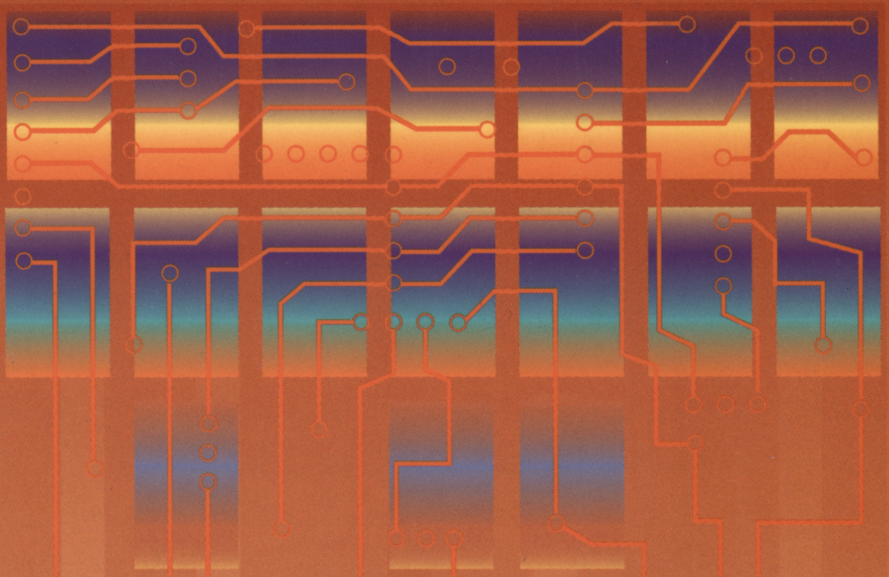

The Key to Profit

A practical guide to managing science and technology

Scott Tiffin

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A Practical Guide to Managing Science and Technology

by
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Foreword

In almost all the countries of the world, science and technology are viewed as dominant forces shaping development, and, since the end of World War II, governments have been actively involved in directing the course of scientific growth through science policy. The aim of government may be to generally advance the frontiers of scientific thought and research or it may be to generate knowledge and skills that can be used to achieve national goals — goals that vary according to national needs and priorities, be they increased food production, increased employment, increased export, improved health care, or a modern national defense system. This second objective — the pursuit of national (or international) goals — has been the primary focus of science policy.

In most developing countries that have "formal" policies to direct the course of scientific and technological development, government interventions are directed toward social and economic development. In the process of policy formulation and implementation, however, governments (the policymakers) must set priorities among the many different needs competing for limited resources, and, in the case of developing countries, these needs are of a wider variety and greater magnitude. Also, the available resources for which they compete are very limited indeed. Policymakers then must make difficult choices in helping to set the course for development; choices that will be reflected in the application of science and technology, the selection of appropriate policy options, the application of policy tools, and the extent of policy intervention.

C.P. Snow, in his book *Science and Government* (Harvard University Press, Cambridge, MA, USA. 1961), presents an early account of policymakers choosing policies for the application of science and technology to achieve well-defined national goals. It is essentially an anecdotal account of two eminent British scientists who were responsible, during World War II, for directing the application of science and technology toward the war effort. In one case, the policy choice was to support the development of radar, an air-defense technology that proved to be very successful. The other policy choice — strategic bombing — proved to have a much lesser impact on bringing the war to a speedy conclusion. In this example, the policymakers made their choices based on their perspectives of what the British government could support to achieve its war objectives. In general, policymakers must ensure that their choices are compatible with national interests. All government policy decisions are made by a handful of people, sometimes in secret. Nevertheless, it is assumed that they always take into account the distinctive needs, interests, and available resources of the state. When policies — and particularly science and technology policies — fail to reflect this, the consequences can be tragic.

This book — *The Key to Profit* — is a personal reflection based on the author's own extensive experience in science and technology policy. It provides a set of guidelines to assist managers of private firms, aid workers, and government policymakers in developing countries in the management of technology. However, it should not be viewed as a recipe for all countries to follow. Some managers and policymakers will find many of the guidelines in this book difficult to accept and implement; many will be surprised by the book's frankness and tone. Different firms, industrial sectors, regions, and governments will have varying needs and capabilities to enact the author's recommendations and suggestions. On the other hand, some users may find selected components and strategies outlined in this book to be appropriate in managing their own science and technology projects. Similarly, policymakers may also be successful in applying these components to advance their appropriate development goals.

This book offers one perspective on applying science and technology. It does not attempt to be a theoretical exercise; rather, it is a practical approach to managing science and technology in the developing world. It fills an important gap in the development literature and is a unique contribution that both challenges and informs users, practitioners, and all those interested in mobilizing science and technology to further advance development goals.

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Acknowledgments

I am indebted to those men and women in many developing countries around the world who lent me valuable time and insight while I was on international development assignments in their countries. I have relied heavily on their suggestions and on the experience they have helped me to gain. May this book help them continue their good work.

Many of the key ideas expressed in this guidebook have been honed in frequent discussion with Mr Jeff Pallister. As well, Dr Charles Weiss, Dr Charles Davis, Professor Fola Osotimehin, and Dr Mary Wallis have lent invaluable assistance in reviewing the manuscript.

Chapter 1

How to Profit from Science and Technology

If you run a private company, you can increase your earnings by managing technology; if you are in public service, you can manage technology to help private industry become more profitable. This holds true in all Third World countries, no matter what the level of development, and in all industries, no matter the sector or level of sophistication.

Written for managers of private firms and aid programs in development agencies and for government policymakers responsible for science, technology, and industrial development in the Third World, this guide shows how you can begin to profit from science and technology (S&T). It focuses on the following areas:

- Why technology is important for competitiveness;
- How to manage technology to improve a firm's competitiveness and foster national industrial development; and
- Key projects that will build technology-management capacity and foster national industrial development.

The primary focus of this practical book is industrial production. Both science and technology are important for improving health, controlling environmental impacts, or modernizing a cultural outlook; however, this guide is concerned only with managing technology to create profitable industry.

This book is a personal reflection based on my own experience and study. I have seen people like you wrestle with complex and difficult problems, with little practical guidance to show you how to maximize the benefits derived from S&T.

My objective is to make you aware of some of the opportunities within easy reach, show you some of the tools, and encourage you to apply them. Many of the ideas in this book — as well as the idea for this book — come from your own colleagues. Use it as a practical guide for action, take the suggestions as a starting point, and adapt them to your own situation.

Harnessing Science and Technology

The book begins with a few real examples where private industry has used S&T in the Third World. Too few government planners, aid administrators, and private entrepreneurs in developing countries allocate sufficient resources to S&T. There is a widespread view that S&T is a suitable investment for richer countries only and that, for countries that are poorer and less developed, S&T is less of an appropriate investment. Only reasonably developed countries, such as Taiwan, Thailand, or Venezuela, or very large countries, such as Brazil, China, or India, are mistakenly viewed as the only ones able to use S&T for industrial production.

It is my experience that all countries can use S&T for industrial development. This is shown in the following examples from Nigeria, Peru, the Philippines, Thailand, Tunisia, and Zimbabwe.

Each example tells a story with a different lesson; each is drawn from my own experience in Asia, Latin America, the Arab World, and sub-Saharan Africa. Not every story has a happy ending — it is not easy to manage technology — however, these stories tell how and why decisions were made and it is hoped that you will learn and profit from the mistakes as well as the successes.

Patis in Thailand

In the early 1980s, *patis*, a fermented fish sauce used in traditional Filipino cuisine, gained popularity on the west coast of the United

States. Filipinos not only created the market, they also captured about a 90 percent share. By 1987, their market share for traditional *patis* had dropped disastrously to less than 10 percent, as Thai food processors introduced a new version of the sauce more suited to American tastes.

Patis is not used in Thai cuisine, but all the necessary ingredients to prepare it are available in Thailand. The Thais mounted an aggressive research and development (R&D) program on food chemistry, developed the manufacturing process to a consistently high level of quality, and undertook careful market studies of consumer preferences. The small, traditional manufacturers in neighbouring countries stood little chance against such a well-coordinated, aggressive attack. Consequently, they simply abandoned this lucrative market, and the negative repercussions were felt all along the production chain, right down to the fishing industry in the small villages. The effect on the Thai fishing fleet was, of course, the exact opposite.

This story illustrates two important points. It shows why a modern industrial approach is vital for national development, even in traditional sectors. This approach has a positive effect on the balance of payments and controls employment all the way down to the rural economy. The story also shows how vital S&T is to industrial development. But it is not just the *amount* of S&T, but also the *type* of S&T, and the type of S&T *management* that make the crucial difference.

While the market share for traditional *patis* was shrinking, market data were not being transferred to any appropriate R&D laboratory or industrial marketing agency. The government R&D infrastructure, implemented to develop and improve food products, proved unable to link effectively with the producers of the traditional *patis*. The Thais, on the other hand, understood completely how to integrate R&D with process engineering, product design, and market research. In this case, government R&D infrastructure worked efficiently to support product development in private industry.

Carrageenan in the Philippines

During the 1970s and 1980s, the Philippines took a commanding lead as the world's biggest producer of seaweed, thanks to an abundant natural resource — one of the major production areas is in the southern island of Mindanao — and the drive, imagination and determination of local companies. Once agricultural extension officers set up the production systems and convinced the local fishing community to take up cultivation, there was a general improvement in the social climate. A long tradition of violent insurgency against the central government stopped, as useful, remunerative work became available. In some cases, harvesting of seaweed became so profitable that members of the fishing community could earn up to 50 percent more than a university professor.

The seaweed is used primarily to extract carrageenan, a popular intermediate chemical widely used in pharmaceuticals, aerosols, cosmetics, fine chemicals, and foodstuffs. When the Filipino producers realized the potential profits from moving downstream into higher value-added carrageenan processing, their efforts were thwarted by processors in the United States (one of the biggest users of carrageenan). The US processors convinced the Food and Agriculture Organization (FAO) of the United Nations to require new toxicology testing.

There is no hard evidence to support the US producers' claims of improper processing, and the Filipino suppliers maintained the accusation was a fabrication, a ploy to bar them from lucrative markets. Without any local laboratories to run sophisticated analyses, the Filipino producers approached an R&D laboratory in the United Kingdom. At the time I examined this case, the smaller producers could not afford the UK laboratory prices, and it seemed likely that they would lose significant markets, as well as the potential to evolve into more sophisticated, downstream activities.

The lessons? S&T is a strategic commercial weapon in the modern marketplace. Despite the Filipinos' demonstrated ability to reach the international marketplace with a quality product, without the capacity to wield S&T as aggressive attack and defence, they remain in a tenuous, subservient position, especially when compared with firms that use S&T in a coherent, strategic manner and are supported by national, public R&D institutions.

Tobacco in Peru

Although Peru has ecological zones suitable for growing tobacco, there have been several obstacles to replacing imported tobacco with local tobacco in Peruvian cigarettes. The quality of Peruvian tobacco is uneven; it tastes "different" from imported tobacco; and there is a market preference for cigarettes from the developed world. To solve these problems, the government attempted to create a greater market for local tobacco, to stimulate development of local agroindustrial linkages, and to reduce the outflow of foreign currency reserves. A law passed in 1974 obliged local cigarette manufacturers to increase Peruvian tobacco levels to 80 percent, up from 40 to 50 percent previously.

As a result of the law, new types of tobacco were produced and processing techniques were significantly adjusted to attain the same quality and taste levels to which customers were accustomed. Several private firms established the Asociación Tabacalera de Investigación Científica y Técnologica as a cooperative R&D company. Its mandate was to solve production and processing problems. The programs, which involved agricultural research on Virginia, Burley, and Negro tobaccos, were financed by the companies. The companies' contribution to an obligatory R&D fund financed a series of research programs involving quality and processing of tobacco leaves. The studies were successful and, over 2 years, helped achieve the local-content goal.

Unfortunately, when a new government was elected, the local-content law was repealed. The tobacco companies returned to their former sources of supply; R&D stopped and the percentage of local tobacco leaves used in local cigarettes dropped. The negative effect was felt by everyone in the industry, right down to the farmers.

The lessons? It is often obvious how to promote industrial development through S&T, and it need not be difficult to attain spectacular results quickly if appropriate public policy is implemented. Unfortunately, it is just as easy to undo positive developments by changing public policy. Local-content laws and regulations governing both upstream and downstream processing can be very effective, providing they are supported by a competitive business climate and related manufacturing and service industries. That support, however, must be backed by technological research and innovation capacity. If these conditions are met, regulation can sometimes spark sustainable industrial development. Protective regulation is not a long-term solution, but merely a way to incubate initial development.

Road-Construction Machinery in Zimbabwe

A public agency in Zimbabwe for maintaining government construction equipment received a large shipment of road graders through a development agency. After several years, however, it became extremely difficult to keep the machines running. There were severe maintenance problems due, in part, to complex sociopolitical factors and a lack of training. Also, the graders were not being used as designed and spare parts were hard to obtain.

I was asked to evaluate this project, and suggested a way to make the machines more readily available. The solution was to create a partnership involving the aid agency, a group of local manufacturers, a Zimbabwean university and technical college, and the grader company. The goal was to manufacture locally some of the heavy — costly to transport and low profit-generating — parts that did not require complex technology. In addition, the grader company and the local university would establish a local engineering-design team to redesign the machine specifically for use in Africa.

The arrangement would have benefited all parties. The government maintenance shop would have been able to obtain some spare parts from local manufacturers and, designed appropriately, the machines would have required less maintenance and repairs. The grader company probably would have sold more machines and parts — not only in Zimbabwe, but also all over Africa — once the machines established a better track record, and local manufacturing companies would have gained from the transfer of new technology, new products, and new markets.

The project was designed to the prefeasibility stage and finally accepted to proceed to the feasibility stage. However, breaking the established patterns of foreign aid is difficult. Typically, local manufacturers are skeptical of foreign companies' intentions, and sometimes lack the self-confidence to move aggressively forward. In this case, the manufacturers preferred the well-worn route. They limited their involvement to making quick sales and selling replacement parts only. The donor agency had difficulty understanding the key industrial technology-transfer aspects of the project and the need for a new kind of partnership with industry in both countries.

The lessons? Managing S&T is new to many donor agencies and is seldom a high priority. Although technology-based projects offer substantial benefits, they are often expensive, complex, and time-consuming. They are not the typical way of doing business, and demand new forms of cooperation among industry in both countries, local government, and the aid agency.

Local government should not depend on aid agencies and multinationals to ensure their country's technological development. Government must be aggressive and proactive in promoting its own self-interests.

Biotechnology in Tunisia

In an industrial city in Tunisia, a university biology professor recognized that S&T would help the local agroindustry improve its products and processes. The professor actively promoted the department's consulting and laboratory services to local industry, and was so successful that demand soon outstripped supply. The professor then designed and promoted a new biotechnology centre that would be attached to the university. The centre would carry out applied research related to local industry's needs. As a result of his tenacious, intelligent entrepreneurship, he secured financing from a combination of sources, including the UNDP (United Nations Development Programme). Over the next few years, the centre expanded and attracted more students, researchers, and technical support staff, and gradually moved from research to development and pilot-scale testing.

There were problems, however. Principally, it was difficult to turn promising ideas into commercial products and to go from pilot-scale testing into commercial production. The centre is now considering how to promote spin-offs. As a first step, the centre transformed itself into a private enterprise and left its protected position as a government- and university-regulated laboratory. Within this process, the centre renegotiated its funding contract with the United Nations and obtained permission to exploit its inventions commercially.

This story is an excellent example of "technical entrepreneurship." A technical entrepreneur is interested in establishing a business based on the exploitation of new technology. This process is very different from founding an ordinary business because the initial purpose is to obtain the resources necessary to turn the technology into a commercial product during the first few years of operation. Only when the product has been fully developed will the company begin to show a profit. The biotechnology centre expressed technical entrepreneurship within the context of an organized institution. In the next story, technical entrepreneurship is expressed by an individual, working alone.

Animal Vaccines in Nigeria

As the value of his salary declined, a Nigerian professor of pharmacy was forced to supplement his income to support his family. Rather than invest in an existing commercial venture, such as a minibus taxi service — a common practice among professors at the university — he decided to put his technical skills to work.

His thoughts turned to chicken farming — a highly profitable business in the big cities. Although mass-producing chickens in enclosed buildings can be very efficient, the closeness of the birds invites disease. Within a few days, an entire flock can be wiped out, leaving the producer in financial ruin. With antibiotics, these infections can be controlled. The standard procedure is to take an infected chicken to a laboratory where the disease is identified and a drug prescribed. Response time is critical; the disease must be identified and drugs administered within hours of the outbreak. In Nigeria, there were no facilities for biochemical analysis; infected carcasses were driven to Lagos and shipped to Europe for analysis, and the prescribed drugs returned by air. The process took, at best, at least 2 days. In the meantime, the disease would continue to ravage the flock.

The professor began his enterprise by conducting the analyses and prescribing the drugs himself. At first, he rented university laboratory equipment, but as the financial rewards of his endeavour became evident, he bought his own specialized equipment and set up a small facility near the university campus, hiring students and technicians as needed. Initially, he only did analyses and stocked drugs for the most common diseases, but when I last heard from him, he was expanding for the second time and was planning to produce some of his own vaccines. His company had grown to several dozen employees.

The lesson? This is an example of a highly successful "high-tech spin-off" from a university. An individual with specialized scientific skills transformed himself into an entrepreneur — normally a difficult transition with a high failure rate. In this guide, we offer an "incubator facility" design to make these spin-offs easier and more successful.

Do You Really Need This Guide?

Although the most successful businesses in rich countries base their economic success on S&T, few Third World countries believe S&T can be managed successfully. The stories here tell only a tiny part of how companies and governments in the Third World are using S&T. You can learn from these experiences and profit from S&T.

This practical guide to the underlying principles and organizational designs of technology management is the result of many years of working in the developing world. Companies in developing countries face many of the same problems and opportunities. As well, the strategies, organizational changes, and basic project designs required to increase a company's competitive edge have much in common, no matter where the firm is located.

This book is intended as a practical guide. All firms are dependent on S&T to some extent, whether they operate in a developed or Third World country. Only the best firms, however, manage S&T in a sustained manner to gain maximum competitiveness. All companies in the Third World must learn how to manage technology, and all Third World governments must learn how to help productive enterprises use S&T. In fact, using S&T to maximize industrial competitiveness is one of the best indicators of development, because it is one of the most powerful tools available for generating sustained profitability.

Getting results from S&T investment at any level is difficult; S&T is immensely complex and poorly understood. Only recently has a professional practice for its management developed. This field is known as Management of Technology (MOT) at the company level and Science and Technology Policy (S&T policy) at the government level. By now, the public sector has considerable knowledge about S&T policy and planning. To create this practical guide, I have blended academic research and public policy with my own experience in the field.

This book speaks directly to entrepreneurs, university professors, educators, government-program administrators, and policymakers in the Third World, and to international development program administrators and policymakers in the developed world. The purpose of this book is threefold:

- It is an introduction to the new fields of MOT and S&T policy as they can be practiced in the Third World;
- It is a guide to the underlying principles of structuring public policy for S&T; and, finally,
- It presents designs for several new private- and public-sector organizations that can put these principles into practice.

With this guide, you can begin to take action and profit from S&T. If you manage an industrial firm, you can begin the process by yourself. However, if you act in isolation, you will never achieve all possible benefits. By cooperating with other firms in your industry, you will gain access to all the facilities you may require. Of course, the right kind of government policies and public S&T institutions will also be necessary.

It is equally true that government, acting on its own, cannot ensure industrial development through S&T. Government can only instigate, coordinate, and facilitate the process. This is why Chapter 4, "Key Projects to Consider," is so important. It provides proven recipes for bringing the public and private sectors together to ensure that as many companies and social groups as possible realize the benefits of S&T, and that investments in new policies and organizations are sustainable.

Chapter 2

Managing Technology in the Firm

Many different people and organizations are involved in generating, transferring, and using technology. They include scientists, technicians, engineers, government bureaucrats, entrepreneurs, and investors. Each has a different objective, viewpoint, and role: convincing them to work together to help S&T make money for a company is no easy task.

Can technology be managed? Can it be managed to increase a company's competitiveness? Can the state manage technology to promote industrial development? Yes, it can, and this chapter shows how.

Basic Concepts and Definitions

Why Technology is Important for Industrial Development

The cases presented in the first chapter show that technology can be used throughout the Third World to benefit industry. They also show that the process is seldom easy. Technology management requires special skills, conditions, and organizations; nevertheless, the benefits can be enormous.

Why is Technology so Important?

By controlling technology, firms can gain commercial advantage over their competition. Technology supports production of better quality products at lower prices. It can also enhance the sophistication of products, justifying a higher selling price, and thereby increasing the firm's profits. Control of technology also promotes efficiency, which, in turn, reduces production costs. Managing technology can make a product more valuable to customers, thereby creating larger and more loyal markets. For resource-based firms, technology is a major factor in determining which resources are economically or technically exploitable.

The state must be involved with S&T; industry cannot profit from S&T acting alone. There must be an equal partnership. The state benefits from the firm's profits and, in turn, must support the use of technology by productive enterprises. By investing in S&T, the state can increase development; the success of that investment can be measured by the number of new jobs created throughout the economy, better delivery of social services, more profitable companies, and companies committed to increasing their sophistication and competitiveness.

Technology is not the only means to increase development and profitability. Quality products, skilled human resources, and a commitment to customer service are also important. A strategic geographical position and control of natural resources also factor into the equation. In the past, increased profitability hinged on strategic geographical position or the availability of abundant natural resources. Today, however, one of the most valuable resources — the country's ability to use S&T to gain competitive advantage — is neither geographic nor natural, but developed.

What is Technology?

First of all, it is important to distinguish between science and technology. Science is the organized search for understanding of nature; technology is an organized way of using natural principles to design and construct something. This does not mean that science comes first and technology simply follows in its wake. Technology has its own directions for growth, its own independent areas of inquiry, and its own techniques of operation.

It is important to distinguish between science and technology because science receives most of the attention in official development projects and technology tends to have a shadowy presence. Scientists communicate and publish for a living; engineers read about science, but rarely talk about their work because it is often commercially confidential. This difference has serious implications. Science enjoys a very high public profile and has, until recently, received considerable public funding because of its lead role in fueling economic development. In the three decades following World War II, S&T expanded considerably; consequently, government directed an enormous amount of money into scientific research in the developed world.

In much of the Third World, the conviction that science is directly related to development still prevails. In fact, science has very little direct effect on national development or on a company's profitability. Its greatest effect is to modernize and secularize culture, to assist in educating a skilled work force who can use technology, and to conduct essential "reconnaissance" and monitoring work in such areas as the environment, geology, and oceanography.

Industrial benefits come largely from technology. Only in certain industries — such as those involved with advanced biology in disciplines such as gene splicing — is there a direct link between fundamental science and product development. Scientific knowledge is important to technology and product development, but the fundamental knowledge component of a profitable product is but a small part of the entire investment.

Now that the distinction between science and technology has been made, it is important to reunite the two. In practice, it is difficult to distinguish between science and technology. Scientists focus on science and engineers on technology; however, the work of both groups overlaps much of the time. Both science and technology advance through a formal method of inquiry carried out by organized teams and called *research and development*. Most R&D takes place in a "factory," more commonly known as a laboratory.

Science and technology may be somewhat separate, but they are interdependent activities, in constant communication with each other. In this book, the term *science and technology* is used almost interchangeably with technology. However, because of the interest in the industrial, commercial, and profit-making aspects of S&T, the emphasis is on the word technology most of the time.

Technology has a tremendous economic impact because it is something that can be used and sold almost immediately. However, although technology can be bought and sold, in most instances it cannot be easily used. Most people identify technology as a physical object, such as a machine in a factory, or a consumer good, such as a car or radio. They are correct, but not entirely. The physical aspect of technology is hardware. It is the hardware that can be used almost immediately and it is the hardware from which any benefits accrue. For example, if you buy a car and already know how to drive it, you can realize the benefits immediately. If you do not know how to drive, however, you must invest further in learning how to operate the vehicle. This implies that technology has other unseen dimensions. In fact, technology has five distinct dimensions — hardware, software, liveware, systemware, and innovationware.

Anyone who has tried to operate a computer knows that the hardware is useless without software — the programs or instructions that tell the machine what to do. Most machinery or production systems cannot be operated without manuals or instructions. In industrial plants, these manuals can fill thousands of pages and require extensive staff training. So in a sense, all skills required to manage a firm can be considered software.

Even when software is transferred, often the equipment still does not perform as well as expected. The differences in performance between a site in the developed world and in the Third World may vary from a few percent to a complete breakdown. No matter how carefully the software is designed, inevitably some instruction is omitted. These omissions, which are filed away in the heads of skilled operators, are known as liveware.

Sophisticated buyers of technology are familiar with the concept of liveware, but few realize there is yet another dimension to technology, involving systemware. To understand this dimension, think of a pen. A pen is a technology, but without something to write on, it is useless. To write something requires knowledge of another very complex technology — writing skills. Furthermore, it assumes that the recipient knows how to read and speak the same language — another sort of technology — as the sender. To get the letter from writer to reader requires an extremely complex set of transportation and communication technologies, involving, among other things, the post office, roads, and trucks. In other words, every individual technology hardware is part of a much larger and more complex system of interrelationships. In developing countries, the systems are typically weak, with key nodes missing. Therefore, buying or making a new technology must be undertaken with full understanding of the systemware involved.

Finally, there is innovationware. By focusing on the other dimensions to the exclusion of innovationware, at best you will only be able to buy existing technology. Usually that technology is outdated and you will find yourself lagging behind the competition. Technology does not just appear out of the blue — it is made by a complex process of research and innovation. The innovation process is the most difficult to learn, but the most powerful to use. Technology innovation ensures competitive advantage; it produces high-quality products at a price no competitor can beat.

Figure 1 depicts the innovation process in the electronics industry, from identification of opportunity to sales, service, and, eventually, to phaseout. If any step is not completed successfully, the entire investment in the innovative new technology may be jeopardized.

Different industries and technologies follow different innovation patterns, so the sequence of individual steps will not always be identical. Note as well the two curves at the bottom of the diagram. Profits are negative during the early stages of the

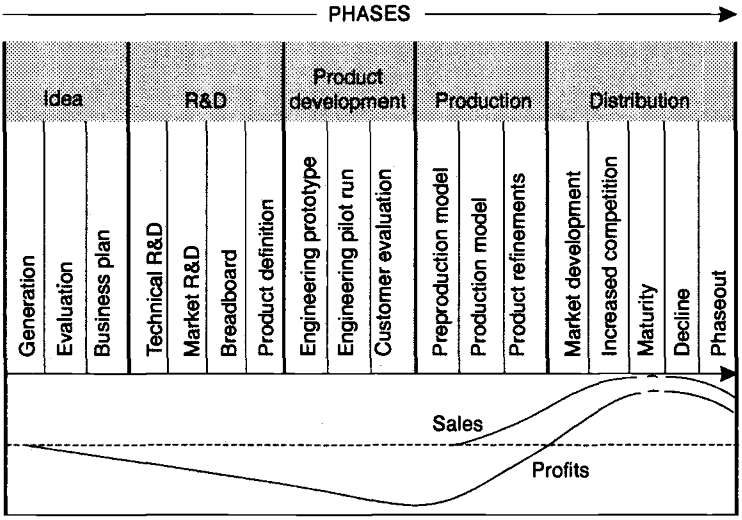

Figure 1. The innovation process.

innovation process; it is only when sales are well under way that cumulative profits become positive. The life cycle of all technology inevitably ends with a period of decline; sales and profitability decrease, and finally the technology is phased out.

To make this figure fit on the page, the horizontal time-line is not drawn to scale. The "production" and "distribution" phases, especially the section called "maturity," are much longer than the earlier phases. This means the curve showing positive profits and sales is really much bigger.

The Stages of Technology Involvement

Managing the five dimensions of technology is no easy task. It is a skill that comes with experience, as a company or nation grows and prospers. Acquiring management capability is further complicated because technology is constantly changing. It is constantly advancing and becoming more powerful. Therefore, the most sophisticated technology users and producers are also constantly improving. If a firm or country is not somehow involved with using and producing sophisticated technology, it risks being left out in the cold. This is known as the "technology gap" between rich and poor nations. This gap is constantly widening, and because technology advancement is accelerating at such a fast pace, the technology gap is also widening very quickly.

This does not necessarily mean the situation in the Third World is worsening. In some instances, technological advance simplifies technology transfer. For example, satellite telecommunications does not require costly, time-consuming, and expensive-to-maintain wire transmission systems. In other instances, new technologies mean that raw materials, which previously had no economic value, suddenly take on new importance because they are either necessary for the technology itself — for example, uranium mines for nuclear power production — or they make a resource economically exploitable — for example, new pulp and paper techniques that use tropical hardwoods.

Companies and nations must plan the use of technology in a rational manner, moving progressively from the simplest to the most complex stage. There are three main stages of technological sophistication — technology transfer, technological innovation, and technical entrepreneurship. A firm's performance can only be as good as its technological infrastructure allows, and in most cases a firm's technological base fixes a ceiling on the quality, volume, and design of goods produced. The only way to move through this built-in ceiling and improve competitiveness is to acquire new technology. The first stage is, therefore, *technology transfer*, a popular term whose meaning has become vague with overuse.

The precise meaning of technology transfer is the exchange of hardware, software, and liveware from a developer or user to a company that wants to acquire both the physical aspects of the technology and the knowledge to operate it. The first stage of technology management begins, therefore, at the level of technology transfer.

From the perspective of government policy, technology transfer, which can apply either to an entire industrial sector or to a whole nation, is better considered as technology diffusion. In diffusion, the goal is to spread the technology among as many users as possible. Although one firm initially gains advantage from a technology transfer, the whole sector eventually benefits — by modernizing and restructuring, for example — as more users gain access to the new technology. Governments, therefore, are principally concerned with the "big picture" of technology diffusion.

The next stage occurs when a firm begins to produce its own technology rather than buying it from some external source. This is called *technological innovation*, and it is at this stage that the company can gain radically new market advantage.

Technological innovation takes time, capital, consistent effort, and technical skills. A key difference between innovation and transfer is that the former requires self-reliance and the use of local resources to capitalize on local opportunities, whereas the latter tends to promote passivity or dependency on some other agency, usually located in the developed world.

Technological innovation does not necessarily require science or an R&D laboratory. As Thomas Edison, the inventor of the light bulb and phonograph, said: "Invention is 1 percent inspiration and 99 percent perspiration." Edison's success in developing the original electric light bulb hinged on finding a filament that would not burn out after only a few hours. To find the right one, he tested hundreds of materials and took the one that lasted longest. Any firm with skilled technical staff can make small, incremental changes to improve its products and processes. Most technological innovation is achieved through incremental change.

Fundamental advances or major new products, however, require formal science and R&D. Few industrial firms, even in the most advanced countries, attempt these revolutionary innovations by themselves. Innovation usually requires the combined efforts of groups of companies, universities, and government R&D laboratories working at the forefront of S&T knowledge.

It is only in the final stage, *technical entrepreneurship*, when all aspects of technology management are linked into corporate strategy, that a firm begins to reap all the rewards of its efforts. Technical entrepreneurship refers to the creation of a new business based on the exploitation of a technological innovation, or to the expansion of an existing business through the acquisition and marshaling of resources, or to the creation of a small, at-arm's-length venture through a spin-off from the parent company. Technical entrepreneurship is the most powerful way for a firm or a country to achieve true self-reliance and sustainable industrial development.

Managing Technology for Profit

Can you manage technology? Yes, just as you manage your firm's finances, personnel, or marketing. This book is a guide to the basic principles of managing technology; throughout it you will see the terms managing technology, managing technological innovation, and managing innovation. Managing technology means extracting all the potential benefits from S&T, usually to maximize the firm's competitive advantage. Managing technological innovation is a more restricted concept and deals solely with the techniques for inventing, designing, researching, manufacturing, and marketing a new technology or a new product based on a new technology. Innovation is a more general term than technological innovation, as there are other types of innovation, but it is used here as shorthand for technological innovation.

A Standard Action Process

Any firm that wants to examine how it uses technology to improve its competitiveness should follow the process shown in Figure 2.

The decision to act is the first step in the process. When a firm asks me to help define the process of action, I begin with introductory staff briefings and a needs analysis. This guidebook presents some of the information you will require to begin the process yourself, but to apply the techniques fully, you will require additional resources as outlined in Chapter 4.

Once you have decided to take action, the second step is to determine the customers' needs for your product or service.

At the third step, the firm must look inward to determine whether it has the competence and capability to satisfy the customers' needs. The concept of core competence is extremely

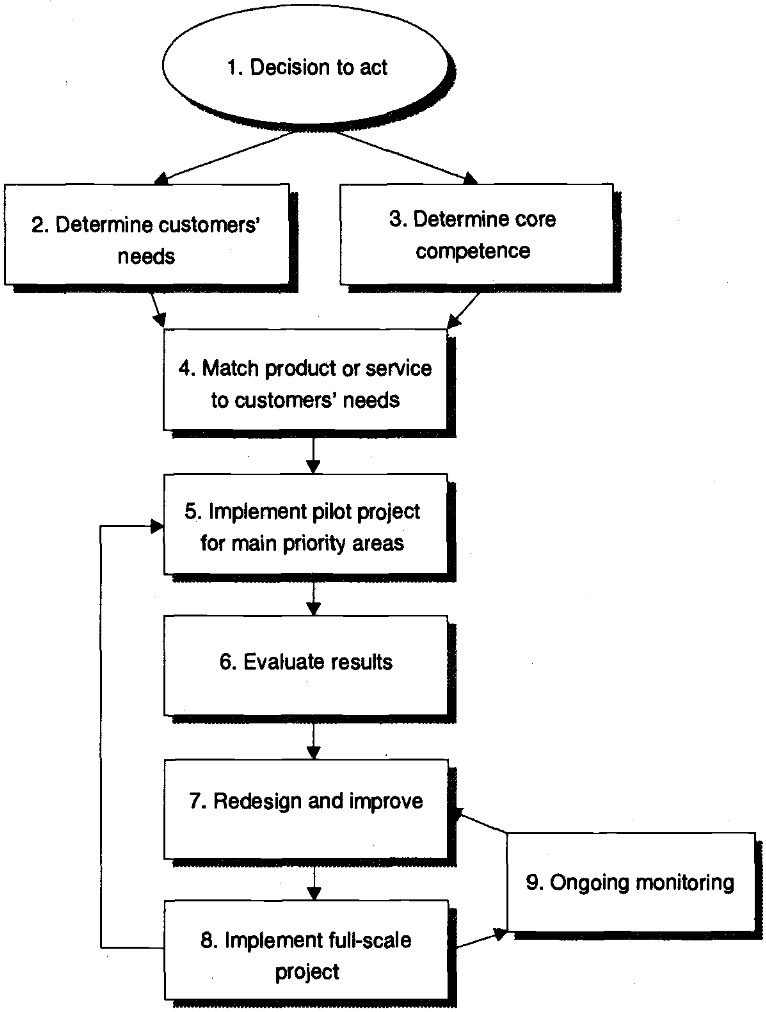

Figure 2. A standard action process.

important. Firms typically focus on the products they market, rather than on their technological production capability. When market conditions change, the company, because it does not have the capability to monitor change, is unable to produce new products to meet the new market demands.

The technological capabilities — the ability to design new products, undertake the necessary R&D to produce them, develop the appropriate production processes, and formulate an effective marketing strategy — are part of a company's core competence. In a sense, the end products are like the fruit of a tree, and the core competence represents the root system. Firms must develop a strategy to nurture this core competence and make long-term investments to strengthen it.

The fourth step in the process is to match the firm's core competence with customers' needs. It is recommended that you use the concept of the value chain, as illustrated in Figure 3, to structure your analysis.

The matrix in Figure 3, adapted from Michael Porter's book, *Competitive Advantage* (The Free Press, New York, NY, USA. 1985), provides a basic framework for evaluating how technology increases — adds value to — the efficiency, quality, and effectiveness of all operations within a company. Note that technology adds value not only to "operations" (the manufacturing process), but upstream in "inbound logistics" (getting the material and equipment inputs to the firm), to "outbound logistics" (getting the

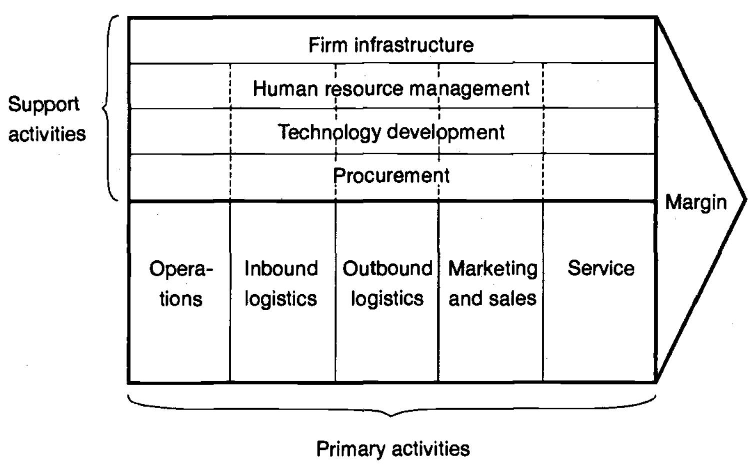

Figure 3. The value chain.

product out the door, downstream), and to "marketing and sales" and to "service" as well.

This interlinking of separate stages is called the value chain. The process that takes place inside the firm is called the internal value chain. The concept of the value chain also relates to a firm's relationship with its suppliers and customers. You can use this diagram and the underlying concept to examine closely every operation in and around your firm to determine the implication of technology to your operations and how it adds value to them.

In the language of this diagram, "technology development" should be classified as a "support activity" — something as essential to the firm as "human resource management" or "procurement." "Technological development" should assist all "primary activities" — logistics, operations, marketing, sales, and service. By following this framework, a company can increase its margin, or profit.

The value chain is fundamental to ensuring that a company's core competence meets customers' needs. It facilitates the flow of necessary data so that supply and demand are properly aligned.

In Figure 2, the fifth stage of the "standard action process" treats the main priority area as a pilot project. This project addresses the most important issue that arises when the company's core competence is compared with customers' needs. The pilot project should be carefully monitored and the results evaluated at Stage 6. Make all necessary changes at Stage 7 and set up the full-scale project at Stage 8.

Every project should include a "technology management system." This system is directly analogous to a financial management system. It consists of trained people charged with specific responsibilities, and is provided with the resources, operational plan, and physical infrastructure necessary to computerize parts of the operational plan, using specialized software.

Note that the process has no exit. Once the first priority is solved, the cycle repeats the process for the next topic. In fact, no topic is ever totally completed. Ongoing monitoring and continuous improvement are required and provided for at Stage 9.

This process of analysis, design, action, and monitoring should be applied to all projects involving technology management. The process will vary, however, depending on the particular area of concern. For example, a firm may wish to analyze the importance of technology to its internal operations. In this case, although the analysis focuses immediately on the value chain, the overall process should still consist of analysis, design, action, and monitoring.

Key Focus Areas

When managing technology formally, a company should focus only on key areas that require action. In the pilot-project stage, the entrepreneur should take the following action to ensure that core competence matches customers' needs:

- Formulate technology strategy;
- Manage technology investments;
- Optimize technology transfer;
- Focus R&D;
- Develop strategic alliances;
- Commercialize R&D and innovations; and
- Manage strategic quality.

This guide briefly outlines these seven key areas, introducing them as background to Chapters 3 and 4.

Formulate Technology Strategy

To ensure competitiveness immediately and in the future, companies must set a goal, and organize and use their core technology capabilities to achieve that goal. A technology strategy will deliver an action plan that identifies the technologies with the highest payoff; it also sets a clear direction for the future and designs the best type of organization to get the firm there.

Manage Technology Investments

Whether a firm manages R&D, directs technology acquisition, or invests in other technology-based firms, it faces tough choices in allocating resources among competing projects. Many techniques are available to assist in making rational choices.

Optimize Technology Transfer

Nearly all technology used by a firm — whether hardware, software, or liveware — is acquired by some form of transfer from outside the company. This process of technology scanning, acquisition, adoption, and incremental improvement is complex, but it can be systematically undertaken and continuously improved.

Focus R&D

A firm's R&D laboratory often represents the largest single technology expenditure, and yet laboratories typically have difficulty integrating their work with strategic corporate goals, choosing the right topics, and convincing researchers to share management objectives. There is an extensive literature of practice in this subject that dates back 20 years. Some of the organization designs in Chapter 4 address the issue of how to focus R&D.

Develop Strategic Alliances

No single company has the in-house resources to develop, acquire, or exploit all the technology it needs. However, any company can leverage other people's resources to get the job done, and done faster, cheaper, and better. Strategic alliances allow firms to work effectively with competitors on generic R&D projects, public R&D laboratories, and universities. Strategic alliances are also covered in the next two chapters.

Commercialize R&D and Innovation

Firms, laboratories, and universities involved with R&D invest heavily in upstream activities, but rarely realize all possible benefits. Technology inventions are too often left on the bench and forgotten. In fact, if these inventions can be sold or commercialized, they can represent a significant source of potential income from licences and equity in growing, high-technology firms.

Manage Strategic Quality

Meeting product specification standards does not guarantee competitiveness. Increasingly, suppliers are required to meet management system standards such as ISO 9000, set by the International Organization for Standardization in 1987. The highest international standards for quality assurance, ISO 9000 focuses on organizational structures and processes that ensure products and services meet a consistent and predetermined level of quality. ISO standards are more comprehensive than national or industry-sector product codes and are becoming accepted worldwide. ISO certification can be gained for specific plants or products. The developing field of management practice called "strategic quality management" can assist in reaching these standards. Strategic quality management has much in common with technology management.

Chapter 3

Principles for Structuring S&T Policy

In advanced industrial economies, the state and private sector cooperate closely on technology management and policy. The same must be true in developing countries if they are to use these tools successfully. In fact, the less developed the economy, the more important is the role of the state in creating the S&T and technology management infrastructure required by the private sector. The key point underlying this chapter is that the state must provide not only S&T infrastructure — including R&D laboratories and S&T education — but also S&T policy and management infrastructure.

Governments accelerate the process of technoindustrial development by establishing the appropriate institutions to support industry. Once these institutions are in place, industry can then take its own initiatives independently. This chapter focuses on design principles for government programs to support the development and use of S&T by and for industry. It does not cover the many other socially important aspects of S&T — promoting a rational culture, improving health and protecting the environment, and creating products that, although not for market, have an overriding social purpose.

To development planners accustomed to working with poor, rural, and typically dispossessed social groups, the language and concerns in this book may seem remote and applicable only to the modern sector. There are undeniable differences between many countries' "modern" and "traditional" sectors; despite these differences, this guide spans the two sectors. S&T is important to all sectors of the economy and can be transferred to any group. Furthermore, all groups can apply the tools presented here, if not by themselves, then by requiring those with more sophisticated skills to act on their behalf. The following case illustrates how technology management supports business development.

In a small country in the Sahel, one of the least developed regions in the world, lives one of the world's foremost experts on African bees. When encountered, this entomologist was working in a dilapidated research laboratory, with virtually no equipment and a very limited scientific research program. Most of the staff had difficulty identifying how to obtain and manage increased research resources; consequently, many had outside jobs to make ends meet.

When I noticed that all the honey served in the hotel restaurants was imported from France, it became obvious how to put these researchers to work.

With some elementary training in technology management and access to public facilities for promoting industrial development, these scientists could have developed local honey production into a flourishing industry. They could have been remunerated for their expertise and, in the process, created a new market for the farmers' superior product. Apparently no one had ever contemplated such a project, however.

Failure to capitalize on the opportunity for technology-driven enterprise development is common in the Third World. There are, of course, many impediments to action. This guidebook shows how to overcome some of these hurdles, and all suggestions made here can be applied to any Third World country, including the poorest.

To understand how to design policy and projects that promote technology-driven enterprise development, this chapter considers the following government actions:

- Conditioning the business environment;
- Supporting technology management infrastructure;

- Undertaking public S&T;
- Procuring for innovation and integration; and
- Encouraging industry to act.

The focus on design principles for the public sector does not imply that government is responsible for initiating all action. In fact, government can do little more than establish the appropriate environment and infrastructure. The private sector must work with government in an active partnership, and must ultimately be responsible for applying S&T to its own development.

Conditioning the Business Environment

Conditioning the business environment is the most fundamental principle of development. Government must condition the business environment to create stability, rational markets, competition, developer advantages, technology incentives for foreign firms, and the freedom to innovate. If these conditions are not met, private investment in S&T will be limited.

If S&T is to be used as a tool to achieve competitive advantage in the marketplace, there must be incentives to promote competition, and markets must be open to allow for fair competition. This principle applies not only to foreign investment in a country, but also to open access in foreign markets for local products. Normally, product development initially targets local markets; however, exports are usually the key to long-term prosperity.

Technology investments are costly and take years to bear fruit; therefore, tax regimes, import and export laws, labour conditions, and environmental regulations must be kept as stable as possible. Abrupt changes in the basic legal structures of business operation can be ruinous to investment. S&T is a creative process requiring the free flow of information and ideas; to harness S&T, there must be a climate of openness and willingness to experiment.

The principle of rational markets must be qualified. Markets should be open, but governments must have the power to support developers of technology temporarily. A powerful trading partner may view an innovation-incentive system as an "unfair subsidy" and press for its removal. In most instances, however, the trading partner will have an identical, but differently named, incentive in place. For example, military R&D is often used to develop new civilian products. There are many kinds of incentives — regional development subsidies, R&D tax breaks, temporary import protection, and so forth. All are fair game.

You should also encourage foreign firms in your country to purchase and help innovate local technology. On one hand, there are technological benefits to be derived from the presence of multinationals — pressure to improve the quality of local material inputs and enhance skills, for example — but on the other hand, multinationals can actually hinder local firms from harnessing technology. Companies must ensure appropriate mechanisms — including World Product Mandates or royalties from resource extraction — to prevent any problems arising from the presence of multinationals.

A World Product Mandate is granted to a subsidiary of a foreign-owned multinational company, allowing it complete responsibility to carry out R&D, product design, marketing, manufacturing, and servicing of a product line, worldwide. This allows the subsidiary to act as a mature, complete company, not merely to supply parts — designed elsewhere and most probably made with imported components — for a local market.

Supporting Technology Management Infrastructure

With the collapse of Marxism, many Third World governments have swung to the other extreme in economic theory; most are busy trying to dismantle and privatize public structures, including investments in S&T. In many instances, the pendulum has swung too far; governments are abandoning legitimate and essential responsibilities. Government must continue to play a large and forceful role in national technological development. All developed countries accept this principle and try to achieve a dynamic partnership between the public and private sectors. Acting alone, government can do little to support national technological development, but neither can the private sector working in isolation.

Government has an essential and unique role to play in providing S&T infrastructure, especially in the following areas:

- Services;
- Education;
- Awareness; and
- Facilities.

Services

Within infrastructure services, three areas require attention: technology services, alliances, and extension services.

Technology Services

National government is responsible for a wide range of technology services, including patents, trademarks, standards, and quality control. Within government, there must be a core of expertise to develop and administer these services, even though private firms acting under contract may be responsible for their delivery.

Alliances

Government must assume a lead role in bringing together firms with complementary interests with university researchers and educators, government technology support workers, and public R&D laboratory staff to help all parties work better by working together. Cooperative technical alliances are one way to make these connections.

Most governments run a national R&D laboratory system to support industrial development through S&T. In the Third World, however, R&D laboratories are often isolated from the industrial community. All governments support a university system with some public R&D, but seldom is the university R&D related to the needs of and opportunities in private industry. Universities tend to be far too isolated from the productive sector; as a result, there is little public, financial, or industrial support for R&D. Much of the investment goes nowhere and ends up as scientific research papers, a few unexploited patents, or interesting prototypes that literally sit on a shelf. Cooperative technology alliances involve industry in an R&D project from the outset, thereby ensuring that the project is properly defined, that research meets an industrial need or application, and that researchers are adequately funded.

An alliance can leverage other people's resources and ensures the involvement of everyone necessary to complete the project successfully. If anyone instrumental to the project is not formally involved or readily available by means of a standard contract, the entire project could be jeopardized. Formal alliances must be strongest where the economic and technological infrastructure is weak and unresponsive to traditional market signals. In most cooperative alliances, the following people or organizations should be involved:

- Producer of the innovation;
- End-user;
- R&D laboratory or research team;
- Training groups who will ensure that all necessary skills are provided;
- Consultants and government service personnel who provide a wide range of technical services, including industrial design, patenting, and quality management;
- Consultants who supply management services for such things as MOT and marketing;
- Investors who expect a high rate of return on the project;
- Government policy or program officers to ensure the appropriate legal structure is in place; and
- A promoter and manager of the alliance.

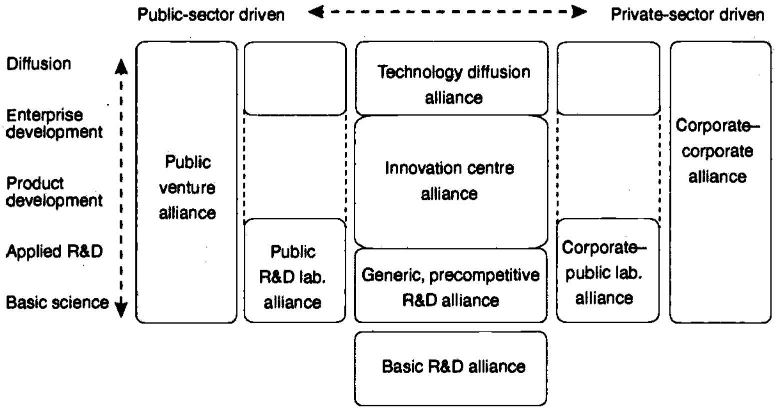

Figure 4. Strategic technology alliances.

There are many types of alliances, and each one depends on the specific needs of the project. Figure 4 illustrates the main types of alliances.

On the right are alliances driven by the private sector and on the left those driven by the public sector. In the middle are alliances shared by both sectors. The recently announced partnership between IBM and Apple to develop a new personal computer that combines the user-friendly characteristics of the Apple and the MS-DOS standard of IBM is an example of a purely private-sector alliance.

In this case, the objective seems to be to connect applied R&D with product development. However, there may be a further objective — to create a new business common to both Apple and IBM. Figure 4 illustrates these objectives. At the bottom is basic S&T, which leads up through applied R&D, product development, and enterprise development to, finally, diffusion at the top. An alliance between two corporations can span this entire process.

Corporations often ally themselves with public R&D laboratories, but normally only to seek assistance with applied R&D. A corporation does not typically involve the public sector with the commercially confidential aspects of product development.

There are too many different alliances to catalogue them fully here. Alliances shared equally by the public and private sectors are probably of most interest to Third World organizations. The following chapter describes some project designs for various shared alliances.

An alliance can be temporary — established for a project only — or it can take a permanent form, such as a laboratory or management structure. The alliance may involve physical infrastructure, or it can simply be a contract, involving staff from participating organizations, as required. The alliance can be permanently located in an institution, or it can be a network of people widely dispersed, but linked by a common work program and an excellent communications system. An alliance may carry out research, fund technology projects, or simply diffuse information or promote ideas. It can be organized around a specific sector or formed to develop a geographic region. Alliances can involve firms of fairly equal size and business orientation, or large, mature firms that hope to spin off entrepreneurial, high-technology ventures, or simply invest in these spin-offs to ensure future avenues of growth.

Large- and small-scale technology alliances are widespread in developed countries, but scarce in developing countries. One of the biggest problems is that, because alliances are a fairly new industrial organization, there is little information about them. The Zimbabwean equipment manufacturing and Peruvian tobacco projects described in Chapter 1 are examples of technology alliances. They prove that such alliances are not only possible, they can also work successfully. Again, however, it is important to stress that government must play a key role in promoting cooperative technology alliances and in structuring laws to support them.

Extension Services

Typically, the mandate of government R&D laboratory systems is to upgrade national technological capacity. Unless the laboratories actively promote and sell their services, however, no one will know what technologies they have to offer. In reality, too many laboratories run in isolation from industry. One solution is to involve them in cooperative technology alliances; the other is to encourage them to operate technology extension services.

A technology extension service is a public S&T infrastructure activity that allows laboratories to solicit industry. Its role is very similar to that of an agricultural extension agent.

It is not necessary for the public sector to operate the extension service; it can be contracted out to the private sector — to consulting engineers, for example, or to any competent, local technology group. However, the direction and design for its operation must be a public service. Although extension services are publicly funded, clients should be charged in proportion to their level of benefit.

When designing an extension service, it is essential to strike a balance between "emitters" and "receptors." The extension agent, who acts on behalf of the laboratory, is the emitter. At the other end, there must be a "receptor" — an engineer, scientist, or manager in the private firm to receive the message. In some countries, the public technology infrastructure has expanded to fill the gap left by private industry unwilling to invest in S&T. In most cases, the result is an expensive public facility isolated from its clientele. Some facilities actually began to compete with the private sector because no one ever attempted to increase the client firm's capacity to desire, receive, and use S&T and new S&T-based products. It is not enough to simply build an extension service; firms must also be helped to desire, receive, and use S&T. One solution is to plant the extension agents within the bigger or more important firms, as part-time or partially subsidized employees.

Education

If the state is to play a more direct role in national development, it must address the following issues more fully:

- S&T education in secondary schools;
- Technicians and technologists;
- Management of technology and S&T policy; and
- Industrial design.

Although support for standard science and engineering disciplines at the university and technical-college level is important, it is not covered here because this issue already receives considerable attention.

S&T Education in Secondary Schools

In many Third World countries, the science-education system of the secondary schools bears little relationship to national economic potential or needs. The focus is on abstract scientific principles and scientific theory, with little emphasis on technology, engineering, design, manufacturing, and entrepreneurship. These latter skills are much more important than abstract scientific laws taught — and learned — in isolation from their applications because they will enhance the students' earning power and contribute to national development.

Government has a responsibility to expand and strengthen science programs that promote practical and productive applications.

Technicians and Technologists

In most countries — and especially in the Third World — a university education is overvalued for its social status, whereas the education of technicians and technologists is undervalued. Consequently, the Third World produces many more engineers and scientists than support staff. In developed countries, there are significantly more support staff than university graduates.

The chronic difficulty for developing countries to just maintain and extend infrastructure — never mind building technology-intensive enterprise — is closely related to the overproduction of theoreticians and shortage of technicians and technologists. Young engineers usually end up doing the work of support staff, for which they are ill prepared and ill equipped. The most motivated engineers try to emigrate. One of the most important investments is, therefore, to increase the output of technicians and technologists.

Management of Technology and S&T Policy

As mentioned in Chapter 1, there is a new field of academic research and professional practice called Management of Technology (MOT). Its function is to show a company how to use technology to maximize its competitive advantage. MOT is an interdisciplinary field involving both engineering and management. It is similar to S&T policy, except that S&T policy deals with industrial competitiveness and the use of science and technology from the perspective of public planning. MOT takes place at the micro level, within the firm, and is concerned with individual products.

Most countries need at least one university that conducts research and trains students in MOT and S&T policy. Without this infrastructure, industrial and national development may be hampered. Students can be educated abroad, but if they do not understand the use of technology in their own country and their own national-development structures, their effectiveness will be severely limited. At best, policy and management will be nothing more than educated guesswork; at worst, the students will apply models derived from research abroad that do not suit their own country's needs.

Industrial Design

Industrial-design departments are not usually found in universities in small Third World countries. This is unfortunate; it costs little to set up an industrial-design department and it can substantially benefit industrial development. Governments must develop industrial-design education and ensure that it is directed toward product design and development, not just advertising.

Industrial design deals with the human aspects of manufactured products — how the product looks, smells, feels, and tastes, and how it is packaged. It is somewhere between art and engineering, and is much like architecture's role in civil engineering. When it comes to consumer goods, marketability is one of the most important aspects of industrial design. Consider the example of *patis* described in Chapter 1. When the Thais introduced a more attractively packaged product, they virtually wiped out the Filipinos' market share. Industrial design must be a key component of any innovative product development.

Awareness

Government is responsible for building long-term public awareness of S&T in two areas outside the formal education system. The first is in supporting S&T in the media and the second is in promoting S&T museums.

Media

Generally, Third World markets cannot support a purely commercial medium devoted solely to S&T; consequently, it becomes largely a public function. Government must support the print, radio, and television media in stressing the importance of S&T to development. The objective should be to propagate broad information about the following areas:

- Science, technology, and modernization;
- Technology transfer to various industrial sectors;
- S&T that underlies health and environmental issues; and
- S&T as a career choice.

A vibrant S&T media presentation and a real interest in S&T by the public are essential to national development.

S&T Museums

Closely related to science education and S&T media is government support for a "science museum." This widely used term refers to a public awareness mechanism for S&T, usually directed at children. Science museums are immensely popular worldwide, even though they are not usually venerated or financially supported in the same way as national art museums. However, art and science museums share a common goal — to express national genius in an international context. In the case of a science museum, the genius is more closely related to the taxpayers' immediate needs. I prefer the term "science and technology" museums, because it is important to celebrate the productive aspects of S&T, and not just the cultural components.

Facilities

Government must also develop two closely related facilities — technology parks and venture capital. These facilities are introduced here and discussed further in Chapter 4.

Technology Systems, Technology Parks, and Incubators

Governments in all parts of the world are beginning to see technology parks and incubators as a means of promoting regional industrial development and realizing a return on R&D investments. The concepts have merit, but they must be carefully applied to maximize investment value.

Before discussing technology parks, it is important to determine which industrial sectors will pay the greatest return on public investment. Government cannot predict who will use S&T most effectively; planning can do nothing more than facilitate development at a broad sectoral level. There are some basic principles to guide the decision. The first principle is to build on strength. No industry can be invented by government pronouncement. Strength is achieved by first realizing that technology develops systematically. No technology exists in isolation of many closely interrelated factors, including the flow of materials, regulation, finance, knowledge, and other technologies. Each individual technology is embedded in a dynamic "technological ecosystem." Remove any of the interconnected elements and the technology may function poorly, if at all.

A technology system usually involves complex interrelationships between producers, customers, technology service companies, R&D sources, trainers and educators, government regulators, equipment sales and service organizations, and financiers. Some of these organizations are portrayed in Figure 5.

Figure 5 illustrates a technology system in the forest industry. It shows the primary industry — land management, harvesting of trees, and production of wood and paper products — at the centre of a network of product, information, and technology exchanges. It also shows a well-balanced technology system where the flows between products, information, and technology connect the main players, and where the key source of connection is the technology supply node. Government sits in the top oval, setting policy and regulating transactions. Consumers of wood and paper products, as well as suppliers of the machinery and services necessary to operate the primary industry — airplanes, trucks, sawmills, pulp mills, and so forth — are found at both the international and local levels.

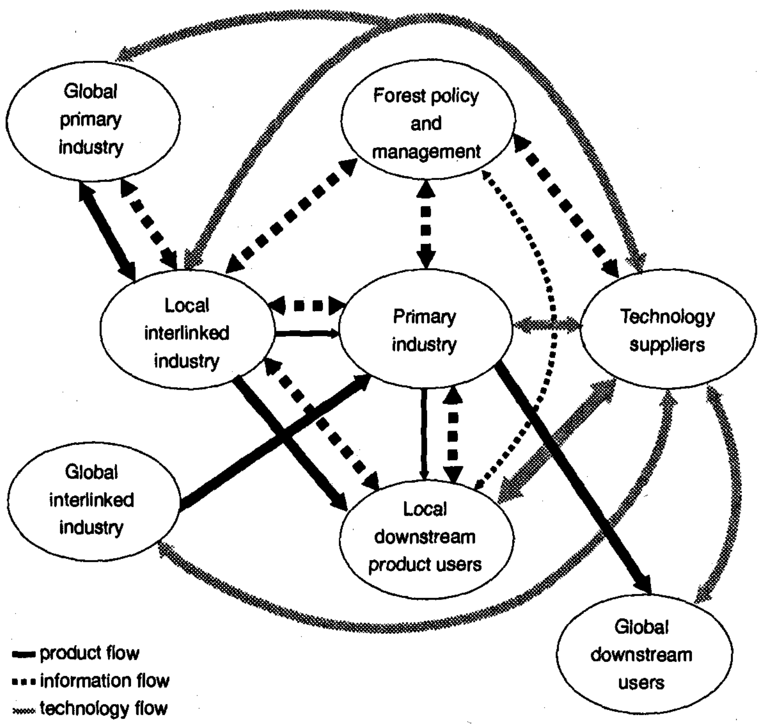

Figure 5. A balanced technology system.
Arrows indicate direction of flow, line thickness indicates volume of flow.

The system illustrated here is probably very different from a forest technology system in most Third World countries. Developing countries are nearly always primary-resource exporters and the equipment needed to exploit the resource is nearly always imported. There is no involvement with local technology and almost none with local industry. Figure 6 shows an unbalanced technology system in the Third World.

This system, viewed from the point of ecosystem analysis, is inherently weak and unbalanced, and easily disrupted by changes in the pattern of exchanges. Nevertheless, it can still provide the embryo for sustainable, self-reliant growth. The system can be built from a small core, and will gradually grow in complexity, size, and sophistication. Furthermore, much of the development can be

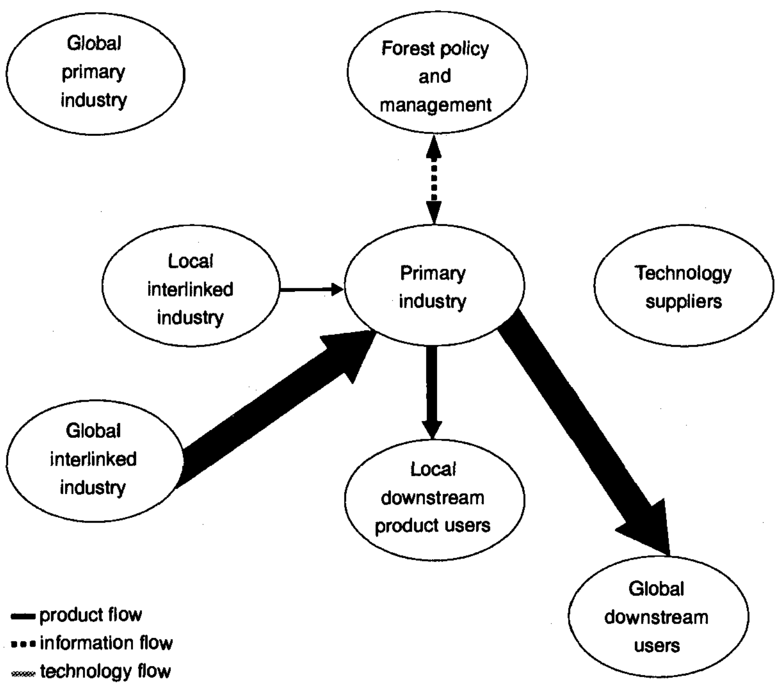

Figure 6. An unbalanced technology system.
Arrows indicate direction of flow, line thickness indicates volume of flow.

self-financed. Government's involvement should be to design the technology system, seed its start-up, and guide its continued development.

Which sectors best foster development of technology systems? The answer is simple: industrial sectors where many of the necessary players and links are already in place and functioning. In practice, this usually includes construction, natural-resource exploitation, transportation, communications, health, and environmental protection, to name a few. To get a better picture of where to focus your efforts and resources, it is helpful to seek the advice of a S&T policy expert.

The reality of the technology system is why technology parks have been created. The technology park creates a dynamic technology system by artificial means. Unfortunately, what is often called a technology park in many Third World countries is merely an export-processing zone, a protected enclave for foreign-owned and managed assembly plants, which uses cheap local labour only and contributes little to sustainable industrial development. In this case, the word "technology" in technology park means only that the industries are modern by local standards; in reality, the structure is nothing more than an industrial park.

Industrial parks have been developed to provide the physical infrastructure — including security, large tracts of land, heavy use of electrical power, and environmental protection — required by some industries. In the case of new technology-based industries, the need is for technology management, finance, industrial design, and industrial engineering. These services do not require a distinct physical location. A technology park can serve both small and large firms, but it is my experience that most large Third World companies involved with innovation or technology-transfer projects are already established and are not likely to move to a technology park. The technology park promotes small start-up firms. However, most of them do not usually require any special physical facilities that an ordinary building cannot supply.

The objectives of a technology park can be more easily achieved by a variety of other investments, as described in

Chapter 4. There is one special circumstance, however, that justifies a type of technology park. I suggest building a physical facility on a university campus to house any new ventures initiated by students, professors, or other entrepreneurial professionals. I prefer to call this setup an incubator because the physical infrastructure is simply a building that provides basic support equipment and services; there is no special site requirement or need for any of the other physical features associated with a technology park. An incubator can house technology-intensive companies that generate new, technology-based products based on their own in-house R&D programs or on strategic technology alliances with other firms, government laboratories, or universities.

A very large-scale incubator is, in fact, a type of technology park: as the concept grows and becomes more complex, it evolves into a type of "science city." Although it is important to invest in incubators, technology parks, and, in some limited cases, science cities — if they are appropriately designed — the limitations of absorption and investment capacity quickly become evident. An economy can absorb only so much S&T, and each country has only limited resources to devote to S&T projects. In most cases, the internally generated finance and management capability to develop dynamic technology systems around science cities is insufficient to warrant the investment. My advice is to begin by investing in an incubator.

Venture Capital

No technology transfer, technological innovation, or technical entrepreneurship project should be undertaken without first ensuring that risk capital is in place. Without proper financing, S&T will have little impact on industrial development.

In most Third World countries, the financial system does little to foster growth of new technology-intensive enterprises. Even in developed countries, financing for technology-based enterprise is extremely limited. In many developed countries, governments have established public venture-capital firms as part of a broader attempt to stimulate development of a venture-capital sector and to take over first-round financing of technology-based start-up firms.

After initially showing a brief interest in technology start-ups, most private venture capital has now moved to lower-risk, shorter-payback investments. This includes second- and third-round financing to help more established firms expand and go public. High failure rates have discouraged many private investors from putting money into technology start-ups. However, few of these venture capitalists have strong management skills; instead, they base their investments on a combination of "hope" and basic financial management skills. Although this strategy has proved rather weak, it does not discount technology start-ups as a worthy investment. Recent experience shows that strong technology management skills coupled with a good incubator facility can increase the success rate for start-ups from 10 to 50 percent.

In addition to capital, a venture-capital firm must possess technical knowledge and technology management and financial management skills. Venture-capital firms can be established in many Third World countries, although most require government assistance. Immature stock exchanges in many countries seldom allow investors to sell their shares on the public market and take a profit. Although the related issues of investment laws and market regulations are not covered here, Chapter 4 includes a project to overcome these difficulties and to realize many of the same benefits enjoyed by a private venture-capital company in the public sphere.

Undertaking Public S&T

The third major principle underlying public-sector involvement in S&T is government's responsibility to fund and implement S&T within the public sphere. This principle is treated separately from infrastructure issues because of its high profile. The key issues of public S&T are as follows:

- Public S&T financing;
- Salaries;

- Range of S&T services;
- Coordinating government S&T;
- Relevance of R&D; and
- Balancing university and government research.

Public S&T Financing

Governments throughout the world agree that the public sector is responsible for a standard range of S&T services and activities. Governments own considerable national S&T infrastructure and usually fund all or most of this internal activity from tax revenues. In most developed countries, government S&T funding constitutes 20 to 50 percent of the total national effort. In the most powerful industrial economies, public input tends to be lower and industrial participation higher. This is not always the case, however; in the United States, for example, a very large defence budget acts as a hidden support to private, civilian R&D.

It is not realistic to expect most state S&T agencies to become totally self-financing. Third World governments have an inescapable responsibility to fund a significant portion of S&T activities if they wish to promote industrial and other related development. The level of funding can be determined by carefully studying needs, projects, and funding capabilities. In most of the Third World, the absolute amounts are not only small, but funding, as a percentage of gross national product (GNP), is usually far lower than in the developed world. State funding must be sufficient to pay not only for researchers' and support staff salaries, but also to fund equipment, facilities, and research programs. Too often, salaries take most of the funding.

Salaries

In Asia and Latin America, the huge wage gap between the private sector and university professors and researchers in public laboratories promotes migration toward the private sector, and compromises the public sector's ability to fulfill its mandate. These work-force deficiencies are legion and cannot be solved until public-sector salaries become more competitive. It is possible to implement salary-supplement schemes with additional funding from the private sector and from international donors. In Zambia, for example, the mining industry supplements the salaries of university and research institute staff who work on solving industry problems.

If government salaries and working conditions cannot be maintained to attract and motivate high-quality S&T personnel, it might be better to privatize S&T services and accept certain losses — including fairness, access, and policy direction — in return for the much greater benefit of useful employment in a more dynamic sector of the economy. Intermediate steps may also be possible; for example, a private management team may run the laboratories on a contractual basis. This route works in some cases, but in others it has proven difficult. Only careful analysis and pilot-scale testing will provide a reliable answer.

Range of S&T Services

Government should have the following basic R&D services in place:

- Public R&D laboratory system;
- Technology extension system;
- University R&D funding system;
- Research and promotion organization for S&T policy; and
- System of R&D or innovation tax credits to private industry.

These services should be structured to support existing industrial strengths and monitor future technological opportunities, as well as any potential threats to industry. Generally, most of the available resources should be directed to providing a large inventory of researchers, manufacturers, and users and to creating a dynamic technology system. The remaining resources usually support essential services and development of new initiatives.

Most developing countries appear to have a public R&D system in place, but, hampered by insufficent financial resources and a lack of direction, it is often weak. The remaining S&T services are often absent altogether. Development of the technology extension service and university R&D funding and tax-credit systems depends on the creation of an S&T Policy and Promotion Council (see Chapter 4). The Council's mandate is to explore public S&T issues and promote policy solutions.

Most public S&T financing will always be directed to R&D laboratories, extension services, university research, and tax breaks to support R&D in the private sector. An S&T Policy and Promotion Council will never account for more than a few percent of the entire public effort. Nonetheless, because it is the one agent that can ensure the overall system is on track, it is probably the most critical investment mechanism. The Council has a difficult role to play. It should be at arm's length from government to maintain independent views, but at the same time it cannot afford to alienate government or it may be ignored or eliminated.

Coordinating Government S&T

Many government departments have their own R&D laboratories, technology policies, technology-development programs, and technology-funding systems. To avoid overlaps, gaps, and inefficiencies, government's total S&T effort should be coordinated in some way. No one solution is better than another; each has its own strengths and weaknesses. The possible solutions range from one extreme to another — from total independence of each department to total integration in one centralized national system. Neither extreme is productive. Optimizing government S&T coordination is one of the tasks of the S&T Policy and Promotion Council.

Relevance of R&D

Public laboratories in the Third World tend to be isolated from industry; consequently, their R&D is driven by internal, scientific agendas. Researchers often propose excellent projects for developing local resources or improving local industrial capacity, but the proposals do not usually involve outside participation. The problem is not with the researchers themselves, but with a lack of local demand for S&T. As a result, laboratories too often spend considerable financial resources bringing internal projects to a demonstration level without first trying to determine market demand. Despite the potential of the product or service, there are few takers, and much of the effort is wasted. This situation is not exclusive to developing countries; it exists in many laboratories all over the world.

Generally, public laboratories should sharply reduce any internal R&D that cannot be shown as relevant to industry. There are several ways to ensure industrial relevance: the laboratory can invite members of industry to sit on its board of directors; it can promote extension services to attract clients; and it can build formal alliances with industry. In fact, public laboratories should only undertake R&D where industrial participation is established at the outset and where ongoing participation is guaranteed. This will ensure that R&D meets market needs and that it can be transferred out more effectively.

Balancing University and Government Research

Over the last decade, university research in most of the least-developed countries has declined drastically. There has also been a corresponding deterioration in the quality of tertiary education and in the ability of institutions to play their proper role in national society. In these countries, declining university research has often been countered by growth in public research. A better balance is needed, however. Universities have an essential role in long-term, fundamental research, and should receive a larger share of public funding, limited though it is. Also, public laboratories should concentrate on coordinated, applied research that will lead quickly to improved productivity and products for industry.

Where regulatory or financial restrictions limit university funding, and where R&D laboratories receive the best researchers and the lion's share of funding, the two institutions should collaborate to ensure that teaching and research are intertwined.

Procuring for Innovation and Integration

The fourth basic principle for public S&T policy relates to procurement policies that support innovation and development of dynamic technology systems in the private sector.

Government is probably the largest purchaser of technology-based goods and services in any country; therefore, its procurement policy must support local development of new S&T-based goods and services. In the procurement process, government acts as a direct buyer, using its purchasing power to control development of specific technology, products, and industry. Procurement is the most direct, most powerful, and easiest industrial development tool to apply.

Assisting local industry to innovate products and services is basic to government procurement policy in the developed world. If such policy can be put into practice in the Third World, it will have an enormous positive effect on industry.

There should be a specific procurement policy and mechanism for promoting innovation, and the principle of encouraging participation of local suppliers of technology-based goods and services should be extended to all government purchases. Here, I am not talking about government's responsibility, as first user, to develop or prove an innovation, but simply about government's obligation to use *all* possible investment — including both national and international development aid projects — to enhance the technological capacity of all national suppliers. These policies often exist in principle, but are seldom applied by either central ministries or state companies.

From experience, it is clear that failure to institute technology policy has seriously affected long-term industrial development in many countries. It is also true that international development assistance is sometimes allowed to distort some national economies and industrial structures. Development assistance, no matter how well intended, inevitably changes the conditions that influence commercial and physical transactions. These changes can severely alter normal development patterns. There are examples where almost all the skills, materials, and equipment for a project are imported as part of a foreign development "assistance" project. Yet in some instances, a modern local company could have easily supplied some of the material inputs, but was unable to bid because the project terms favoured the donor country. All aid projects should be screened by the government to ensure that they will have a favourable effect on development of national technological capacity.

These suggested policy changes are not new. The laws to support them are often on the books; they are simply not applied because local industry cannot supply high-quality inputs or adhere to strict production timetables. The suggestions made here require innovative structures that encourage local industry to form alliances with foreign suppliers to promote strong technology transfer, and that emphasize the importance of quality and the need to meet deadlines.

Encouraging Industry to Act

Although the last principle in promoting S&T is the most general, it is still very important. If government wants to support technology transfer, innovation, and entrepreneurship within private industry, it must mount a strong initiative to *encourage* industry involvement.

Government cannot force technological and industrial development because it does not create or employ much technology itself. Only industry can lead technological and industrial development, and, in a free market system, the responsibility falls on private industry. One very simple and basic principle summarizes this whole chapter, and, indeed, this entire book:

> *The main function of government S&T policy is to get private industry to "pull" S&T according to its commercial needs at the micro level.*

It follows from this principle that most government investment in regulation, policy, programs, and R&D is useful only if industry is willing and able to absorb it. At worst, government investment in isolation from industry can be very costly and show virtually no return.

It is clear, then, that government policy's primary function is to encourage industry to demand and use technology. Government should realize, however, that three major factors influence industrial use of technology:

- Obligation;
- Attitude; and
- Incentive.

Obligation

Many firms do not use S&T because they are in protected markets and do not have to compete to survive. To encourage use of S&T, government can either change market conditions or regulate for quality. In export markets, government must first emphasize why certain quality standards must be met, and then show industry how to meet them. For example, ISO 9000 standards do not describe product characteristics only; they also consider the management systems the firm must use to achieve the necessary product characteristics. ISO 9000 standards can be used, therefore, to oblige firms to consider more sophisticated use of powerful management techniques.

Attitude

Industry's attitude toward S&T must also change. Too often industry — particularly weak or traditional firms — is unaware of and uninterested in learning about S&T's potential to boost competitive advantage. Here government must use training and education to increase awareness of S&T management.

Incentive

In many Third World countries, there are seldom tax incentives to encourage private companies to invest in R&D or S&T-related training; if incentives do exist, they often have a very low limit. In Peru, for example, there is a 2 percent R&D tax. Although it is a good idea for generating an initial, minimal, level of R&D, in certain sectors — including electronics, materials, and chemicals — it is not enough to sustain international competitiveness, especially when other countries routinely invest as much as 20 percent of their income in R&D. If Peruvian companies are even to contemplate competing in the international marketplace, government must offer the same R&D support that private companies in the developed world already enjoy.

Chapter 4

Key Projects to Consider

This chapter incorporates the principles of technology management and public-sector support into a series of projects designed to assist your organization in profiting from technology. These projects include the following:

- MOT Training and Research Centre;
- Incubator;
- S&T Field Advisory Service;
- Technology Development Corporation;
- National S&T Policy and Promotion Council;
- Cooperative Technology Alliance; and
- Regional Technology Promotion Council.

These designs are based on proven concepts; by investing in them, you are likely to realize both short- and long-term benefits. In each case, you should use the basic idea to design an infrastructure project suited to your own needs and circumstances.

The suggestions made in this chapter offer much, but not all, of the support you will require. Issues such as the need for a good standards organization, patent structure, investment legislation, appropriate tariffs, and training for scientists, engineers, and technicians have not been included because they are covered extensively in other publications. The purpose of this guide is to focus on key areas not yet widely appreciated.

MOT Training and Research Centre

The first project deals with human-resource development, one of the most fundamental principles of technology management. The objective is to train university students in science, engineering, management, industrial design, and architecture in the new field of Management of Technology (MOT).

Most technology investments should include professionals skilled in MOT. Without their input, all projects described in this chapter will be severely hampered. To apply MOT techniques successfully to their own environment, these professionals must acquire a base of knowledge through original MOT research in other countries.

The training and research centre project, along with funds to support research, trains the new professors and operates a seminar program and documentation centre. It will generate original MOT research and will train a few scientists, engineers, and managers at the master's level; these individuals, in turn, will become specialist professionals, trainers, and doctoral candidates.

The project will deliver a single MOT course to all undergraduate science, engineering, and management students, and will offer the same course, as an option, to industrial design and architecture students. It will also operate seminars, a small reference library, and a publication service for MOT research, and seminars on specific topics. Periodically, the centre will run short training courses for industry and government professionals; however, once there are sufficient trainers, the courses should be privatized.

The research centre is best developed as a new, interdisciplinary group sponsored by the engineering and management faculties of a university, but allowed sufficient independence from the university to operate a revenue-generating training program.

To promote this project and to familiarize faculty, government, and potential students with it, it may be useful to run a few pilot demonstration courses on key MOT topics. These courses can last from a few days to several weeks.

Table 1. Proposed budget (USD), MOT Training and Research Centre.

Equipment and furnishings	50 000	
Training fund	150 000	
Subtotal		200 000
Annual operating costs		
Salaries		
Three professors	52 000	
Document-centre operator	3 600	
Secretary	2 400	
Equipment maintenance	5 000	
Library acquisitions	7 000	
Research fund	30 000	
Seminar fund	5 000	
Publications fund	5 000	
Income from training courses	10 000	
Annual subtotal (cost)	100 000	
5-year subtotal		500 000
Total		700 000

The budget for this project is based on a preliminary 5-year estimate (Table 1). All figures in Table 1 are in US dollars (USD) and represent typical averages across much of the developing world.

Incubator

The incubator is an essential complement to the MOT Training and Research Centre.

The objective is to create on, or adjacent to, several university campuses, a facility with the necessary equipment, personnel, financing, and specialized technology innovation services to support development of technology-based, entrepreneurial businesses.

In the MOT project, there is no "laboratory" for the students to practice their skills. The incubator, therefore, becomes the place where students with the interest and drive to become entrepreneurs put theory into practice. In addition, the incubator serves those professors who wish to establish their own businesses and witness their technical inventions and skills carried to a logical conclusion. This facility can also serve the community at large.

The project will give students a chance to practice their MOT skills and will assist start-up businesses run by entrepreneurial professors and outside professionals. It will constitute a stimulating meeting place between industry and university. By hiring students, businesses may also be able to participate part time in the activities of the incubator. Some of the businesses will evolve into large, profitable, and dynamic firms working in a global marketplace. At the very least, the incubator will lend direction to the university and help students feel they can contribute directly to their own futures and to national development.

The facility should be a building on or adjacent to the same university selected as the site of the MOT training project. It must supply all basic business infrastructure — offices, reception, cafeteria, meeting rooms, common laboratory or pilot production facilities, secretaries, phones, fax, electronic mail, photocopying, and so forth — as cost effectively as possible. It is usually cheaper to rehabilitate an old building than build a new one.

The incubator must establish relationships with all the technological, management, market, and financial specialists required to innovate products and develop small businesses. These specialized services, like the building itself, may be partially subsidized; in return for the subsidy, the incubator can negotiate part ownership in the firms.

Finally, and most importantly, the incubator should have its own seed-capital investment fund because seed money to launch new ideas is very hard to come by. Therefore, if the incubator were able to evaluate proposals and business plans and had its own seed capital, it would most probably attract other investors. The seed fund must be controlled by the management team and answer to a board of directors drawn from members of private industry, university management, the national R&D laboratory system, and investment institutions. The management structure should ensure that any profits are used to develop the institute's programs, again under the board of directors' guidance.

A new, 2 000-square-metre building would typically cost about 800 000 USD; operating costs would add about another 80 000 USD per year. Equipment costs are estimated at roughly 200 000 USD, with another 20 000 USD per year for maintenance and repairs. Considering all project costs together, the incubator needs about 2.5 million USD for the 5-year period. The seed-capital fund should be set at 1 million USD for 5 years. First-stage concept funding should be made strictly on the basis of the project's commercial viability.

In some instances, incubators can be run at a profit or break-even level; however, for this project, it is not clear what percentage of cost recovery would be possible, or desirable. The seed-capital fund should, however, realize a profit.

S&T Field Advisory Service

The objective of this project is to create a technical and managerial extension service, run by the national R&D laboratory system, to increase industry's capacity to transfer and innovate technology in the short term. This project will also attract paying industrial customers for the laboratory's R&D services.

National R&D laboratories typically have a very low profile in industry, although they offer important services. Much of the problem is simply that the laboratories do not have the resources or structure to promote themselves. To support industry more effectively, national R&D laboratories must learn more about industry's needs and how to promote their own services more fully.

One proven solution is to establish a countrywide, proactive technology extension service. In some developed countries, extension services are among the most popular, effective, and efficient technology-development programs available.

To be effective, an extension service must take the following action:

- Repeatedly visit as many industrial firms in the country as possible;

- Determine industry's needs;
- Promote S&T as a tool for increasing a company's competitive advantage;
- Open one single entry point for the client firm to all government and key international S&T services;
- Help establish links to other firms to promote joint ventures or sales; and
- Promote the concept of alliances and help to design and operate them.

Depending on the size of the country and its industrial base, the laboratory would require from 10 to100 specialized professionals. Initially, the number of professionals should be kept to a minimum, then gradually increased over 3 years. It is unrealistic to begin with a large-scale operation without first ensuring a secure source of funding or proving the effectiveness of the concepts and the design of the delivery system.

The professionals should be from the private sector — not employees of the laboratory system — and hired on contract by the laboratory. This arrangement allows a more entrepreneurial service and encourages the consultants to obtain follow-up work. At the same time, it avoids the problem of low salaries and poor incentives that plague the public sector. It also allows the laboratory more flexibility in choosing its employees and ensures that all necessary specialists are available, even if only required periodically. The consultants should represent all the requisite fields of engineering — with emphasis on industrial engineering — and should include management advisors, industrial designers, and financial experts.

Hiring consultants has an additional advantage: it represents a type of government procurement and fosters the development of a much stronger and extensive private consulting industry with expertise in key technology and management areas. The consulting industry will be able to react quickly to other market opportunities, thereby generating significant spin-off benefits over the middle and long terms.

Initially, two managers assisted by two support staff should run the advisory service. Professionals should be hired to operate the pilot project — which is best located in the main industrial city — and should work in areas where the need is greatest for their services.

Because this is an experimental pilot project, it is difficult to determine exact costs. A reasonable portion of the operating costs should be funded by the users, and user fees should increase as the project establishes itself in the industrial community. During the initial contact stage, the field advisory officers would not charge for their limited assistance. At this point, the purpose is largely to gain the clients' confidence and to illustrate the importance of S&T to their company's future. However, specific services should be chargeable. From this viewpoint, the service is somewhat a "loss leader," as it loses money at the beginning, but brings in revenue later on.

The service has an added benefit: it also promotes other government and university laboratories.

Technology Development Corporation

The Technology Development Corporation (TDC) project is designed to establish a privately managed public corporation to create and foster the growth of new, technology-based businesses.

The Third World has considerable need for technology-based businesses. Many natural resources can be exploited and many people are capable of becoming entrepreneurs. However, technical and market knowledge and management and financial skills are lacking. An entrepreneur who must depend on the development of technology and the availability of risk financing and management expertise faces enormous difficulties.

Although these skills and knowledge may be in limited supply in developed countries, they are delivered reasonably well through either commercial services or special government programs. In most developing countries, there is no venture capital and the provision of technical and managerial skills is neither coordinated nor effective.

The TDC starts as a pilot project so that it can begin operation as soon as possible, and can be monitored carefully, and adjusted accordingly, to ensure the greatest chance of success.

The TDC establishes a nonprofit, privately managed corporation to seek out technology-based business opportunities, create them, and foster their growth. The nonprofit clause is somewhat limiting, but probably necessary because the corporation is publicly funded initially and carries out a public mandate. The TDC is a management company, similar to a venture-capital firm in the developed world, but with the following key differences:

- It has a mandate to identify and create the business opportunity itself, without waiting for an entrepreneur to do so.
- It has expertise in technology management, in addition to the more usual skills in venture financing and start-up management.

The TDC should have a minimum seed fund of 5 million USD to cover its management and investments. The board of directors should include members of management from key technology-based businesses, agencies, and funding sources. The staff should consist of a small core of senior people experienced in start-up management, venture capital, and technology management. Initially, they may all be imported from abroad with nationals apprenticing to them. Young nationals should be cycled through the TDC to gain experience in its operations.

The staff receives proposals from any outside sources, including the board of directors, but may also initiate its own ideas. Interesting proposals are further elaborated and sent to a committee for rigorous evaluation as to their commercial feasibility and profitability. Proposals that survive this process — the rule of thumb is less than 10 percent — may be further developed into business plans by teams consisting of staff, outside experts, and proponents of the proposal. The TDC provides funding for this critical stage. The completed business plans are further evaluated and the survivors partially funded by the TDC and vigorously promoted to other investors. If adequate capital can be secured, the project proceeds. All decisions must be based solely on business considerations and made within the TDC's mandate.

At this point, the TDC's role is just beginning. It will most likely assist in establishing the new venture, arranging staffing, developing the establishment of the innovation program, and securing any additional funding. Staff should be recruited from all possible sources and nationals should apprentice to foreign staff. The TDC is usually a major shareholder, and in some cases becomes the majority shareholder.

The TDC then sells the new venture as soon as it shows an appropriate profit; this could take anywhere from 5 to 8 years. Technology-based ventures are risky and difficult to bring to a point where they can be publicly traded. However, it has been proven that by providing strong technology-management skills and continued assistance during the early stages, the mortality rate can be reduced from 90 to 50 percent. This makes the concept of the TDC worth trying as a pilot project.

When several ventures have been sold at a profit, the concept can be considered a complete success. Profits are then directed back into the seed fund. By training nationals and by setting up companies that may not succeed themselves, but may spawn other ventures that may eventually succeed, the TDC can be judged a partial success.

Near the end of the targeted 8-year plan, the TDC should lay the groundwork for its conversion to a fully private company, with no government ties, and should seek additional funding for the next round of investments. As a private company, it should become profit-oriented. In this way, the TDC becomes a way of creating a private venture-capital industry.

It is difficult to determine an exact budget for the TDC without further study into this novel area. In developed countries, venture-capital funds require a minimum of about 15 million USD. The TDC management costs will be higher than for a standard venture-capital firm because the TDC requires much more project definition work, more technology and market networking, more technology funding, and continued management assistance. This increased professional assistance will, however, greatly increase the success rate of investments. As a first estimate, the fund should not be less than 5 million USD and probably not more than 10 million USD as a pilot project. Management costs should be less than 3.5 percent of the fund.

National S&T Policy and Promotion Council

This project establishes a state agency, operating at arm's length from the government, to carry out applied research on nationally important S&T policy and management issues and to promote its findings to those groups that can best act on the opportunities.

In most Third World countries, there is little knowledge about national S&T policy and management issues. Until strong university research groups are in place, each country will need a public institution to investigate problems and realize opportunities in a rational manner. S&T policy and management issues can only be solved by careful research, not guesswork.

Research by itself is not sufficient, however. Research must be incorporated into action. The Council's second function, therefore, is to promote action based on research. This process includes identifying the appropriate stakeholders and working with them to study, publicize, and resolve the issue. The Council should split its effort fairly evenly between doing research and initiating action.

The size of the Council depends on the size of the country and the complexity of its industrial and S&T infrastructure. The first step is to constitute a board of directors representing key interest and knowledge groups across the country. At the maximum, there should be 20 board members, at the minimum 12. The board directs, but does not control, the research projects. The board, together with a professional secretariat, suggests possible research projects and approves them jointly.

Table 2. Proposed budget, S&T Policy and Promotion Council.

Category	Employees	Salaries (USD)	Expenses (USD)
Management	12	10 000	10 000
Professionals	5	80 000	80 000
Support	3	25 000	
Library	1	15 000	15 000
Publications	3	30 000	30 000
Process action			80 000
Subtotal	24	160 000	215 000
Overhead			160 000
Total annual operating expenses			535 000

The secretariat is essential because the board seldom has the time or specialized skills to address the issues in detail. The size of the secretariat can range from one professional with one support staff to a dozen professionals, most of whom should be trained in MOT or in S&T policy.

The project budget shown in Table 2 is for a Council in a medium-sized Third World country with an average level of development.

Cooperative Technology Alliance

All projects discussed so far have been government initiatives. A cooperative technology alliance, however, can be set up and operated privately. As discussed in Chapter 2, alliances can take many forms; each one depends on the technologies, participants, and industrial sector involved. No one alliance is more important than another. Following are sketches of three alliances with which I have been involved. Each is slightly different, but all are based on the common concept of joining technology, financing, and business to create a powerful organization whose goal is to use S&T to increase a firm's competitive edge.

Biodiversity Research Corporation

The objective is to create a cooperative, industry-owned technology alliance in a major city located in an equatorial rain forest. The alliance would assist corporate members to develop new products based on the biological resources of the rain forest, thereby increasing industrial capacity to support sustainable development.

The rain forest has a wealth of biological resources. Some, such as tropical fruits or hardwoods, are currently being exploited. Others, although known, are not exploited commercially, and still others remain undiscovered. Industrial development of these resources is crucial to the prosperity of both the ecological zone and the ecosystem itself. The ecosystem will be protected only when it gains economic value, and only when it generates profitable business will it be possible to generate the economic rents necessary to manage the rain forest ecosystem in a sustainable manner.

S&T plays a pivotal role in industrial development. First, basic exploratory science is required to determine the true biological wealth of the region, to understand the complexity of the ecosystems, and to discover the biology of individual species. Second, applied science is required to determine the value of some species for commercial production, and how they can be manipulated to increase their value. Third, S&T is required to learn how to transform raw materials into profitable products.

Generally, internationally supported scientific research establishments are active in the rain forest, and are successfully using exploratory science to compile field inventories. However, support for applied science and S&T is insufficient. As a result, entrepreneurs in the region do not have sufficient knowledge to determine which of the many resource properties could be marketed commercially.

The project should encourage industry, not scientists, to take a greater lead in developing potential resources. Entrepreneurs must be allowed to focus scientific and technical investigations on issues they consider commercially viable and in areas where they want to invest. This project will, in effect, reverse the present order in this rain-forest region where science ineffectively tries to fuel industrial development, and industry pays no attention.

This project calls for a company or nonprofit foundation directed by entrepreneurs who will ascribe their national R&D tax levy to the corporation and create a business plan for it. The business plan should be structured to attract outside investors who are concerned with such issues as rain-forest destruction, environmental protection, biological diversity, and ozone depletion. The project can then justifiably advertise itself to potential investors as an environmentally sustainable enterprise capable of harvesting the unique resources of the rain forest, providing the natural resources, and acquiring the knowledge and resources to manage the unique ecosystems for the benefit of all. In fact, the ecology can be preserved only by this type of industrial development.

When adequate funding is secured, the corporation begins its work. The members generate project ideas and technical consultants help to formalize them. The board of directors evaluates the proposals and funds the best ones from its internal resources. The project teams are then constituted, with care taken to ensure the appropriate mix of technological, scientific, design, market, management, and financial skills necessary for effective project development. After initial investigation, it will become evident what additional work and resources will be required for the next steps in the process. The corporation can develop the business plan as an investment venture and channel seed money into it from internal resources. It can also assist in funding the search for additional investors. The underlying principle is that the corporation acts as a profit-seeking investor. If the corporation is chartered as a nonprofit group, it can simply return any profit to the initial fund. Successful projects make money for the corporation and for the original investors.

This project fulfills three objectives: S&T supports business; a new company is created; and a type of local venture-capital business is established.

The project budget depends on the initial fund created by the participating members from their national R&D tax levy, if there is one, or from internal resources. Outside investment should, at least, double the fund, making it possible to attain far higher leverage.

Mining and Technology Development Council

The objective of this project is to link mining-equipment manufacturers, mines, new technology sources, university, government, and finance groups in a mutually beneficial strategic alliance. The alliance then identifies, researches, designs, produces, and sells better equipment in support of the national mining industry, thereby increasing its competitiveness.

The country for which this alliance was created is caught in a dilemma common to many resource-exporting countries. The policy of exporting as much of the mining resources as possible has shaped the country's economic structures. This practice has greatly facilitated importing extraction and processing equipment, but in the process has stunted development of an indigenous mining-equipment industry, even though mining activity is sufficiently large, modern, and prosperous to support substantial secondary activity. Now that natural resources are declining in value relative to technology, this strategy is becoming even more counter-productive.

There are excellent samples of proven solutions. Both Sweden and Finland have transformed their small peripheral economies by linking their mining and forest industries to secondary and tertiary activity. This transformation is based on a long-term S&T investment strategy that supports continuous innovation in resource-based products, resource extraction, processing machinery, and spin-offs. The latter are based on the underlying technological competence gained in the more basic industries. Some of these spin-offs consider themselves as technology companies rather than mining enterprises, and make their living by exploiting R&D related to mining technology.

All countries should follow this lead, if their resource industries are large enough. The first step is to ensure that the national mining industry has access to the technology best suited to its needs, and that new mines can be opened with better technology. This can be accomplished by forming a strategic technology alliance involving all members of the local mining-technology system. There is an excellent model for this alliance in Canada, where the mining industry is trying to counter the declining value of the natural resource, caused by importing foreign-manufactured machinery. The mining industry has established a Mining Industry Technology Council to promote technological innovation and diffusion in the industry, as well as the development of more Canadian mining-equipment manufacturers. The Council cannot effect change by itself; therefore, it has promoted the creation of several new university chairs in mining and in closely related fields of mining engineering. In addition, it has encouraged mining companies to participate in a national strategic technology alliance involving generic, precompetitive research on robotics.

Finally, Chile has shown how alliances can help mining companies use advanced technology. In one well-documented and successful case, Chilean biotechnology was developed to leach ore deposits. Some of this technology has already been diffused to other Latin American countries, but by selling the technology, the Chilean developers became the main benefactors.

By following these examples, it is possible for any mining industry to develop mining and other resource-technology alliances.

This project requires a national technology or industry group to promote the concept of a Mining Technology Development Council, and then to manage an investigation, design the structure, and operate the mechanism. This project will regroup everyone interested in the mining-technology system, develop technology projects, and select, fund, and manage the most viable ones.

The project management team may be drawn from the participating organizations, with virtually no independent structure and operating only for the life of the specific technology activity. Or it may be a permanent council with a budget and small staff, fulfilling broader functions in addition to project management.

The initial management group would be funded by participating companies; the only cost would be to bring in a "big name" attraction to help promote the process to prospective participants.

A Precompetitive Research Network for the Modern Sector

The objective of this project is to create a strategic technology alliance to assist a group of modern, competitive firms to grow and become competitive internationally.

In this case, an association of large, modern, Latin American technology-based firms was set up to work together to promote growth in various areas of national S&T.

Most of the association members' capabilities already surpass those of the state or university R&D systems, and most are competing successfully in other Latin American countries. To ensure continued growth and competitiveness, they require specialized S&T support, which neither the public sector nor development agencies can provide. This support can only be achieved by working together on generic, or common, precompetitive S&T facilities, which they fund themselves. In other words, the concept of the association as a promotion group must be expanded to a strategic technology alliance.

Many successful models exist for this type of alliance. One is in Canada where the function of the group — although similar to the Latin American association — is to take basic strategic research one step closer to product development, while remaining at a precompetitive level. The members pay a fee to join the alliance and can propose R&D projects periodically. The membership fees are matched by a government fund and allotted to successful projects. Normally, the alliance's internal funds do not cover investigation past the feasibility stage. After the research concept is proven and a full research program designed, the alliance management team concentrates on selling the concept to investors.

This design is appropriate as a model, with one modification: venture capitalists and investment bankers, from both within and outside the country, should be included to ensure that product innovations are more directly tied to the market and more completely financed. Once a larger financial base is established, projects will proceed more quickly and more directly to commercial innovations.

Initially, group members would contribute to a seed fund and pay a membership fee. The resulting fund would be used to leverage matching funds from other sources, including, perhaps, development agencies. Because the group members are modern firms competing on international markets, however, it might be possible to obtain commercial funding or enter into other alliances with partners in the developed world.

Regional Technology Promotion Council

Comprised of both individuals and organizations, the Regional Technology Promotion Council explores how S&T can best be used to give value or competitive advantage to businesses and to the community, and promotes supportive action in the community.

Regions far removed from a capital city generally have few S&T services and do not receive the support necessary for their development. Rather than risk a lengthy wait for the central government to lend assistance, regional governments, municipalities, and individuals should initiate action themselves. They often do a better job because they are closer to the local realities and are more directly affected by the success or failure of development initiatives. Communities can establish a Regional Technology Promotion Council involving entrepreneurs, university professors, and residents who want to improve their community's economic life. A Council can be set up for an industrial sector or for industry at the national level. An industrial organization can also establish a new group, or a working group within itself, to investigate and promote S&T as a tool to increase competitiveness.

There is a considerable difference between a Regional Technology Promotion Council and a National S&T Policy and Promotion Council. The regional council is largely a volunteer organization and operates solely in a city, sector, or region. Its main function is to organize events that bring people together to discuss S&T-based industrial issues that inspire action. The National S&T Policy and Promotion Council is countrywide in scope and paid professional staff do insightful analyses. Although diverse, the two groups are also complementary and should work together on appropriate issues.

Regional Technology Promotion Councils are very easy to structure; nearly all are volunteer groups operating rather informally. They require only a skeleton part-time staff drawn from their membership. There should be a small membership fee to fund a news bulletin, or more regular newsletter, and to sponsor special events and training courses. Once a Council becomes successful, it may develop a more permanent and professional structure.

Initially, this project requires no investment because it relies on private initiative and volunteers. As the Council grows, however, it will require a few part-time, and then full-time, staff.

Chapter 5

Taking Action

This book shows that S&T can be harnessed to improve a company's competitive position and that it can be supported at the national level by appropriate policy and infrastructure projects. The next step is to take action.

For project officers with international development agencies, the next step is obvious — simply apply the suggestions offered here to your program area. Government planners in the Third World should first discuss these ideas with local industry and then work with their industrial counterparts to develop the appropriate concepts. Entrepreneurs in the Third World can start by establishing an alliance or Regional Technology Promotion Council.

If you are an entrepreneur and you want to improve your competitive advantage through technology management, it may be necessary to wait until the other pieces of public MOT infrastructure are in place. This infrastructure will be supplied by the MOT Training and Research Centre, the incubator, the S&T field advisory service, and the venture-capital group. Once in place, these organizations will help with your requirement for professional advisors trained in MOT, investors with experience in venture-capital financing, and S&T specialists. You will probably have to lobby government to create these infrastructure organizations; this usually means talking to the ministry of industry or to the ministry responsible for S&T.

If you intend to promote these infrastructure projects to government, be prepared for setbacks. Governments are being asked to act in areas where they have little expertise. Consequently, they may not react to your request because the concepts are new and different, or because they are simply overworked. Alternately, the original idea may be drastically changed to fit a bureaucratic need. Unfortunately, government is the key to nearly all international aid financing and expertise. Moving from the preliminary idea to, finally, the real project is a long and arduous process involving the national government, aid agency, and investigatory team.

Rely on your own resources whenever possible. If you require financial assistance and specialized S&T and MOT skills, obtain them commercially. Official development assistance projects often *seem* advantageous because of the accompanying "free" or concessionary financing and expert advice. In reality, they often carry a high price tag. These projects require considerable preparatory work and must often satisfy some other criteria — usually the priorities of the development agency's home country. The project can end up delivering something different from what you initially had in mind.

We have seen many cases of missed opportunity because agencies and companies have waited for years for development aid, rather than pay an expert to design an appropriate project in a few weeks. Because few groups have the financial resources to pay for specialized advice and assistance, it would be much more advantageous to form an alliance and pool your resources. Technology transfer is effective only when the group who wants the new technology is aggressive, self-interested, and proactive.

If you are a government planner, looking for official aid programs or experts to help you develop the MOT infrastructure projects suggested in this guide, where do you start? The organizations most knowledgeable in S&T are the United Nations Educational, Scientific and Cultural Organisation (Unesco) in Paris — which recently began emphasizing the more practical use of S&T, instead of just promoting S&T capacity; the United Nations

Industrial Development Organization (UNIDO) in Vienna — which focuses on industrial development, but considers the S&T aspects as well; and the International Development Research Centre (IDRC) in Ottawa — which has recently moved more strongly into the "commercialization" aspects of research.

The main international development banks, such as the World Bank in Washington, DC, tend not to have programs directed specifically to S&T management, although they often deliver projects involving technology support as part of related initiatives. Some of these projects meet the highest standards in terms of knowledge and professionalism. Development banks will consider projects suggested in this guide if they are presented within the framework of the banks' usual activities.

Occasionally, national development agencies — including the Canadian International Development Agency (CIDA), the Swedish International Development Authority (SIDA), and the United States Agency for International Development (USAID) — will undertake projects aimed at developing institutions for production or use of S&T. This occurs more often in Southeast Asia, where the prospects for success are considered to be higher, than in Africa, for example. The "better" national aid agencies, however, pride themselves on being responsive to local needs; these agencies can be approached with any proposal, regardless of your country's level of development. It may not be easy, but it is possible to make the international aid system work for you.

You *can* take your future into your own hands and manage technology to increase your competitive advantage. Remember, however, the key to success is your own entrepreneurship, commitment, and drive.

Appendix

Suggested Readings

There are thousands of books and research journals on technology management. Most are for academics and university students, and deal with broad principles and developing research ideas. Few, unfortunately, provide practical guidance to technology-based industrial development in the Third World. The few listed here are more practically oriented.

Betz, F. 1986. Managing technology. Prentice-Hall, Englewood Cliffs, NJ, USA.

Good summary of the issues in an easy, readable format.

Doyle, D. 1992. Making technology happen: a handbook for entrepreneurs, investors, scientists, economic development officers and public servants. Doyletech Corp., Kanata, ON, Canada.

Highly recommended for its practical, do-it-yourself, can-do approach, based on a lifetime of experience as a senior business executive and investor in new technology-based companies. Deals with modern S&T-intensive industry in Canada, but the lessons are instructive for Third World economies as well.

Kamenetzky, M.; Maybury, R.; Weiss, C. 1986. Choice and management technology in developing countries. World Bank, Washington, DC, USA.

Broad range of examples in humanistic context by authors with extensive experience in the field.

Nelson, R.R. 1993. National innovation systems: a comparative analysis. Oxford University Press, New York, NY, USA.

Highlights the key concept of building dynamic technoindustrial systems of public and private groups.

Noori, H. 1990. Managing the dynamics of new technology: issues in manufacturing management. Prentice-Hall, Englewood Cliffs, NJ, USA.

Excellent survey of technology management in the manufacturing industry from the perspective of industrial engineering. Deals with the manufacturing industry in Canada; readers in countries with poor infrastructure will have to be imaginative to apply its conclusions.

Timmons, J. 1990. New venture creation. Irwin, Homewood, IL, USA.

Practical workbook on how to set up a new business in the United States. The approach can be easily adapted and duplicated for other countries.

World Bank. 1993. The East Asian miracle. World Bank, Washington, DC, USA.

Focuses more on macroeconomic issues relating to technology.

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His previous publications include *New Technologies and Business Development in Africa*, which he coauthored with Fola Osotimehin (OECD Development Centre, Paris, France. 1992).

About the Institution

The International Development Research Centre (IDRC) is a public corporation created by the Parliament of Canada in 1970 to support technical and policy research to help meet the needs of developing countries. The Centre is active in the fields of environment and natural resources, social sciences, health sciences, and information sciences and systems. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

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- What are the key projects to undertake to build the capacity to manage technology?

In answering these questions, *The Key to Profit* challenges and informs all those interested in mobilizing science and technology to further advance development goals.

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