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Key Considerations in the Technology Assessment Process

by

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Abstract

Technological change is an accepted fact of the global business environment. The problem of accelerated technical change affects mature industries more acutely as they struggle for survival in the fiercely competitive world market. As companies scramble to implement various technologies, they are becoming more aware that managing resources with technology requires a commitment to managing the technical change process.

Major considerations include: (1) understanding the organizational and environ- mental factors driving technical change, (2) understanding how technology and science differ and how this affects the corporate R&D strategy, (3) constant technology intelligence gathering and a commitment to life-long retraining of staff members, and (4) a realization that technology for technology's sake is unacceptable in a competitive market. A Technology Assessment Program needs to anticipate the impact of innovation on the elements of the product/service value chain and strengthen the overall corporate strategy.

About the Author

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Technological change is one of the principal drivers of competition. , a great equalizer, eroding the competitive advantage of even well entrenched firms and propelling others to the forefront. Of all the things that can change the rules of competition, technological change is among the most prominent.

-Michael Porter , from *Competitive Advantage*

In today's highly competitive global economy, organizations are taking heed of Porter's famous statement. While endorsing the power and, indeed, the necessity of companies implementing technology as a facilitator of competitiveness, Strategic Systems, Incorporated proposes that matters be taken a step further. As Porter would no doubt agree, technology is not important for its own sake, but is important only if it affects competitive advantage, industry structure and the implementing company's bottom-line business results. Managers can no longer rest upon the luxury of a large unfocused and unplanned Research and Development budget. They can no longer merely hope that dollars devoted toward the latest technical fad will somehow benefit the organization. A technology assessment program, tightly coupled with corporate objectives and the constraints of the market, is highly recommended.

Why our emphasis upon technology assessment as a logical, indeed a common sense, part of doing business? Why now? Is this just another addition to the yet unfulfilled collection of consultants' promises such as Management Information Systems or Decision Support?

Definitely not! Technology assessment is a process, not a product. No one can sell it. It is a process that can be implemented by successful companies in- house if they have the good fortune to be able to spare their key technical and business managers for ongoing technology research and planning. We will out- line the major considerations of technology assessment in this paper, but first we must understand why such a process is needed today.

Consider that Business Week's 1986 forecast and Drexal Burnham Lambert's Chief Economist see a long business cycle expansion with low inflation. Low inflation will force companies to accept smaller price increases. Such small increases demand strict controls on costs and productivity. SSI expects companies to look to new manufacturing, distribution and marketing technologies coupled with advanced information systems to play crucial roles in increasing productivity and controlling costs.

According to Porter, costs, productivity and how a company gains market share are directly related to the elements of the product value chain. Since information is a factor in every element of the value chain, and since technology is increasing the rate of information flow, the number of possible combinations of technologies that could be applied against the factors of the chain are increasing almost exponentially.

The competitive success of today's business clearly depends upon the use of technology. Modern organizations face the dual challenge of keeping up with rapidly changing technology and making sense of it. Surpassing mere technology gate keeping, managers must implement solutions to problems in a way that fundamentally changes HOW they do business and how customers relate to them. Gone are the days of merely automating operation~. It comes as no surprise that executives find that automating bureaucracies creates efficient bureaucracies. The creative application of technology far surpasses simple automation. Companies with the edge are integrating technologies to increase their competitiveness. However, mere haphazard application of the latest technical bell or whistle provides little benefit. Technology for technology's sake is unacceptable in a competitive market. In fact, it is likely to waste R&D resources and disrupt the human activities in what is already a complex organization.

Therefore, it makes sense that one who is~ assessing the potential impact of emerging technologies on a business entity and its people:
1) Understand that science differs from technology and this, in turn, helps focus the R&D strategy toward practical results,
2) Understand the trends and synergistic tendencies of the factors driving technology development, and
3) Understand that successful technology assessment and organizational change require more than technology. Creative approaches by broadly skilled and motivated people complement the sterility of pure technology.

Before discussing detailed technology assessment considerations, we must clearly delineate the roles of science and technology in competitive organizations. This is important because many companies have poured money into the R&D budget without tangible results. We now take a short diversion to address "science" policy versus "technology" strategy with the intent of avoiding the misapplication of resources.

The Essence of Science and: Technology

What do we mean by technology, or for that matter, science? With the help of the media these words have become loosely interchangeable in a society racing through what is popularly called the "High-Tech Age." As technically literate as America professes to be, many of us fail to understand the definitions of and relationships between these terms. J.B. Conant notes that many laypersons consider "science" to be the activity of people who work in laboratories and whose discoveries have made possible modern industry and medicine. Likewise, modern advertising would have us believe that "technology" is equivalent to the personal computer. These impressions are inadequate descriptors, short selling the richness of two of the fundamental characteristics of advanced society. For example, many people who clearly qualify as scientists do not have any association with laboratories and their discoveries have no clear applicability to either modern industry or medicine. As Important as contributions to these areas have been, these concepts illustrate the importance of developing a working definition that clarifies the essence of "science" and "technology".

Science is the body of knowledge obtained by methods based upon observation. Derived from the Latin word scientia, which means knowledge, the modern usage employs the German concept of wisenschaft, which means systematic organized knowledge. Thus, science implies not mere isolated facts, but knowledge that has been put together in some organized manner.

Much of the relevancy of science to society arises by way of technology. There are close relationships between science and technology; yet, science is not technology and technology is not science. Technology is derived from the Greek words, techne and logos . The former means art or craft and the latter signifies discourse or organized words. The practice of technology is frequently that of an art or craft, as distinguished from science, which is precise and is based upon established theoretical considerations and formal processes. Although we may not think of technology as consisting of written words, as implied by logos, it does involve the systematic organization of processes, techniques and goals.

One important connotation of the working definition of technology is that it is a human activity whose products are used by humans for sustenance and comfort. Whether actually accomplished by technology or not, the goal of technology is generally the improvement of the human condition. Technology is goal directed. Typically, material objects are its output. This is not meant to exclude the importance of non-material concepts to our sustenance and comfort, but is meant to emphasize the central theme that technology is driven by physical needs and in Western society it has also involved control of the environment and its resources for human need.

Discovered with tools, million-year-old African skeletons indicate that technology has a much longer history than science --a history as long as humanity. We have evolved together with our tools and techniques over millions of years. The major changes in human population are due to the technology we have developed such as the domestication of grain, the use of irrigation, and the invention of methods of storing and preserving food. We exist by the generosity of the earth, but how many of us thrive and how many of us starve depends on how well we use and distribute the earth's bounty. It is the wise use of technology that allows society the freedom from want to afford the luxury of thought for thought's sake, i.e., "science." For example, the great pre-European dynasties of the Inca, Mayan and Aztec civilizations thrived with about 15 million people living in the Americas. Most human labor was needed to produce food. We now have over half a billion people living in the Americas with less than five percent of the labor force needed for food production. Without technical developments in agriculture, we could not sustain such a population growth, and in no way would we have time nor the energy to develop an even more advanced civilization. All of our time and effort would be devoted to the maintenance of life.

Technological change has generally evolved empirically, simply by trial and error. The method used in proceeding to the development of new technological advances is determined by two primary factors: the existing technology and knowledge of the properties of matter and energy --that is, existing scientific knowledge. Scientific knowledge used in technical change is not a replacement for the trial-and-error methodology, rather it provides a means of selecting which trial to undertake next and therefore contributes to the effectiveness of the trial-and-error process. Although technology us scientific knowledge, technical innovation continues with little or no basic scientific knowledge. For example, the photographic process was developed to a high degree of sophistication even without the fundamental understanding of the underlying chemical phenomena.

Suffice it to say that for the competitive organization's purpose, technology is science plus purpose. While science is the study of nature and subsequent development of "scientific laws", technology is the practical application of those laws, in sometimes non-rigorous ways, toward the achievement of some purpose -usually material.

As we have seen, science is pure neutral knowledge extracted from nature through systematic means for dissemination. Technology, on the other hand, is not science; it is how we do things, not how we think of them. However, technology relies very heavily upon basic scientific knowledge and it (technology) is never neutral. It is always directed toward a goal.

There is also a strong influence in the reverse direction. Modern science relies, to a large extent, upon existing technology as well as prior scientific knowledge. Science is dependent upon technology for its tools and instruments, for the preparation of materials, for the storage and distribution of information, and for the stimulation of further research.

Indeed, science is not technology and technology is not science but they are inherently related. One could not exist in modern form without the other. However, a competitive organization needs to clearly delineate the components of its R&D strategy. It needs to know whether there is a tilt toward science or technology. We have found that research centers, "think-tanks", laboratories, high-tech manufacturers, and other organizations whose products are technologies need strong science programs as input to their technology development strategies. Companies producing goods and services, i.e., those whose products are other than technologies, need to concentrate on technology strategies as input to their product value chains and as a way to focus limited R&D funds.

Technology Drivers

Technology development and innovation, as stated in the previous section, is driven by a goal. As John Naisbitt, of the Naisbitt Group, notes in Megatrends, "Change occurs when there is a confluence of both changing values and economic necessity, not before." BBC reporter and author of Connections James Burke designates six major initiators of technical innovation. They are: deliberate invention, accidents, spin-offs, war, religion, and the environment.

First, as one would expect, technical innovation occurs as a result of deliberate attempts to develop it. When Lewis Howard Latimer and, later, Thomas Edison began work on the incandescent bulb, it was done in response to the in- adequacy of the arc light. All associated technologies were available: a vacuum pump, electric current, the filament, and the arc light itself. These components were then synthesized toward a definite goal --the light bulb.

A second factor that frequently occurs is that the attempt to find one thing leads to the discovery of another. For example, William Perkin was in search of an artificial form of quinine when some of the molecular combinations of coal tar produced an artificial aniline dye.

A third factor is one in which unrelated spin-off developments have decisive effects upon the primary event. Consider how the medieval European textile revolution, based upon the spinning wheel and the loom, lowered the price of linen to the point where it became available in rag form to revolutionize the paper industry.

The fourth and fifth factors are very familiar: war and religion. The need to find more effective means of defense (or offense) has driven technology from the most ancient of times. The use of the cannon led to defensive architectural developments that made use of astronomical instruments. Ethiopian, Egyptian and pre-European Aztec religious beliefs led to great strides in engineering and architecture. The world of Islam developed advanced astronomy because of the need to pray, feast and fast and specified times.

Finally, physical and climatic conditions play their part. For example, the extreme changes in Europe's winters in the 12th and 13th centuries provided urgent need for more efficient heating. The chimney filled the need and had a profound effect on the cultural life of that continent.

For whatever reasons we seek to apply it, technology, borrowing from scientific revolutions, forces changes in thought, as does science, but also modifies behavior. Because of the social effects sometimes wreaked upon the organization by technological change, such advances are frequently resisted. One fact of history is certain --we cannot turn our backs on technical change as the English Luddites did by destroying textile looms. Technology will not go away that easily. The company that ignores innovation tends to meet it again under more unfriendly circumstances, e.g., as the ally of one's competitor. The wise money is betting on those organizations that assist, rather than fight, the technical change process. As Francis Bacon warned, "Surely every medicine is an innovation and he that will not apply new remedies must expect new evils [ills]."

Considerations of the Technology Assessment Process

The process outlined here is, by definition, general. It is not a prescription because obviously each organization will require any process to be modified to meet its unique corporate objectives and culture. The staff of Strategic Systems has found that synthesizing technologies along the lines described below and asking the right questions of the right people can help successful technical change occur, not in a vacuum, but with the full concurrence of the organization.

Process Overview

Consultants, systems analysts, engineers, and technology managers inside the organization must spend time at end-user locations getting to know their business and their people. Needs and opportunities, problems and promising strengths should be noted. Focus on their corporate vision, goals and the components of their product and processes that add value in the eyes of their customers. After fully understanding their business operations, structures, and competitive environment, immerse yourself in technologies that could impact them. Visit experts, attend conferences, research applications in seemingly unrelated areas, and be willing to build prototypes. The most important aspect of this data gathering phase is one's ability to LEARN HOW TO LEARN. If you are an expert at this process, no technology will be beyond your grasp. Match technical developments with business opportunities. Recommendations should be reviewed by a multi-disciplinary team for a broader perspective. Insist on including a study on how humans may react to the new technology as well as an analysis of what the competition is doing. Keeping clients informed and a partner throughout the process is standard procedure. Never expect blanket acceptance of a recommendation in which the end-users have had no input and no chance for review. Then present your findings and specific proposals to the client's technical staff and executive decision-makers. It does not end there, however. Keep clients periodically abreast of new developments with ongoing reports and tips.

Specific Steps, Considerations and Questions

Paraphrasing Michael Porter, consider the following specifics:

1. Identify all the distinct components and technologies of the organization's value chain for products and processes, i.e., know what it takes to produce their product.

2. Identify potentially relevant technologies in other industries or under scientific development. Examine current and future R&D projects underway internal to the organization. Examine exploitable interrelationships and technologies among business units.

3. Brainstorm, exercise visioning techniques, and simulate the effects of various combinations of technologies upon the value chain.

4. Determine the likely path of change of key technologies.

5. Determine which of those technologies and potential changes are most significant for competitive advantage and industry structure. Test their significance by asking, in a matrix team environment, the following questions:

a. Does the technological change lower costs?

b. Does it enhance product differentiation?

c. Is the advantage protected from imitation by competitors?

d. Does it provide advantages to the first one to adopt it?

e. Does it improve overall industry structure such that the client benefits?

f. Are the economies of scale of value chain activities raised or lowered?

g. Does it enhance the pace of product introduction?

h. Are the competition's costs of entry or exit raised?

i. Does it alter the capital required for competitors to catch up?

j. How are customer or supplier switching costs affected?

k. Is the bargaining relationship between customers or suppliers changed?

l. How does it influence access to distribution channels?

m. Are substitute inputs blocked or enhanced?

n. Does it enhance the client's response to national market differences?

6. Evaluate likely technology proposals with respect to human factors and organizational success, ability to implement the proposal, the reaction of internal vested interests, likely opponents, and changes in the way people work. Do not forget to evaluate proposals against government regulations.

7. Compare proposals with actions by the competition and demonstrate a clear advantage.

8. Develop and present a technology strategy that strengthens the organization's overall corporate strategy by choosing the technologies that enhance the client's position and blocks a rival response from competitors.

It Will Take More Than Technology

We must understand that science and technology cannot solve every problem. If we understand our limitations as humans, we will understand the limitations of science and technology. A major reason for managers' current skepticism of technology is the mismatch caused by technology producers' claims of panacea and managers' expectations. Indeed, the lingering computer slump is due, in part, to customers taking a long hard look at the tangible benefits (or lack thereof) of the newly adopted technology. The computer industry and other technology suppliers cannot afford to oversell the power of technology and expect to maintain long-term trusting relationships with customers.

Likewise, line managers and executives need to protect themselves by under- standing that technology lends itself toward those problems that can be quantified. With a few corner case exceptions in the Artificial Intelligence field, qualitative issues tend to evade technological solutions.

Scientists operate based upon the assumption that (1) nature is real, (2) nature is orderly, and (3) nature is, in part, knowable. As Carl Sagan notes in Broca's Brain, we can never expect to know everything in either the microscopic world of a grain_of salt or the macroscopic universe. However, if we use empirical methods and seek out regularities, we can get some pretty good indications and draw rational conclusions. But often we fail at technical fixes be- cause the human element is ignored. We know that humans cannot be quantified, they don't always behave rationally, and they operate on hidden agendas. Technology meets its match! However, conscientious technology assessors are combining organizational and human motivational experience to fuse non- technical, creative, intuitive approaches with technology. This expands technology's applicability beyond the world of pure quantification and materialism. These new approaches are not only helping to solve a broader range of problems, but also minimize the stress of technical change on the organization.

The key to success seems to lie in understanding how end-users view their world. Believing in a world of fixity, one tends to resist change; knowing a world of fluidity, one tends to cooperate with change, as Marilyn Ferguson notes. Science is helping society, and its corporate inhabitants, see the world in a new light. The Industrial Revolution spawned modern organizations, as such, it comes as no surprise that industrial companies operate on the Industrial Revolution's assumptions. Specifically, the technology that facilitated industrialism was born out of classical Newtonian science. Newton's laws helped scientists view nature as an orderly clock --tangible, predict- able, quantifiable. Other philosophers of his age were also influential. As the physicist Fritjof Capra points out, Francis Bacon stressed objectivity, Rene' Descartes argued that problems could be reduced to simpler components, and John Locke thought the individual's drive to satisfy his or her own demands would uplift society as a whole. We now realize the limitations of these philosophies and we are seeing it daily as economists' models fail to predict the global market, as technology's double-edged sword creates new problems as it solves old ones, and as employee motivational factors change rapidly. We now understand that a diverse culture cannot be reduced to mere mathematical equations.

Developments in Physics are helping society view the world as fluid --one in which change is normal and explanations are seldom complete. Those problems that are discrete, which can be reduced to pure materialism, and are predictable will continue to be perfect technological matches. Moon landings and electronic banking have directly benefited from the Newtonian approach to science and sub- sequent technology. Those problems that are non-physical, emotional, continuous, and non-quantitative require much more than classical scientific views of the world. In other words, the real world doesn't fit into a Harvard Business School financial model.

Scientific developments are helping us see that forces can be thought of as force fields which have their own frames of reference and defy mechanical description. Heisenberg showed us that there is no such thing as an objective observer. Einstein's work is helping modern society understand that there are no absolute answers; everything is relative to your point of view. The Entropy Law helps us understand that we cannot get something for nothing --every technology application extracts a price on someone. Synergism contends that the ideas generated by multiple people are more, and usually richer, than those generated by a single person or a single point of view. In addition, brain research helps us understand that maybe industrialized society has concentrated too heavily on developing linear thought processes to the detriment of intuition. It is this set of complementing assumptions that allow technology assessment to go beyond technology to at least attempt to see the total picture of the organization's problems and opportunities.

The agenda for technologists will be to act on this new knowledge in concert with the old. Newtonian science, so sure and tested by countless successes, must be fused with intuitive humanistic approaches. All intellectual approaches_are feasible in a complicated world, especially when what we have been using no longer works, as Capra would agree.

Keeping Up With Changing Technologies

Since technology is being developed at a fierce pace, it is clear that staying abreast of innovation will become a more difficult challenge. Indeed, we at SSI have found that the traditional educational approach that most of us learned needs modification. Technology assessors must be able to learn new technologies as a daily matter of standard professional practice. The key skill, once again, is LEARNING HOW TO LEARN and apply that learning toward anticipatory visioning exercises.

Anticipatory visioning is the skill of preparing for new situations, not merely adapting to the present. As James Botkin, author of No Limits to Learning stresses, anticipatory learning goes beyond choosing among desirable trends and averting catastrophic ones. It enhances one's ability to create new alternatives.

With anticipation as the overall goal, a new systematic educational approach, such as the one outlined by Joel de Rosnay in Le Macroscope, can be an effective guideline for multi-disciplinary analysis of emerging technologies. Paraphrasing de Rosnay and adding our SSI learnings, consider the following;

1. Avoid exclusively linear learning approaches. Review the material to get the total picture and then analyze each component. It is only when the work under study has been examined in total that we see the picture of a jigsaw puzzle and we can appreciate its discrete parts.

2. Avoid definitions that are so precise that they polarize people or limit the play of imaginations.

3. Stress the concepts of limits, interdependence and mutual causality.

4. Integrate many disciplines around a central theme.

5. Never separate the facts from the relationships that link them.

6. Understand that no observer is totally objective and therefore various cultural views and professional perspectives should be considered.

7. Allow for and encourage an intuitive, creative, non-rational approach to en- visioning alternatives.

8. Our final consideration is perhaps the most important one --consider how people with non-technical backgrounds will use a new technology as a tool. The technology cannot be the master. User-friendly tools require user-friendly designers. As engineer~, our profession too often forgets this rule. We are justifiably seen as Sherry Turkle depicts in The Second Self --as stereotypical "computer hackers" or lonely scientists who seem out of touch with human needs and shortcomings. Technology assessors should never allow themselves to become technically competent barbarians. Always consider the human element.

Conclusion

Technology Assessment need not be a mystical art or a precise science. In fact, considering it as technically astute, common sense strategic management is a pragmatic approach. It is clear that change will occur and that the organization that uses technology wisely will gain and maintain the competitive edge. It is Strategic Systems' goal to make our clients winners in business via technology utilization, not technology havens per se. We have found that being aware of the issues raised in this paper, following a process with a multi- skilled team, and asking the right questions of the right people can produce competitive champions.

Retention of custom is as turbulent a thing as an innovation; and they that reverence too much old times are but a scorn to the new. --Sir Francis Bacon from "Of Innovations"

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