technology, but policy planners in developing countries do not appear to be taking advantage of the unique characteristics of technology. This is perhaps because we do not understand technology well enough for its proper management, and hence, technology is still being treated as black-box or residual in models representing production functions. We also lack the understanding of major distinctions between science and technology as we fail to see that technology is the vital link (with both push and pull effects) between scientific knowledge and economic development. We find that technology is changing very rapidly and the technological gap between developed and developing countries is increasing. However, uncertainty and risk characterize technology change management problems; and time-lags and discontinuities further complicate the matter. Therefore, it can be observed that planning situation appears hopeless due to a lack of appreciation of the presence of "dangers" as well as "opportunities" associated with crises resulting from technological revolution.

Often policy makers are overlooking the real fact that brainpower is the "ultimate source" of all kinds of production technologies. In many developing countries, natural resources have been exploited to a devastating degree while human resources have not been fully developed. We observe the reduction of natural resources due to inefficient use and over exploitation for export, but we fail to see the loss due to brain-drain and poor utilization of human resources. We also do not see that natural resources can be saved for future use, but technology resource becomes obsolete over time. We think that comparative advantages based on natural resource endowments can be maintained for a long period. We do not know how to use technology as a strategic variable, but know that application of any technology may have some unwanted side effects (which may be immediate and/or very long-term).

Decision makers in developing countries still view technology as "a thing" or machinery only, and not as a composite resource for competition. There is a lack of appreciation that market value addition by productive enterprises means really technology content addition, which depends on the stock of physical resources, quality of human resources, usefulness of knowledge resources, and effectiveness of management resources. We generally considering factor endowments only, and not market requirements, as criteria for selecting appropriate technologies. We fail to see that technology strategy is related to capability status and demand characteristics. We sometimes overlook the fact that technology developed for one location is seldom equally well-suited to others; thus, investment to tailor foreign technology to local circumstances are rules not the exceptions.

Economic restructuring efforts in most developing countries indicate our doctrine that having production capacity is considered equal to having technological capability. Restructuring is mostly seen as progressing from basically agricultural to any or all kinds of industrial production without specialization. Observably, there is a mistaken expectation that attracting any foreign investment in production capacity automatically results in technology capability. Also, we invest in similar types of production capacities in most countries without strategic specialization considerations. Although we see that economic growth results from technological capabilities localized in productive enterprises, we have failed to learn that technological capabilities are not acquired when production capacity is built through "turnkey" projects and direct foreign investment. We find persistence of an illusion that production facility transfer by transnational companies means automatic transfer of technology capability to developing countries.

For a long time, we have followed many of the developed countries' science and technology related models, but perhaps not those which could have ensured real success. There is a derived conclusion, from the situation existing in developed countries, that increasing research expenditure alone can enhance technological capability. We have not noted that in developed countries bulk of the research and development efforts are undertaken by private enterprises. Furthermore, compared to developed countries, total research and development efforts in most developing countries is also insignificant and generally unproductive.

Increased government funding and fiscal incentives for innovation are being given to universities and laboratories, without matching technological capabilities in locally owned firms themselves. Research and development emphasis in government funded institutions have failed to strike a balance between market pull and knowledge push. Minimum critical mass, continuity and proper linkages which are very essential for innovation are lacking. Most centers of academic and research excellence in the public sector have been, for the most part, isolated and disconnected from production, and have often proved unable to transform new knowledge into new and improved products or processes suitable for application in the production units.

In many countries, we are establishing science and technology parks as "incubators", but without having universities producing state-of-the-art knowledge. Due to over protection and also scarcity of funds, small-scale private enterprises in developing countries do not undertake in-house technological innovation efforts. On the other hand, most of the public sector organizations suffer from outdated facilities and rigid management style which inhibit creativity. These organizations are often engaged in too many diversified and everlasting activities with subcritical financial resources. Also, mechanisms used for funding support, and performance evaluation using available indicators gave only misleading signals. Like other government administrative activities, for innovation management also there is widespread emphasis on doing things right (efficiency) rather than doing right things (effectiveness).

Chronic balance of payment problem of developing countries reflects unbalanced international technology content trade. This is primarily because we have failed to look into technological needs identification problem in a serious manner. There are no procedures established for needs planning by three technology domains -- import/adapt; evolve/prosper; produce/export. As actual technological needs are for both self-reliance and sustainability, it is essential to consider world technological trends and situational realities for needs planning. Furthermore, prioritization of needs and specialization decisions require consensus building, which is lacking. All countries are following the bandwagon of getting into the emerging technologies without adequate preparation and specialization. We are unable to deal with long term considerations in planning decisions.

For some reason or other, we are still unable to integrate technological considerations into the socio-economic development planning process. Functions of newly created ministry of science and technology and coordination council for science and technology remained mostly peripheral. Development planning process, by and large, stayed fragmented and departmentalized, and also traditionally incremental. We do not distinguish between latent capacity of science and technology related institutions from technology capability in productive enterprises. Instead of appreciating the problems of our small scale enterprises which cannot invest in technology factor creation, we blame that it is problem of attitude and culture. We are not paying any attention to the fact that strong commitment and active involvement by top leadership is the key factor.

Sustainable development aspect is being looked only from environmental conservation point of view, and not from technological self-reliance angle. We chose to ignore that technological self-reliance and sustainability are mutually reinforcing. It requires the accumulation of skills, knowledge and procedures. We have not recognized that there is a lack of environmental standards, monitoring and impact assessment of development projects; and prevention is far better than correction after causing environmental degradation. Environmental degradation is a result of poverty in the developing countries and affluence in developed countries. There is a lack of any strategic policy formulation mechanism that can integrate shared technological vision. Policy contradictions and uncertainty in policy environment discourage technological risk taking. Although we now recognize that a special focus on technology has become increasingly important for developing countries, we still lack operational procedures to manage technology.

A serious question that must be urgently and carefully answered is: What policy regimes, institutions and programs must be put in place to enable a country to benefit from the new technological changes without falling too much deeper into technological dependence? In other words, the key issue is to manage technology resources properly. Thus, it is imperative that we attempt an integrated approach to develop technology management procedures which should include considerations of: characteristics of technology resources; technology component sophistication; technology capability accumulation; technology strategy progression; technology infrastructure building; national climate creation; and determining technology needs for risk reduction. The need becomes all the more critical under the current pace of rapid technological change. The rationale and a framework for developing a set of technology assessment measures, corresponding to the above requirements, specifically in the context of the prevailing deregulation and privatization trends (focussing on free enterprises) in most developing countries are discussed next.

4. Technology Resource Characteristics

Resources for a productive enterprise refer to all available supplies that can be used as needed. It is possible to categorize these resources into three broad types -- natural resource; human resource; and human-made resource. Natural resource availability is varied but widespread throughout the world -- air is available everywhere; water in most places; food in many places; minerals in some places! There are many constraints with natural resources -- everything is not available everywhere; there is uncertainty regarding supply quantity and quality; inadequate concentration at one place for long-term use; regeneration cycle is generally very time consuming; etc. Although there are problems in determining the true market price of state-owned natural resources (market mechanisms fail if prices are not realistic), endowments of raw materials reduce a country's imports; and natural resource, if saved, can be used later (perhaps in a more efficient and better way). Moreover, the real effective way of conserving natural resources is giving value to these resources. If people see the value of natural resources, they will be more likely to conserve them. It is worthwhile to note that selling natural resources is a zero-sum game (our loss is equal to others' gain).

Technology is a human-made resource for competitive production, and it is being developed and upgraded at an accelerated pace. It is a resource for transformation of inputs to desirable outputs, and it has different features than natural resource. It is produced by creative people at various places for amplification of human capabilities at work and play. The purpose of technology is not only needs satisfaction but, much more importantly, technology is crucial for success in competition. Value is derived by an enterprise from use of technology; there is no intrinsic value without use. Price of outputs depends on both technology content added by enterprise and market demand. We now recognize that technology is the most important resource for development. But, technology for productive purposes mostly changes through a process of successive "substitution of old by new" for better performance.

Human resource has a dual function: it is the consumer of natural resources; and it is also the producer of human-made technological resources. Over many millennium, the size of world population has increased steadily to almost a callous (or inhuman) magnitude. Given the current emphasis on family planning and concern with dreadful (catastrophic) consequences of further growth, it is hopped that the world population will stabilize at the maximum carrying-capacity of the planet earth. When humans and enterprises consume natural resources, we normally produce wastes and cause pollution (environmental degradation). To produce technological resources, people (population) need to be developed into human resource to possess the following characteristics: well educated, trained and informed; have the right kinds of tools; and are highly committed and motivated. Every human being and every enterprise have virtually limitless potentials, and the conduciveness of the national technology climate determines the extent to which these latent forces can become reality.

Regarding the human-made technological resource, it has been mentioned earlier that, in the present day world economy, it is the most important resource for competitive business. However, since technology changes through a process of never-ending "substitution of old by new," any technological resource becomes obsolete when someone has produced a better one. Therefore, not only does technology by itself not produce results (it is only a means), it cannot even be saved for latter application as it becomes non-competitive. So, the often made statement about technological resource: use or lose. However, a variety of risks (to: life, environment, or business) pervade virtually all of the applications of technology. And yet, over the years, the rate at which new technologies are generated throughout the world has grown exponentially. Each new generation of technology suffers from a progressively shorter life-span. Technological life-cycles have become so short that a leading enterprise has to be willing to make its own products obsolete in order to maintain competitive posture.

All enterprises compete for scarce resources and attempt to ensure a steady supply. Consumption of natural and human-made technology resources are very high in the developed countries. Developed countries normally do not export their scarce natural resources, and poor countries generally find it expensive to import high quality resources (both natural and human-made). But developing countries do export their high quality scarce natural resources for earning hard currencies to pay for imports. Moreover, human-made technology resource (as it is not location specific and also as it is our own creation) enables us to develop wherever and in whatever way we want. But, if an enterprise has to depend heavily on imported resources (natural and technological), its ability to continue market value addition remains significantly vulnerable. Therefore, we need to be concerned about resource ownership and local consumption compatibility with available resource endowments. An enterprise needs to consider the relative proportion of locally available versus imported resources, and ensure that it does not become the victim of over-reliance on its suppliers from abroad and on foreign ownership of needed resources.

5. Technology Structure of Production Systems

Technology, as the human-made resource, is the foremost of all means which enables transformation of available natural resources to desirable products and services. Such a transformation process can be simply viewed as adding technology content to the inputs which in turn gives market value to the outputs. One possible way to enhance the competitive edge in the marketplace is to increase productivity of the amount of technology content added by the enterprise operations. Increase in productivity arises from change, and in bringing about this change, technology is a crucial factor. Investment in new technologies is the key distinction between enterprises that achieve consistently high productivity gains and those that do not. Hence, the pursuit of increasing the sophistication of all forms of technology used for transformation of inputs, and steady accumulation of technology capabilities by the enterprise. While technology components enable necessary operations, technological capability of the firm arises from performing activities over time, acquiring resources from outside, and/or generating resources from within. However, acquiring technological competence is progressive in nature, and the prosperity of a nation is the result of continuous innovation activities for successful international competition by its productive enterprises. Also, the process of innovation is fraught with risk and uncertainty, and hence, more difficult for small-scale enterprises in capital scarce developing countries.

At the beginning, a developing country enterprise, catering for the domestic market, is almost exclusively dependent on imported and mature technologies to take advantage of relative abundant endowments of either natural resources or unskilled labor, or both. During this period local technological capability is likely to involve principally the effective operation of simple imported technologies. These natural resource or labor intensive industries face difficulties over the years due to either depletion (and degradation) of natural resources or decline in labor productivity. For open market competition, an enterprise needs capability to acquire better technologies and also capability to maintain and adapt imported technologies for which highly skilled and motivated human resources are needed. The transition to international competitiveness requires a greater degree of local capability for improvement of imported technologies. While all firms need not be able to engage in major product and process innovation, they must at least have the capacity to undertake incremental improvements in existing technologies, as competition is based on product differentiation and response to demanding customers. Successful entry into this market requires a large number of scientists and engineers and considerable investment in in-house research and development. Internationally competitive enterprises pursue innovations leading to the commercialization of new products and processes. Thus, technology development capability becomes the most important prerequisite for emerging (such as: Biotechnology, New Materials, Computer Integrated Manufacturing; and Information Technology) technology-based products and services, which are becoming the most fiercely competitive industries of the world. Some of these emerging technologies (being scale-neutral, flexible and situation independent) are opening up new opportunities for developing countries to apply high-tech, but low-cost, solutions to basic needs-related problems. Without utilizing advanced technologies and blends of the traditional and advanced, the surpluses needed for self-reliant economic growth cannot be generated. On the other hand, it is virtually impossible for any nation of the world to cover the entire spectrum of advances in technology. Some practical and strategic balance has to be struck between locally developed and imported technologies.

In a competitive market, the growth of a firm and the course of its technological restructuring are closely interwoven. One can also find a direct link between business strategy and technology life-cycle characteristics. In the introduction phase, the performance requirements for new products and market needs are not well defined, which means the source of innovation is often the users and the business strategy is customer and environment responsiveness. In the growth phase, the basis for competition is on performance and specific features. In the maturity phase, with achieved standardization, the basis for competition shifts from performance to diversification with respect to niche markets. In the decline phase, when a new technology is substituting for an old one, the continuation of older (mature) but still functional products and processes can give a competitive edge to companies with significant brand loyalty due to image or to small enterprises serving the price sensitive market vacated by industry leaders (who adopt new technologies for higher value markets).

To integrate technological restructuring into overall business strategies of an enterprise for successful competition in the international market, it is necessary to consider the dynamics of the overall system structure. The technology structure is determined by the interaction among the elements of the productive system -- technology components; technology capabilities; technology infrastructure; and technology climate -- which influence the technology content addition potential of an industrial enterprise. The influence of technological transformation system structure on the production factor creation mechanism is determined by the dynamic interaction among the elements of the system. Therefore, it is essential that we attempt a thorough understanding of the interactions among the system elements.

6. Technology Components Sophistication

Technology is still most commonly perceived to be as only a physical means (like a black box) used by an industrial enterprise (either private or public, of a national economy) for all kinds of productive activities. Physical facilities can only enhance human capabilities (such as, amplifying power of muscle, brain, sight, reach) and condition work surroundings (such as, increased comfort, better health). Therefore, by equating technology with machinery alone, the importance of many other associated elements, such as skills, information, and management techniques, can not be fully and explicitly recognized. Technology should be understood thoroughly to be managed properly. It should not be treated anymore as just "a thing" or simply "a black box." One possible way to discern technology fully is to decompose technologies needed by any productive enterprise into four specific embodiment forms (or components). Unique characteristics of the four components of technology are as follows:

Object-embodied physical facilities, such as: tools; devices; equipment; machinery; structures -- called technoware -- which enhance human physical powers and controls for all necessary transformation operations;

Person-embodied human abilities, such as: skills; knowledge; expertise; creativity -- called humanware -- which contribute to actual utilization of available natural and technological resources for productive purposes;

Record-embodied documented facts, such as: design parameters; specifications; blue-prints; operation, maintenance and service manuals -- called inforware -- which enable quick learning and help time and resource savings; and

Institution-embodied organizational frameworks, such as: methods; techniques; linkages; networks; practices -- called orgaware -- which coordinate all productive activities of the enterprise for achieving purposeful results.

All four embodiment forms of technology (which could be at different degrees of sophistication) interact dynamically, and all are required simultaneously for the successful performance by an enterprise. For any particular work within an enterprise, however, there is a wide range of possible choices between the required minimum level of sophistication and the available maximum level represented by the best practice (or state-of-the-art) for each component of technology. Obviously, the choice of technology depends upon: the complexity of the enterprise work to be performed for meeting any particular market demand; the interrelationships among the degrees of sophistication of the four components of technology; and the resources available to the enterprise. It may be noted here that some of the human abilities required for control and operation are often built into sophisticated physical facilities.

It is the unique combination of various components of technology utilized that determine the market value of the outputs produced by an enterprise (which essentially performs a transformation activity that contributes to technology content addition to the inputs). However, relative importance of the four components of technology depends upon the type of transformation and operational complexity. Also, there can be considerable variations in the efficiency with which a given combination of available technology components are used in terms of: intensity of adaption and improvement; and intensity of introducing new bases. Due to the existence of interactions and trade-offs among the components, similar outputs (in terms of technology content added) can be produced by different combinations of technology components. In other words, a number of technologies (that is, different combinations of technoware, humanware, inforware and orgaware) are available to perform most transformation operations, and the choice of technology is an extremely complex decision problem.

Technology has been changing since the dawn of human history. In this century the pace of change is accelerated, but the process has remained the same -- substitution of old by new. Nowadays, technology is evolving so fast that the shelf life of most technologies now rarely exceeds ten years. Empirical studies show that there are two types of change: one involves the incorporation of new technology through investment in new system or substantial addition to existing system; and other is the incorporation of continuing upgrades of new technology into existing systems. Certain technology components (particularly technoware and orgaware) usually change through a process of non-linear step-jumps from the current generation to the next. In practice, a new technology component substitutes an older one because the newer one is better in some way -- performance, cost, or user appeal. For other technology components (particularly humanware and inforware) the change is generally incremental (addition to existing stock) -- upgradation and update. Although new knowledge can sometimes replace (even negate) old knowledge, unlike computer, human memory cannot be erased to "unlearn" something that is not useful anymore. In general, each new technology component is adopted by an enterprise through a process of diffusion conditioned by economic and political factors. Thus, over a period of time, technology changes through a process of successive substitution. Also, technology developed for one locale is seldom equally well-suited to others; thus, investment to tailor foreign technology to local circumstances are rules not the exceptions. A great deal of costly and purposeful efforts must be expended to assimilate any newly acquired technology.

Technology content added depends on the stock of physical resources, quality of human resources, usefulness of knowledge resources, and effectiveness of management resources. Improvement in the degree of sophistication of the four components of technology gradually enhances the potential for more technology content addition by an enterprise. Technoware changes through a process of continuous substitution of old by new. Humanware changes through a process of progressive learning of new things. Inforware changes through a process of cumulative acquisition of knowledge. Orgaware changes through a process of evolving arrangements and networks. Generally, the degree of technoware sophistication corresponds to increasing complexity of physical transformation operations; the degree of humanware sophistication indicates increasing level of competence; the degree of inforware sophistication represents increasing utility of available facts; and increasing degree of orgaware sophistication results in improved overall performance in the marketplace. Also, under certain conditions technological leapfrogging is possible, and developing countries may be able to take advantage of their late starter situation provided they are very selective and it is clearly understood that leapfrogging in technoware requires considerable investment in humanware, inforware and orgaware. Thus, these four components of technology provide a dynamically interacting base for transformation of inputs to outputs. But, of the four components, humanware is the most important. The ability to solve problems by applying new technoware, instead of performing rote tasks, is nowadays valued above all else.

A new technology replaces an older technology because the newer one is better than the older one in some ways -- e.g., performance, cost, appearance, etc. Since most new technologies progress on the basis of a large number of continuous incremental changes and basically through the recombination of existing know-how, empirical studies show that the growth pattern of the figure of merit of a technology follows an S-shape. Major breakthroughs, however, come at irregular intervals. Thus the technological change process over a considerable period of time represents a series of sequential substitutions, each following an S-curve. There are two major implications of this technological change process. Late starter countries can attempt leapfrogging in two ways: in the cases where the technological change process is rather slow, eventual catch-up is possible as long as there is no revolutionary breakthrough in any specific technology; and in cases where technology is changing very rapidly, a careful skipping of intermediate stages may be possible under certain circumstances.

Leapfrogging in the use and production of technoware is directly possible if humanware, inforware and orgaware are well developed. With humanware well developed, it is not too difficult to master acquired facilities through reverse engineering. That is why many countries impose restrictions in the international sale of "strategic" technoware. Leapfrogging in the development of humanware is only possible indirectly by compressing the learning period (through the use of modern communication technology) and taking advantage of the very large and inexpensive population base. Leapfrogging in inforware is not possible at all because the information that will provide a competitive edge in the technology market is unlikely to be available to late starters through documents in the public domain. New technology reports involving development in many of the latest commercially relevant fields are no longer being published in open literature and many competitors have moved towards greater secrecy in order to protect new ideas and innovations. Leapfrogging in organizational-frameworks may be relatively easy, but to be effective it requires adaptation. There are many obstacles to the realization of leapfrogging opportunities. A whole range of technological capabilities and technology infrastructure need to be developed within the country to apply and adapt state-of-the-art technologies.

7. Technology Capabilities Advancement

Availability of all four technology components in an enterprise is a necessary but not a sufficient condition for competition. Technology capability is also essential. Capability is important because an enterprise must be able to react to and take advantage of new opportunities of the changing world. However, technology capability is often confused with the ability to carry out research and development only. While this is an important element of technological capability, the most critical aspect is the ability to manage technological change. Furthermore, accumulation of technology capability is a process of institutional learning, which results in both increased productivity and economic efficiency of the enterprise. Even in developed countries research is almost never the core activity in technological capability accumulation. Major innovations require the design, construction, and testing prototypes and pilot operations, and expenditure on these development activities far outweigh those made on research activity. An enterprise in a developing country may obtain the above-mentioned components of technology in two ways -- either by importing or by developing locally. However, to use imported technology or to develop indigenous technology components,. the experience of "individual learning by doing" and the experience of "institutional learning" needs to be accumulated.

It may be stressed that capability involves more than the possession of technology components. It also involves continuing, often incremental, technological change management in two ways -- technology components are modified to fit specific situations and particular conditions; and development and first commercialization of new components. Most important aspect of technological capability is the capacity to manage technological change. This is neither automatic nor easy. It requires the accumulation of skills, knowledge and procedures. Furthermore, technology developed for one locale is seldom equally well-suited to others; thus, investment to tailor foreign technology to local circumstances are rules not the exceptions. Technological development takes place through accumulation of technological capabilities of an enterprise by means of investments in all four technology components (physical facilities; human abilities; documented facts; and organizational frameworks). It is a continuous process of capacity enhancement and never ending innovation. Progressive and continuous learning is required in four self-reinforcing areas:

Technology Utilization Capability -- which includes: operation, monitoring and maintenance of technology components (technoware; humanware; inforware; and orgaware) for transformation and other supporting activities;

Technology Compilation Capability -- which includes: commissioning all required physical facilities; coordinating supply and demand; and mobilization (handling and storage) of all resources necessary for transformation and support activities;

Technology Acquisition Capability -- which includes upgrading all components of technology (technoware; humanware; inforware; and orgaware) through: searching, selecting, negotiating and arranging timely procurement; and

Technology Generation Capability -- which includes: defining market driven needs; developing new products, processes and techniques; building prototype and scale-up models for testing; and arranging venture capital fund for implementation of innovations.

The four types of capabilities mentioned above can also be looked at from the point of view of two kinds of learning -- learning by doing (utilization and compilation) and learning by changing (acquisition and generation). Advancement of the utilization capability generally refers to increasing the scale of operation, monitoring and maintenance of all technology components. It enables gradual progress towards optimal use of all currently available technology components resulting in increased productivity. Compilation capability advancement refers to the increased augmentation in mobilizing all resources for optimum efficiency and economic benefits. It corresponds to increasing scope of operation for responding to different market niches. Acquisition capability advancement results in greater vitality of the enterprise in undertaking technological change management. It also means better procurement. Generation capability advancement indicates realization of crucial self-reliance and control in the supply of critical technology components for effective international market competition in the face of rapid technological innovations.

With respect to the acquisition capability, it may be noted that, internationally, financial and strategic imperatives rather than welfare motives dictate the direction of resources flow. For instance, technoware for production and services (other than the state-of-the-art) can normally be bought on the international market for a price determined by the relative bargaining position of the buyer and the seller. However, high quality humanware generally migrate from localities with poor standards of living (developing countries) to places with superior material and professional standards of living (developed countries). Inforware, that can provide a competitive edge, is not sold on the open market, rather restrictions are imposed on the flow of valuable (strategic and critical) inforware for commercial benefits.

Imported orgaware needs adaptation to local conditions as it evokes both opportunity and threat to the existing system. Although some advanced technoware can be transferred, to maintain competitive edge, technology generation is essential. Moreover, decisions regarding which technology to transfer and which technology to develop, require proper understanding of the unique nature of the technological change process (which is a series of never-ending successive substitution over time), so as to take advantage of possible leapfrogging. Leapfrogging in the use and production of sophisticated technoware is often possible, if humanware, inforware and orgaware are well developed.

Accelerating the rate of industrial technology development requires steady improvements in the productivity of the learning process -- what is known as "learning to learn". This learning can be effective through the acquisition of better technologies -- either imported or locally developed. By necessity, in most developing countries, there is heavy reliance on imported technology for industrial development. However, mere importation of technology is not a sufficient condition for sustainable development. Even though most non-state-of-the-art industrial technologies can be easily moved (transferred) from one place to another, they cannot be so easily mastered. Experience shows that one of the most critical elements for the success of technology transfer is its assimilation. Acquiring the ability to operate and maintain the imported technology is only a good beginning. Unless it is assimilated, technology transfer is generally ineffective. Domestic capability must be developed to enable adaptation and improvement of imported technologies, which may involve changes in the design, process and materials inputs.

Technological capabilities are acquired through learning, in which practical experience plays a critical role, but in a far more complex way than assumed in simple learning by doing models. In a dynamic context, technological necessities cause technological change usually to occur as a cascade of distinct but related changes. Experience gained in making the first change yield important understanding required to accomplish the next change. Experience and intentional search for pertinent technology can provide necessary understanding that lead to introduction of technological change. It may be noted here that two types of change are common: one involves the incorporation of new technology through investment in new system or substantial addition to existing system; and other is the incorporation of continuing upgrades of new technology into existing systems.

There can be considerable variations in the efficiency with which a given combination of available technology components are used in terms of: intensity of adaption and improvement; and intensity of introducing new bases. Therefore, the components of technology and technology capabilities are interrelated in a systematic way. They are self-reinforcing, even though some of the interactions occur over vastly different time frames. Also, there is a definite order in capability advancement -- starting with utilization capability up to generation capability. Initially, firms must accumulate operating experience for producing marketable outputs (utilization capability); second stage, optimization experience for improving performance of technology in use (compilation capability); third stage, changing experience by seeking out and acquiring technologies from other firms and economies (acquisitive capability); and finally, adapting and innovating experience by developing and first commercializing new technologies (generating capability). This means learning by doing for operations and optimization capabilities and learning to change for acquisition and generation capabilities advancement over time. Although efforts can be made to advance more then one capability at a time, but still in the proper sequence.

However, for advancement with respect to each capability, it is necessary to achieve increasing degree of sophistication for technology components relevant to the corresponding capabilities. Advancement in the level of capability accumulation means a better level of synergy as the combined actions of separate components make the total effect greater than the sum of individual effects. Capabilities enable an enterprise to react to and to take advantage of new opportunities of the changing world. Capability enhancement is a process of institutional learning, which results in both increased productivity and increased economic efficiency of the enterprise. A great deal of costly and purposeful efforts must be expended to assimilate any newly acquired technology.

In a developing country context, the purpose of introducing technological change through the twin activities -- technology transfer from abroad and/or indigenous technology development -- is to enhance the international market competitiveness of the productive enterprises (both in the private and public sectors). This enhancement of any enterprise's competitive edge in the marketplace is to be accomplished by increasing the quantum of the technology content added by the enterprise operations, which in effect is achieved through the enhancement of the degree of sophistication of technology components utilized and the level of accumulation of technology capabilities of the enterprise with respect to the specific functions involved in managing technological change. Generally, improvement in the degree of sophistication of the components of technology gradually enhance the accumulated technology capability of an enterprise. The status of the technology infrastructure and the technology climate development are very much linked with both market condition and government policies which set the rules of the game. A cascade of infrastructure and climate factors determine the ability of a firm to manage technological change effectively. Therefore, specific measures with respect to the technology infrastructure and technology climate should also be undertaken to ensure conduciveness of the national setting for technology-based industrial development.

8. Technology Strategy Progression

In the present era, for competition under a free market condition, technological considerations must be properly integrated into overall business strategies of an enterprise. Many practitioners have found useful to begin the desired integration process by considering presently practiced business strategies which give rise to comparative advantage in the marketplace. The business strategies can be categorized as striving for: price leadership through producer cost minimization; quality leadership through user value maximization; niche leadership through segment feature specialization; and image leadership through customer prestige (status/appeal) creation. Most business enterprises use some combination of these strategies for different outputs and different markets. Nowadays, factors of production can be moved from one country to another almost at will. What's more, everywhere, everything is on sale at cut-throat prices. Low-wage countries can exploit their comparative advantage using extender strategy until sophisticated customers (demand) put a premium on reliability, quality and performance than on price.

Although price competition (for declining markets), quality competition (for growing markets) and feature competition (for mature markets) have been meaningful strategies for a long period, increasingly nowadays it is observed that retaining comparative advantage will depend on the ability of enterprises to compete beyond quality and feature on the basis of environmental soundness. Image strategy is currently taking the special focus on "green leadership". Most governments (both in developed and developing countries) have now recognized their special responsibilities for the conservation of the natural environment and thus they are introducing necessary legislation for strict enforcement. Therefore, companies that ignore "green" pressure would be casualties that will sweep the global marketplace. In anticipation of being branded as the black sheep, the business community has also accepted a proactive responsibility and is voluntarily introducing a green strategy for image leadership. The green strategy is to directly prevent or reduce negative/adverse effects on environment (as opposed to corrective measures). Environment related business is expected to be the driving force of the future economy and the source of most new competitive advantage in international market. Developing new technology for sustainable development will naturally link environment management with innovation management of the firm.

The growth of a firm and the trajectory of its technology are closely interwoven. It is a major factor in determining the cost, quality, feature, and environmental impact, which may be observed to be directly linked to the life-cycle characteristics. In the introduction phase, the performance requirements for new products and market needs are not well defined, which means the source of innovation is often the users and the business strategy is customer and environment responsiveness. In the growth phase, the basis for competition is on performance and specific features. In the maturity phase, with achieved standardization, the basis for competition shifts from performance to diversification with respect to niche markets. In the decline phase, when new technology is substituting an older one, the continuation of older but still functional products and processes can give competitive edge to small enterprises serving the price sensitive market vacated by industry leaders (who adopt new technologies for higher value markets).

Technological innovations contribute to economic welfare and progress of an enterprise through market gains based on segmentation. First, a new product or innovation is introduced in a market niche where the unique properties of that product or innovation is highly valued (valued highly enough to compensate for any negative attributes or its less reliable initial performance). As experience is gained, and the product and processes are improved, it can be introduced in still other niches where its special properties and better qualities are also valued. With the increase in sales volume, due to the learning effect, economy of scale and higher competition, product price diminishes. If improvements in product design, manufacturing and distributing efficiencies continue, then the differentiated products eventually gain large market shares. During this process, it is known that the product attributes must be approximately equivalent with competing offerings in order for cost to influence the customer. Similarly, costs must be near parity in order for a price premium for unique features to yield advantage. As different segments of the market has different needs, differentiation allows a firm to command a premium price by providing unique and superior value to the customer in terms of product quality, specialized features, and/or after-sales services. However, firms have to be innovative to find new niches in the market in order to cope successfully with the saturated markets for existing mature products, as benefits of a comparative advantage soon level off as other firms introduce similar changes.

The technology capability advancement (with accompanying technology components sophistication) is expected to contribute to a better market performance by the enterprise through strategic restructuring. As different segments of market have different needs, enterprises attempt differentiation (providing unique and superior value to the customers in terms of quality, feature and image) to command emium price. The ramification of technology is implicit and pervasive in each of these business egies. However, to consider technology aspects explicitly, it is desirable to pay attention to the ible technology strategies for securing competitive advantage. In the context of developing countries, lynamism of the strategic choices can be generally derived from the route for gradual but determined ıncement from price, quality or niche leadership situation to the image leadership on the basis of the wing technology strategies:

Technology Extender Strategy -- imported and old technology based small scale start-up enterprises use this strategy of "salvaging or extending the life of obsolete technologies" to cater to a low-value local market. Some of the general characteristics are: price and service sensitive markets; filling market niches vacated by industry giants/leaders (as they have shifted to emerging areas); utilizing time and production factor cost advantages; price leadership; acquire easily available technology components; use mostly elementary technology capability; practically no local research and development efforts. This strategy has a very short life under competitive business environment.

Technology Exploiter Strategy -- selectively imported technologies (mostly through joint ventures) by medium-size firms using this strategy of "exploiting mature and standardized technologies" for quality leadership in the medium value national markets. Some of the general characteristics are: attempting to become international companies, basically using advantages of production factor costs and market differentiation; reliance on uniform quality; some efforts for method-package innovation; generally price leadership in medium quality market; cost saving by cheap labor and cheap input substitutes; buy available technology components; possess secondary technology capability; need adequate technology infrastructure support; product design often reflects foreign market needs.

Technology Follower Strategy -- creative imitation based on licensed technology enabling large-firms use this strategy of "joining the league by adapting advances and latest technologies" to enter international market. Some of the general characteristics are: companies allocate resources for mastering and using advanced technologies for growing regional and global markets; reliance on adaptive research and reverse engineering; emphasis on skill-knowledge innovation; enough efforts on skill-knowledge innovation; economy of scale; subcontracting approach; subcontracting approach; emphasis on market promotion; niche and quality leadership; high value market; both transfer and development of technology components; need advance technology capability for quick learning through reverse engineering.

Technology Leader Strategy -- introduction of locally developed, technologies giving rise to temporary monopoly, allow very large companies or new-technology based start-up companies to follow the strategy of "being first to commercialize state-of-the-art technologies" in emerging areas. Some of the characteristics are: pioneering companies using state-of-the-art technologies for venturing into emerging global markets; heavy reliance on internal research and development; emphasis on product-process innovation through basic research; niche and image leadership; flexible production system; very high value market; control of segment market; economy of scale as well economy of scope; demand sophistication accelerates quality improvement; need superior technology capability and conducive technology climate.

Any firm needs to progressively develop its technological capability for gradual progression with respect to the above mentioned technology strategies, if it is to achieve sustained growth. For instance, a firm which starts with a technology extender strategy should achieve outputs of desired quantity and quality very efficiently. Thus, the firm needs at least technology utilization capability. But, to move on from the extender strategy to the exploiter strategy, it will need (in addition to the utilization capability) the capability to acquire and maintain new technologies (acquisition and compilation capabilities). The need for supportive and acquisitive capabilities becomes even stronger as the firm develops further and starts pursuing a technology follower strategy. Ultimately, to become a world leader, the capability to generate new technologies on its own (generation capability) is most critical. It may also be noted here that the relative importance of the four components of technology are quite different for different capabilities. For example: facts and abilities are more important for acquisition; facilities and abilities are more important for utilization; facilities and facts are more important for compilation; whereas abilities, facts and frameworks are all very important for generation.

The technological progression pattern from extender to exploiter to follower to leader does reflect a process of industrial restructuring broadly determined by competitive market forces. At the beginning, a developing country industry is almost exclusively dependent on imported mature technologies to take advantage of relative abundant endowments of either natural resources or unskilled labor, or both. During this period local technological capability likely to involve principally the effective operation of simple imported technologies. These resource or labor intensive industries face difficulties over the years due to either depletion of natural resource or decline in labor productivity. For quality competition, industry needs capability to acquire better technologies and also capability to maintain imported technologies (highly skilled human resource is needed) and thus it has to move into exploiter situation. The transition to the next level requires a greater degree of local capability for adaptation of imported technologies. While all firms need not be able to engage in major product and process innovation, they must at least have the capacity to undertake incremental improvements in existing technologies, as competition is increasingly based on product differentiation and value addition. Successful entry into this follower strategy requires a large number of scientists and engineers. To move into the leader category innovative capability becomes most important and entrepreneurship is the critical bottle-neck.

Being technology leader requires that firms are fast, fearless, fluid, facilitative, and flexible with respect to technological innovation. They become industry leaders, cater to very high value market, spend heavily on research and development, and determine to a large extent the technology trajectory of the industry. Technology followers can reap benefits if they could buy state-of-the-art facilities or modify products and processes through reverse engineering. They need to be very good at quickly adapting advanced technologies to join the high value market in the beginning of the growth phase of the product life cycle. Technology followers neither have the first-mover advantage (super-normal profit) nor their disadvantage (high cost and risk). When the market is growing, exploitation of standardized technologies may give rise to rapid growth (strategy successfully implemented by the newly industrialized countries, like: Korea, Singapore, Taiwan). They cater to medium value market with advantage in production factor costs (cheap labor and raw-materials). But, exploiter strategy can not be sustained unless the infrastructure is built to move into follower and then leader strategy in selected areas. Technology extenders cater for the low value price-sensitive markets which have been vacated by the industry leaders. Production technologies that are suitable for extender strategy are readily transferred to the developing countries.

It is apparent that, unless there is a world class research institution producing state-of-the-art knowledge, it is virtually impossible for a small-scale developing country enterprise to start with a technology leader strategy. The likely path for strategic progression in the developing country context is from technology extender to technology exploiter to technology follower and then to technology leader. Step-by-step the ladder is ascended in very carefully selected areas of specialization. This progression pattern in developing countries does reflect a process of industrial restructuring broadly determined by competitive market forces. There is significant technological implication of the above restructuring process in a developing country. The relative importance of technological capabilities changes as an enterprise attempts to move from the extender strategy to the leader strategy. For higher positions of technology strategy, advanced level of technology capabilities are required. For example, an extender needs to emphasize mostly utilization capability; an exploiter needs both utilization and compilation capabilities; a follower must have adequate utilization, good compilation, and fair acquisition capabilities; and a leader must have all capabilities at a very high level. And, this process of accumulating higher level capabilities should be coupled with progressively higher degree of sophistication in each components. Also, it may be noted that the critical role of technology transfer and technology development changes along the technology strategy progression path -- initially more emphasis on technology transfer and eventually more emphasis on technology development.

9. Technology Infrastructure Development

Due to scarcity of capital resources, small and medium scale enterprises, in both developed and developing countries, are likely to under-invest in technological capability advancement. Also, there is increased degree of specialization in generation of technology today, compared to earlier days, due to high cost and risk of research and development. Existing evidence suggests that most of the fast moving fields are located in large firms in knowledge and skill intensive sectors with highly professionalized and specialized activities in their research laboratories. Some of the common inducement mechanisms for such factor creation are: search to alleviate a relative factor scarcity; exploitation of abundant natural resources; cumulative mastery in some science-based technology; and exploitation on world markets of core technologies with pervasive use. Hence, it is obvious that small and medium scale enterprises need help from the government, and more so in developing countries.

Since almost all enterprises in developing countries are of small or medium scale, their capability to introduce technological change depends upon the support provided by the national technology infrastructure. What can be bought and what can be locally developed depends upon the status of this infrastructure, which is supposed to promote technological innovation through strong triangular linkages among: the academic institutions engaged in science and technology education and research (Academia); a wide range of science and technology related research and development organizations (R&D Units); and the engineering and industrial productive enterprises (Industry). Three major types of technology innovation expected to result from the triangular linkages are: product-process innovation; knowledge-skill innovation; and methods-package innovation. A large number of promotion agents (public and private institutions) are necessary to support any or all of these innovations. The totality of these institutions can be called the "advanced factor creation mechanism" or simply the technology infrastructure. Infrastructure status can be understood by specifically considering the following:

The strength of "triangular linkages" among the three types of institutions -- the academia; the R&D units; and the industries. Linkage means the elements of the connection (the institutions) and flow between them. Major criteria for assessing the strength of the innovation triangle may include: the presence of all links above the minimum critical level; the magnitude of their interactions; and the extent of utilization of facilities. The magnitude of interactions may be considered in terms of flow of money, technoware, humanware, inforware and orgaware.

The continuity of technology "innovation chains", which include three prominent development aspects -- product-process development; knowledge-skill development; and methods-package development. The major phases of the product-process development chain are: searching; designing; generating; and modifying. Phases of the knowledge-skill development chain are: exposing; training; educating; and upgrading. Phases of the methods-package development chain are: conceiving; formulating; preparing; and evolving. The most important consideration is to ascertain the presence and adequate performance of promotion agents corresponding to each phase of the three development chains.

The catalytic effect of "technology mentors", which are generally of two types -- financial institutions (investment promotion corporations and venture capital banks); and technical institutions (certification, testing, quality assurance and standardization organizations). These institutions contribute significantly in screening the appropriateness of imported technologies and promoting the commercialization of indigenous technologies. Major criteria for assessing the impact of these institutions could be: extent of equity participation; and direct involvement of these institutions with the local productive enterprises.

The supportive role of "technology guiders", which are categorized into two broad groups -- all those institutions involved with science and technology information services; and other institutions engaged in advisory and consultancy services (including technology transfer board). These institutions provide the direction as well as the opportunity for self-reliance. Major criteria for assessing their contribution could be: value of service provided; and extent of independence from external (foreign) services.

A major factor contributing to the low level of technological capability in many developing countries may be traced to the poor science and technology infrastructure. For gradually moving from the agricultural to an industrial economy by a developing country, it is necessary to ensure continuity of the technology capability and component development chains and availability of minimum critical mass with respect to all promotion agents. Not only it is important to recognize that each promotion agent must have the minimum critical mass, but it is also important to note that relative importance of the distinctive phases in each of the development chains are not equal. Some of the phases are much more critical and require considerably more resources than the others. For self-reliance, it is essential to attain sufficient strength in each phase of the development chain by adequately supporting the promotion agents. Complete absence of any particular phase in the development chain makes an industry vulnerable to foreign competition. A major contribution of governments to technological capability is through its investment in education and training.

All institutions need a minimum level of critical mass for satisfactory performance. Therefore, a missing link in the technology innovation process exists not only if one of the promotion agents is missing but also if any of the institutions (or promotion agents) lack this minimum critical mass. Furthermore, most of the linkages are non-linear. Therefore, any missing link is a serious weakness to be remedied for successful innovation and self-reliance. Inducement mechanisms for factor creation -- search to alleviate a relative factor scarcity; exploitation of abundant natural resources; cumulative mastery in some science-based technology; and exploitation on world markets of core technologies with pervasive and growing use.

10. Technology Climate Dynamism

The success of an enterprise in achieving technology-based development depends to a large extent upon the national technology climate within which the enterprise has to operate. Many factors determine threats and opportunities contribution to the technology climate. Technology climate refers to: the intensity of national commitment to and socio-cultural acceptance of the use of technology for development; and the effectiveness of national mechanisms for integrating science and technology policy aspects with development planning. Besides government policies, there are other actors -- market forces and cultural aspects -- which set the rules of the game for any productive enterprise and influence the dynamism of the national technology climate. The development of technology infrastructure is also very much linked with the market condition and government policies. At present, in many developing countries, government controls are being replaced by deregulation, privatization, competition and other market features. Government officials are defining a new role as facilitator in which they bring key parties together to encourage collaborative new ventures and resolve disputes. The incentive and regulatory regime affecting industrial development has to put pressure on enterprises to enhance their technological capabilities, and thereby to increase productivity or competitiveness. The order of dynamism of the national technology climate, which determines the technology potentials of an enterprise, can be viewed in terms of the following important stimulating factors:

Intensity of "competition from open market rivals" -- which puts pressure for continuous technological innovation. Some possible measures for assessing the fierceness of competition could be: ratio of export of outputs to total production; difference between the largest and the smallest producer; and number of similar enterprises in the local and international markets. As one competitive industry helps to create related industries in a mutually reinforcing way, this process of industry evolution at a place often breeds new competitive industries.

Extent of "cooperation from a related industry cluster" -- which magnifies and accelerates the process of factor creation. A developed cluster of related industries helps pool private resources for technology factor creation, such as: human resource development; information services; consultancy services; etc. Also, clusters provide mobility of skilled manpower. The strength of the cluster may be assessed indirectly by determining: ratio of imported inputs to total inputs consumed; and share of the local cluster market to the world cluster market size.

Pressure due to "preferences of the customers" -- which makes technological innovation essential. Whether the customers are price, quality, feature or image sensitive, determines to a large extent the business strategy of an enterprise, which in turn influences efforts in technology components and capability development. Preferences for quality products and services are related to factors like economic pressure, culture and education. One key success factor for innovation is that the enterprise must be located in a place which has the reputation for evaluating and using the outputs in a very demanding way (seeking things better than what is available).

General "creativity conduciveness of culture" -- which depends upon many factors, such as: a knowledge seeking and future oriented human resource base; an open reward system that encourages innovation and risk taking; a strong leadership and commitment through direct involvement; and an interest coordination and consensus building mechanism for adequate resources mobilization. The leadership (at every level: firm; industry; nation) should catalyze not only the technological challenges and opportunities of today but also the preparedness of the future. Commitment is essential to translate felt-needs into appropriate actions.

A concentration of rivals, customers and suppliers promote efficiency and specialization, which also influences the innovation process. The incentives and regulatory regimes affecting economic development has to put pressure on enterprises to enhance their technological capabilities, and thereby to increase productivity and competitiveness. Earlier, laws and rules concerning entry, competition, and restraint of trade were adopted to offset the natural tendency of a mass production based system to grow to the largest possible scale. Nowadays, it is necessary to encourage resources accumulation and joint research for the development of pervasive and generic technologies.

11. Technology Needs Identification for Sustainable Development

National development agencies currently consider technology needs from two points of view: one is fund allocation for research and development activities; and the other is promotion of foreign investment (which includes technology transfer). Furthermore, actual technological needs are determined through a process of incremental planning. However, without deliberate attempt in taking advantage of the unique characteristics of the technological change process (such as: leapfrogging), technological dependencies of these countries are expected to grow continuously. Problems also arise due to lack of clear differentiation between technological self-sufficiency and self-reliance. Technological self-reliance, unlike self-sufficiency, does not mean the ability to produce all necessary technologies (which is neither economically efficient nor even possible), but the ability to make autonomous decisions, the possession of critical technologies needed for economic growth and accumulation of capability to manage technological change on a continuous basis.

The same way as an enterprise attempts sustainable development, a nation also needs to consider the principle of make some and buy some technology strategy for self-reliance. There are basically three approaches to increase the level of sophistication of technology components: buy the entire gamut of available technologies; generate all technologies from within; and buy some and make some. Buy all option has the greatest advantage of giving instant results with minimum risk. Make all option, on the other hand, has the greatest advantage of total self-reliance. However, one must avoid being blindly engaged in such noble but certainly financially unrewarding exercises as reinventing the wheel. Also make is a very slow and painful process. The approach which is most practical is "buy-some and make-some". This is a two pronged conjoint strategy for sustainable development. Unless we begin systematic and comprehensive efforts to develop the needed technologies using the make and buy strategy, we will not be able to build our technological foundation and we will risk becoming more dependent on imported technologies. One of the critical need is to identify the appropriate mix, at each stage of development, of imported and indigenous technologies needed.

Both technology transfer and technology development are important for identifying technological needs which will enable meaningful industry restructuring. Overall industrial restructuring refers to the continuous change in the mix of industrial sector of the economy from heavy concentration in "geo-nature" to "raw-materials" to "capital-energy" to "new-science" based industries. But what needs to be transferred and what can be locally developed depends upon the strength of endogenous capability (including infrastructure and climate) and the global trends. Monitoring world technological trends and trade opportunities are important to ensure future orientation and long-term consideration in all make and buy technology decisions.

Major steps necessary for national technological needs identification are as follows: analysis of development objectives for hierarchical derivation of technological areas of relevance; forecasting world market and technological trends; formulation of an acceptable set of criteria for assessment; evaluation of necessary technology inputs for desired national outputs; prioritization of technological needs as -- basic, generic, unique and strategic; and classification of these needs by technology domains -- importing; evolving; and exporting -- for transfer and development. Importing domain represents areas chosen for dependence on others because technologies have very long gestation period and require enormous expenditure. Evolving domain represents areas which are unique from the point of view of local endowments and have traditional heritage. Exporting domain represents areas for future competition and other specific strategic benefits.

The type and nature of the outputs (both desirable ones and the by products) produced by an enterprise generally determines its competitiveness and profitability in the free market. As can be observed from the current international market competition trends, the most important attributes (in addition to price) are: the technology content of the outputs; and the environmental friendliness of the outputs as well as the transformation operations of the enterprise. While the degree of sophistication of the technology components, level of advancement of technology capabilities, and the characteristics of the natural resource inputs do, to a large extent, determine the technology content of the outputs, all transformation activities invariably produce wastes, cause some pollution and often result in environmental hazards. Given the potential severity of possible environmental impacts, all productive enterprises are morally bound to minimize potential risks (not only to their business but also to human living condition in general) while introducing new technologies.

Attempting technology component sophistication (for strategic progression) through technology transfer also requires careful consideration of environmental soundness. Even in developing countries, in addition to economic and technological considerations, one cannot overlook environmental sustainability considerations. And for this purpose we need to assess appropriateness of transferred technology. However, technological appropriateness is a complex and dynamic concept, involving value based evaluation on the basis of many factors: economic feasibility; resources availability; technology progression; and environment sustainability. Besides meeting government regulations regarding pollution control and waste disposal, decisions regarding technoware sophistication should include considerations of: replacement of nonrenewable resources; reduction in the use of scarce resources; reusing all resources; and whenever possible recycling all resources to conserve nature. Technology management for sustainable development calls for importation of technologies that are: economically efficient; commercially attractive; and at the same time environmentally acceptable.

We want to use technology as a strategic variable, knowing very well that application of any technology may have some unwanted side effects (immediate or long-term). But we know that technology by itself is not responsible for environmental problems. Environmental degradation is a result of poverty in the developing countries and affluence in developed countries. In other words, environmental problems are due to the mismanagement of technology. Proper management calls for environment protection without compromising economic development. Therefore, even though not only financial risk, but environmental risk is also inherent in all use of technology, both business and government can and should work together to minimize these risks. In developing countries, generally one can find that over use, waste, inefficiency coexists with resource scarcity. Keeping all of these in perspective, environmental acceptability needs to be assessed in terms of the short-term impacts of the enterprise activities towards air, water, land and atmospheric pollution, and also all kinds of long-term threat to human life.

In addition, business risks can also be considered in terms of international trade resistance (such as, non-tariffs barrier using environmental and human rights violation allegations) to the outputs and the associated processes involved. High trade barriers for transformed goods constitute a constraint for economic restructuring of many developing countries. Trade restrictions caused by national standards and technical regulations include packaging, marketing and labeling requirements. It may be noted here that, at present protectionism is being used by the world's major economic markets to slow their growth of unemployment. However, we also know that established systems give power to the already powerful. Therefore, account must be taken of the distinctive nature of risks inherent in lack of attention to technological capability accumulation and strategic progression. One of the critical requirement is to identify the appropriate mix, at each stage of development, of imported and indigenous technologies needed by the production system and need for supportive infrastructure building.

12. Required Technology Assessment Procedures

In the previous sections, relevant factors for technology management were identified using the basic premise that, even in developing countries, selective generation of new technology and the application and blending of both new and old technologies are important for self-sustained economic growth. However, the infrastructure required to support innovations is often the determining factor for such technology-based competitive economic development. It was stressed that we need to pay more attention to the linkages among various institutions of the innovation processes and to the effective functioning of the innovation triangle. The fragmentation that currently exists is a serious impediment to effectiveness of the innovation system. Besides the support of the technology infrastructure and the conduciveness of national technology climate in developing countries, the most important considerations for an enterprise in identifying strategic progression path require a thorough assessment of the status of available technology components and its accumulated technology capabilities. Although all four components of technology are necessary for each type of capability, the specific combination and the relative importance among the four components of technology are different. Moreover, the relative importance of technological capabilities also changes as an enterprise attempts to move from the extender strategy to the leader strategy. For an enterprise to develop competitively from the initial (start-up) technology extender stage to technology exploiter (expansion) stage to technology follower (consolidation) stage and then to technology leader (mature) stage, technological capabilities need to be upgraded through institutional learning and progressive addition of sophisticated technology components. While introducing technological sophistication, the enterprise should also ensure that the chosen option minimizes business risks and has the least harmful effect to the living environment. It is now possible to summarize the most important indicators for technology management as follows:

Complacence with resources mobilization situation -- Alarming-Disturbing-Tolerable-Reasonable-- representing constraint due to foreign ownership with respect to natural resource, human resource and human-made resource. Assessment of vulnerability and critical dependence on foreign inputs will ensure recognition of supplier power of technology and identify importation constraints in its use as a strategic variable for competitive growth. Potential indicators are: important content of human-made resources; share of foreign ownership of resources; constraint due to automatic technology obsolescence; and failure in using human resource for technological leapfrogging. General interest of owners of the enterprises in technology factor creation and technology capability enhancement should also be considered. Four kinds of situations may be considered -- foreign direct investment; joint venture; licensing; and fully local. For each of these arrangements, the interests and aspirations of owners and technology suppliers in locally generating four components of technology (technoware, humanware, inforware, orgaware) and acquiring four aspects of capability (operative, supportive, acquisitive, innovative) may be assessed, using such criteria as: relative amount of resources allocated.

Degree of sophistication of technology components -- Low-Medium-High-Top -- indicating status of available technoware, humanware, inforware and orgaware in relation to best practice elsewhere. Assessment of relative gap from the state-of-the-art (or best practice) can help in evaluating technological strengths and weaknesses for proper allocation of additional investment funds for achieving increased productivity. Potential indicators are: physical facilities sophistication; human abilities sophistication; documented facts sophistication; and organizational frameworks sophistication. Major criteria for assessing technoware position vis-a-vis the state-of-the-art may include: scale of operation; scope of outputs; quality of outputs; and safety or environmental soundness of operation. Major criteria for assessing humanware position relative to best practice elsewhere may include: level of general education; appropriateness of training; relevant experience; and motivation of the personnel. Major criteria for assessing inforware position may include: relevance; timeliness; and reliability of acquired facts. Major criteria for assessing orgaware position may include: market competitiveness and technology capability self-reliance of the enterprise.

Level of advancement of technology capability accumulation -- Elementary-Secondary-Advanced-Superior -- giving position of institutional learning through utilization, compilation, acquisition and generation of technology components. This analysis can also help in identifying current institutional strengths and weaknesses so as to build a solid foundation upon which to grow the ability to manage technological change (both technology transfer and technology development). Potential indicators are: current status of utilization capability; current status of compilation capability; current status of acquisition capability; and current status of generation capability. The extent to which the enterprise is capable to carry out all of these functions vis-a-vis the world leader could indicate the position of accumulation of operative capability. The extent to which the enterprise is capable to carry out all of these functions vis-a-vis the world leader could indicate the position of accumulation of supportive capability. The extent to which the enterprise is capable to carry out all of these functions vis-a-vis the world leader could indicate the position of accumulation of acquisitive capability. The extent to which the enterprise is capable to carry out all of these functions vis-a-vis the world leader could indicate the position of accumulation of innovative capability.

Prospects of technology based strategic restructuring -- Bleak-Difficult-Promising-Shining -- showing position of strategic progression considering component sophistication and capability advancement conditions. Persistent efforts and step-by-step progression with adequate allocation of resources in highly-selective and high-potential areas is essential for strategic restructuring and competitiveness building. Potential indicators are: restructuring from extender to exploiter strategy; restructuring from exploiter to follower strategy; restructuring from follower to leader strategy; and prospect of sustaining technology leader strategy. As income increases, people start substituting quality for quantity, and also people become more concerned with environment. Environmentally superior products, processes and services now represent the biggest new market in the history of world business.

Status of development of technology infrastructure -- Poor-Average-Good-Excellent -- depicting performance posture related to triangular linkages, innovations chains, mentors and guiders. Adequate attention is necessary to ensure the presence of linkages and minimum critical mass resulting in institutions (promotion agents) achieving both relevance and excellence. Potential indicators are: strength of triangular linkages; continuity of innovation chains; catalytic effect of mentor institutions; and supportive role of guider institutions. The actual position of the innovation triangle can be assessed by comparing the existing status with that of the best practice elsewhere. The actual position of the development chains can be assessed by comparing the existing status with that of the best practice elsewhere. The actual position of the technology mentors can be assessed by comparing the existing status with that of the best practice elsewhere. The actual position of the technology guiders can be assessed by comparing the existing status with that of the best practice elsewhere.

Order of stimulation produced by technology climate -- Negligible-Weak-Moderate-Exceptional -- recognizing dynamism provided by market competition, industrial cooperation, customer preferences and cultural conduciveness. Only increased funding for research and development is not enough, the policy regime has to encourage technological innovation by the private sector. The ability to make effective use of technology is critical to the achievement of self-sustaining development. Potential indicators are: intensity of competition from rivals; nature of cooperation from clusters; pressure from customer preferences; innovation conduciveness of culture. Then the local technology climate can be assessed by comparing the aspirations of the owners and technology suppliers with the best practice elsewhere. Then the local technology climate can be assessed by comparing attitudes of customers and society with the best practice elsewhere. Then the local technology climate can be assessed by comparing the influence of the cluster with the best practice elsewhere. Then the local technology climate can be assessed by comparing with the best practice elsewhere.

Severeness of technology choice mistakes and risks -- Extreme-Large-Some-Little -- warning consequences in terms of the impacts on air, water, land and threat to life, and other kinds of resistance to international market entry. Ensuring proper use of technology as the key resource for sustainable development, keeping in mind: economic efficiency, commercial attractiveness, and environmental soundness; without sacrificing the realization of self-reliance. One purpose is also to promote generation and use of environmentally-sound technologies to safeguard the natural environment for future generations. Potential indicators are: emphasis on quick and short-term benefits; inadequacy on needs balancing and specialization; likely impact due to environmental degradation; and extent of prevailing international pressure.

For each of the technology management indicators mentioned above, qualitative assessment is possible if one identifies a situation specific criteria function (generic examples were given in previous sections) for relative scoring between the worst and the best position. Scoring methods of varying complexity can be used. Scores can be determined by applying a set of criteria (which are preferably quantitative technical parameters) for each assessment aspect. Once the individual positions are assigned the attributes (with predefined scores), a simple weighted average can give the overall situation. The above assessments can be presented as a score sheet (using four broad grading between the worst and the best cases) depicting overall status at any particular time. These measurements can reveal the basis for strategic decisions and they may strengthen the exercise of foresight and prudence in identifying proper business strategies along with the technology strategies. Such measurements invariably involve enterprise specific information perceived to be confidential for release to outside investigators. Hence, these indicators are meant to be used by the enterprises themselves.

Due to the absence of absolute measures and as the technological change process is very dynamic, assessment of technological aspects have to be undertaken on a relative and regular basis. Moreover, since markets in most developing countries have a high degree of imperfection, conventional financial indicators do not adequately describe the technological capabilities of a firm or an industry. Therefore, technology assessments, focussing explicitly on measuring the technological strengths and weaknesses (relative to the state-of-the-art or best practice elsewhere), could give valuable insight for management decision making. Since a "technology gap" is generally re-enforcing, deliberate investment is necessary to get out of this trap. It is possible to use a relative scoring method in terms of selected qualitative attributes. Given limitations in theory and data, relative assessments are usually more valuable to decision makers than attempts at absolute assessments. Although individual aspects of technology can often be assessed quantitatively, when they are aggregated into a major dimension, the measures are still qualitative in nature and are expected to be complementary to conventional economic and financial indicators for management decision making.

Everybody is aware of the difficulties encountered in the operationalization of the concept of technology based development, and the development of indicators for it. Currently, technology assessments are severely limited by a lack of good data. Instead of using only comparative and superlative words, it may be more useful to express oneself in terms of numbers, weights and measures. We need multiple quantitative and qualitative indicators to measure progress. Qualitative scoring against some quantitative bench mark is very simple, easy and intuitively appealing. There are many reasons for measurement, such as: to know where we stand according to certain bench mark; to monitor and control performances; to identify strengths and weaknesses; to focus efforts; to serve as barometer for management actions; to use as an effective vehicle for dialogue for setting targets and for communication; and to quantify achievements for motivating. Furthermore, numbers bring the real world home to the reader in a way that even eloquent writing cannot.

13. Imperatives for Technology Integration

It is obvious that integration of science and technological in the development planning and management process has to be undertaken at all levels. At the enterprise level, it means integration of technological considerations into business strategies -- which results in successful technology transfer and technology development by the productive enterprises. At the industry or sectoral level, it refers to the development of a self-sustaining technology factor creation mechanism -- providing the infrastructure necessary for three kinds of innovation chains (product-process; skill-knowledge; and method-package). And at the national level, the purpose is to create a culture conducive to technological innovation, influencing the orientation of decision making system. Earlier sections of this paper presented detailed description of technology management measures suitable for developing countries. Enterprise level measures include: technology components; technology capabilities; and technology strategies. Industry or sectoral level measures are on: technology resource; and technology infrastructure. At the national level, the measures are related to: technology climate; and technology needs. These measures provide a practical framework to integrate technological considerations at every level of development related decision making. These measures serve four major purposes: assessment of current standing against international bench marks; evaluation of strengths and weaknesses to focus investment efforts; quantifying achievements for setting targets and for motivating; and planning, implementation, monitoring and control of performance. In using these measures, it is very important to remember some of the critical issues which were discussed in earlier sections of this paper. A few of the issues are presented here just to stress the fact that the measures will have to be adjusted with changing situation.

The nature and success of technology transfer would depend to a large extent on the existing technological capabilities of an enterprise. Transfer of technology between two enterprises (a developed country transnational corporation and a developing country firm) with a large gap (in component sophistication and capability accumulation) tends to be one sided with little scope of technology assimilation. On the other hand, when the gap is too small, technology transfer may not take place at all due to market competition. Any transfer between partners with a large gap should have specific steps for strengthening all components of technology -- physical facilities, human abilities, documented facts and organizational frameworks -- if the transfer is to be successful. It may be noted here that, internationally technology is moved either for economic benefits or/and to take advantage of environmental regulations. It can be observed from international market trends that technology transfer to developing countries encounter following limitations: latest physical facilities cannot be bought in the open market; human abilities, provided as foreign assistance, is of generally of poor quality; documented facts, particularly critical ones, are protected; and organizational frameworks need adaptation for transplantation. However, observing from the sequential substitution process of technological change, it may also be noted that "leapfrogging" (by skipping intermediate stages) is possible by late-starter developing countries in physical facilities, provided one is very selective and considerable investment is made in developing human abilities, documented facts and organizational frameworks. Therefore, technology component degree of sophistication, the level of technology capability accumulation, the status of technology infrastructure building and dynamism of the technology climate all would have direct bearing upon possible strategic options of an enterprise.

Due to lack of financial and technical resources, enterprises in developing countries are initially dependent on imports for sophistication of technology components. For advancement of technological capabilities, they are also very much dependent either on the transnational corporations and/or national technology infrastructure and technology climate. Technology infrastructure and climate can be either a constraint to or a catalyst for achieving the full technological potentials of an enterprise. Without proper diagnosis of technological needs or a clear understanding of the value of technological innovations, enterprises cannot effectively acquire or introduce new technologies. Also, in introducing technological innovations, environmental considerations continue to be troubling. At present, when environmental concern is high in the global agenda, it is important to incorporate environmentalism (including "pollution prevention" and "polluters must pay" form of mind) in technology management decisions. Even in developing countries, environmentally sound technological resources can contribute to the wealth of a nation through competitive advantage in international trade. It is the foundation upon which the competitive world market of tomorrow is being built. Environmentally superior products, processes, and services now represent the biggest new market in the history of the world business.

14. Concluding Remark

Technology, as a human-made resource, is inextricably linked with the welfare of productive enterprises: it is an instrument for achieving higher productivity and competitive growth in market share. At the national level, it is considered as a wealth for improving standards of living of the people, and a vehicle of emancipation and greater democracy. However, at the same time, it has also been assailed for social disintegration and sometimes condemned as the cause of environmental decay. Yet, it cannot be helped but to worship technology as the supreme expression of military, economic and political power. Whatever position we take, management of technology is indispensable for both survival as well as prosperity of productive enterprises in developing countries under the current trends of deregulation and trade liberalization, and their attempt to attract foreign direct investment. But to manage technology properly, we need measurable and effective indicators. This paper presented an integrated set of technology management measures for developing countries.

The simple framework presented in this paper can help enterprise, industrial and national level development planners and managers to meaningfully integrate technological considerations into their strategy formulation calculus for joining the global market competition. Senior management should take a strategic view of technology: identifying vulnerability in terms of its success in sourcing technology, and focusing improvement efforts on technology capabilities for better quality outputs at lower costs to the marketplace, faster than others. Investment promotion agencies can also use the framework for project formulation and evaluation. Government departments engaged in the development of technology infrastructure and national leadership responsible for the creation of a conducive technology climate may find some of the indicators useful for their decision making.

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