

III. INITIATIVES IN SELECTED NEWLY INDUSTRIALIZED COUNTRIES

A. SINGAPORE TECHNOLOGY POLICIES¹

The Government of Singapore is committed to the development of a knowledge-based economy for the country, driven by manufacturing and services. Capacity-building measures were initiated in 1991 with the first five-year National Technology Plan (a second was launched in 1996), which sought to encourage industrial R and D and innovation by means of capital investment, technology development and skill formation through training. Technology development has been nurtured under key programmes for electronics, chemicals, the life sciences, engineering, communications and the media. The industrial structure has been considerably altered as a result of direct foreign investment targeting technology transfer.² As a result of all these efforts and its IT2000 strategy (see frame 28), Singapore is now the most technologically advanced of all the South-East Asian countries.

Frame 28. Singapore IT2000 Vision

Singapore is well ahead of other Asian economies in becoming a knowledge-based economy based on its strategy "IT2000: A Vision of an Intelligent Island", formulated in 1991, which states:

"In our vision, some 15 years from now, Singapore, the Intelligent Island, will be among the first countries in the world with an advanced nation-wide information infrastructure. It will interconnect computers in virtually every home, office, school and factory. The computer will evolve into an information appliance, combining the functions of the telephone, the computer, the TV, and more. It will provide a wide range of communication means and access to services. The vision of the IT2000 is based on the far-reaching use of IT."

The main objectives of the IT2000 strategy, formulated in August 1991 as a response by the National Computer Board to *The Next Lap*, a master plan for development formulated by the Singapore Government, are the following:

- (a) Developing a global hub for Singapore to become a switching centre for goods, services, capital and information worldwide, and a hub for business, services and transportation;
- (b) Improving the quality of life through a wide range of electronic applications in the economy, society and households;
- (c) Boosting the economic engine by using ICT to revitalize Singapore's traditional economic sectors;
- (d) Linking communities locally and globally to enhance communication between the Singaporean community at home and abroad and with the rest of the world;
- (e) Enhancing the potential of individuals through government provision of improved opportunities and technologically advanced means for lifelong learning.

Source: OECD, *Knowledge-based industries in Asia* (Paris: OECD, 2000).

In implementing this strategy, the main focus, as recommended by the government-appointed Committee on Singapore's Competitiveness, has been on developing manufacturing and services, strengthening exports, building world-class companies, promoting local SMEs, developing human and intellectual capital, leveraging science, technology and innovation, optimizing resource management and enhancing government as a business facilitator.

¹ This section is based on a study conducted for ESCWA by Sam Garrett-Jones, entitled *National Science and Technology Initiatives for ESCWA Member Countries: Lessons from the South and East Asian Region*, resource document for the Expert Group Meeting on Initiatives for Science and Technology Capability-Building in the Twenty-first Century, Beirut, 1-3 November 2000.

² S. Liyanage and S. Hill, *Taxation Concessions for Research and Development in Selected Asian Countries: A Report Prepared for the Industry Commission by the Centre for Research Policy* (Canberra: Industry Commission, July 1994).

Approximately four billion Singapore dollars (approximately US\$ 2.4 billion) were allocated for R and D under the 1996 National Technology Plan. These funds targeted key technology areas with support for R and D activities, qualitative and quantitative human resource upgrading, and the development of an efficient R and D support infrastructure. A total of 13 public research institutes/centres and two universities linked to these R and D establishments received funding. Much of the research focused on information, materials and manufacturing technologies, but other areas were also covered, including biotechnologies, environmental technologies and remote sensing. The Government of Singapore, in pursuit of its goals, plays a vital role as a catalyst of industrial and technology-related R and D, and intends to go on doing so.

The action plan entitled *Singapore One* is a major milestone in the realization of the IT2000 vision focused on the creation of information infrastructure, including (i) a broadband infrastructure level of high-capacity networks and switches, and (ii) advanced applications and services built on the technological advantages of the infrastructure. As for the development of knowledge-based activities, *Industry 21* is a blueprint for the development of electronics, chemicals, the life sciences, engineering, education, health care, logistics, communications and the media, as well as promoting Singapore-based multinational enterprises.

B. MALAYSIAN INITIATIVES

1. *Malaysian technology policies*

In Malaysia, the Ministry of Science, Technology and the Environment (MoSTE) is responsible for policy formulation on S and T as well as R and D in the public sector. It is also responsible for the implementation of plans and the performance of government agencies concerned with S and T. The National Council for Scientific Research and Development (NCSRD) and the Academy of Sciences advise the Minister on S and T matters.

Malaysia's S and T national plan and "vision" have been very effective in attracting multinational companies to establish technology development and R and D operations in the country, as well as guiding them in selecting appropriate capacity-building initiatives. Knowledge-intensive technologies are the key targets of Malaysia's *2020 Vision: Towards a Developed and Industrialized Society*. ICTs, microelectronics, biotechnology, advanced materials, environment and energy are the main fields targeted by this blueprint for the next 20 years. In addition, the Sixth and Seventh Malaysia Plans (1991-1995 and 1996-2000) as well as the Second Industrial Master Plan (1996-2005) have led to an increase in R and D expenditure in the public and private sectors. At the same time, the Industrial Technical Assistance Fund (ITAF), introduced in the early 1990s, provides grants to SMEs for conducting feasibility and consultancy studies, designing and developing innovative products, and enhancing quality, productivity and marketing.³

Agriculture and natural resources constitute the traditional areas of focus for Malaysian public research institutes, but the government is increasingly targeting industry as a source of future growth in national R and D, and emphasizing ways to increase the capacity of the institutions standing behind industry while establishing strong linkages between industry and the public sector.⁴

Two institutions have contributed greatly to the growth of venture capital and of research result commercialization in Malaysia. The first is the Malaysian Technology Development Corporation (MTDC), an innovative firm aiming at transforming ideas into marketable products. The second is the Malaysian Industry/Government Group for High Technology (MIGHT), a non-profit company whose members are the main research centres/universities, government research organizations and policy agencies, business groups, more than 70 technology-active companies and Technology Park Malaysia.

During the past few years, the Government of Malaysia has launched a variety of initiatives designed to keep the country on top of the latest advances in the ICT services sector. "Corridors" or regional development zones for specific industry capabilities have been given priority in a substantial national effort.

³ Ibid.

⁴ Turpin, *Science and Technology Policies in Asia-Pacific Economies*.

In particular, the Multimedia Super Corridor (MSC) is a bold initiative to integrate S and T with industry (see frame 29).

Frame 29. Malaysia's Multimedia Super Corridor

On 1 November 1995, Prime Minister Dr. Mahathir Mohamad announced the establishment of the Multimedia Super Corridor (MSC), and in June 1996, the Multimedia Development Corporation (MDC) was set up to oversee its implementation.

Geographically, the MSC is 15 km wide and 50 km long, stretching from Kuala Lumpur city centre to the New Kuala Lumpur International Airport in Sepang. Intended to deliver a number of sophisticated investment, business, research and lifestyle options, the ambition of the MSC is to become:

- (a) A vehicle for attracting world-class high-technology companies to Malaysia and for developing local industries;
- (b) A multimedia utopia offering a productive, intelligent environment for producing a multimedia value chain of goods and services to be delivered across the globe;
- (c) An island of excellence with multimedia-specific capabilities, technology, infrastructure, legislation, policies and systems for competitive advantage;
- (d) A test-bed for invention, research and other groundbreaking multimedia developments;
- (e) A global community living on the leading edge of the information society;
- (f) A world of smart homes, smart cities, smart schools, smart cards and smart partnerships.

The implementation of the MSC plan within a 20-year time frame will be carried out in three phases:

Phase I: Initial conceptual and physical phase to attract a core group of world-class companies, launch seven flagship applications (these include Electronic government, National multipurpose card, Smart schools, Telemedicine, Borderless marketing centres, Worldwide manufacturing webs, and R and D clusters), put in place a framework of cyber laws, and establish Cyberjaya and Putrajaya as leading knowledge-based cities.

Phase II: The MSC will be linked to other cyber-cities in Malaysia and the world; a web of corridors will be created; a second cluster of world-class companies will be attracted to Malaysia; and Malaysia will set global standards for flagship applications.

Phase III: Malaysia will be transformed into a knowledge-based society as a global test-bed for new multimedia and IT applications and a cradle for multimedia companies; it will have a cluster of intelligent cities linked to the global information super highway, and become the platform for the international Cybercourt of Justice.

Source: Malaysia Multimedia Development Corporation (1999).

Of key importance in current government initiatives is a move toward a more integrated approach in science, technology and innovation policies. These involve institutional reorganization, infrastructure development, the building of strategic alliances at the national and international levels, and the upgrading of the technical skills and mobility of R and D personnel.⁵

2. Technology Park Malaysia

The first Malaysian technopole, Technology Park Malaysia (TPM), was established in 1988. It was given the status of a company under the Companies Act, and had for its objectives the commercialization of local R and D output and the development of indigenous technology. Other technopoles followed, including the Johor Technology Park, the Technovation Park and the Kulim High Technology Park. All of these are property-based developments that seek to attract high-technology firms by providing advanced infrastructure, a pool of technology specialists, R and D facilities, business management expertise and venture capital within the confines of a single compound.

⁵ Ibid.

Technology parks in Malaysia promote interaction between academia and industry, encourage the development of knowledge-based industries and stimulate job creation. As companies, these parks are also supposed to earn profits, providing a return on investment for their sponsors. They focus on programmes designed to stimulate innovation and sustain the development of novel products based on R and D conducted in local institutions and the commercialization of those products.

TPM, which currently comprises 12 buildings, is located on 3.25 square kilometers of land in the MSC zone. It provides ultra-modern infrastructure and services to facilitate private sector R and D as well as innovation, particularly in knowledge-based industries. This includes a LAN infrastructure, a dedicated Internet connection and tele-conferencing facilities. Facilities such as a business centre, an auditorium, conference and meeting rooms, an exhibition area, a multimedia centre and a “smart” learning centre are also available for tenants’ use.

TPM participates in the commercialization of research results and facilitates technology development partnerships between government and private sector firms. It also provides counseling and support in marketing and management for start-ups. It has three levels of incubation schemes:⁶

- (a) Innovation House: Where entrepreneurs, researchers and innovators can develop a project based on an innovative idea that may lead to a prototype for a new product;
- (b) Incubator Centres: Where entrepreneurs can move from prototypes at the pre-production stage through to market testing and the establishment of start-up firms;
- (c) Enterprise House: Where firms of various sizes or R and D corporate branches can be hosted to develop innovative products based on R and D carried out at TPM.

Venture capital is provided at TPM for funding enterprises at various levels. An initial start-up fund is available for embryonic enterprises or firms that need initial funds for manufacturing, marketing and selling innovative products. An expansion fund is also available for established firms that need to broaden their business spectrum and guarantee continuous growth. Mezzanine funds are available to firms that will go public within six months to a year in order to help them strengthen their financial situation.

TPM’s tenants, of which there are currently 90, focus on the following technological fields:

- (a) Information technology;
- (b) Advanced materials;
- (c) Biotechnology and biomedical and pharmaceutical technologies;
- (d) Aerospace, defence and remote sensing;
- (e) Environmental and pollution control technologies;
- (f) Technologies for the agri-food industry;
- (g) Manufacturing and robotics technologies;
- (h) Microelectrical and electronic technologies.

3. *The SIRIM Technology Incubator*⁷

SIRIM Berhad, which was incorporated in 1996, had been known for over 20 years as the Standards and Industrial Research Institute of Malaysia. It is a multi-disciplinary public R and D institution and a leading knowledge-based industrial solution provider. In 1986, it launched a technology incubator scheme offering integrated facilities for entrepreneurial and SME development. While the initial focus was on classical technologies such as molding, welding, electroplating, ceramics and plastics, advanced technologies such as mechatronics, CAD/CAM, industrial automation and instrumentation, robotics, multimedia, polymers, and environmental technologies have become increasingly prominent in the course of time.

⁶ M.A.H. Aton, N.A.K.N Abu Bakar and H.N.R. Ismail, “Technology incubation in Malaysia,” *Tech Monitor*, January-February 2001.

⁷ Ibid.

During the past 15 years, moreover, the incubation process has developed into a complete process, from technical conception to commercialization.

Tenants usually remain in the incubator for one to two years, going through a three-phase incubation process:

(a) **Entrepreneur development phase:** During this phase, the basic principles of effective entrepreneurial development are taught to would-be entrepreneurs, with a view to increasing their competencies, enhancing their knowledge and upgrading their skills;

(b) **Enterprise creation phase:** During this phase, entrepreneurs learn how to start an enterprise, with the various attendant business and technology requirements, and the details of organizational and management structure, putting into practice, in a controlled environment, the principles and theoretical knowledge that they have acquired during the previous phase;

(c) **Market development phase:** During this phase, the entrepreneur learns how to proceed from a novel idea to the launch of a product on the market; business support links to suppliers and to the business community at large, at both the local and international levels, are also created.

The success of the SIRIM incubation scheme has led to its expansion into a network of eight regional/state offices around the country. The regional incubation schemes emphasize the need for developing and supporting SMEs in accordance with national development plans, thereby furthering the work of realizing the Government's vision.

The SIRIM incubation scheme is being developed into a "one-stop techno-business incubator centre" concept that will be implemented in Sepang, within MSC, and should serve as a hub incubator for all activities in Malaysian technology parks. It is strategically located close to major highways, making the marketing and distribution of products much easier. The main focus areas of this incubator will be artificial intelligence, robotics, sensors, automation and control. It should be able to accommodate about 50 resident tenants and 20 non-resident firms, with links and affiliations to other incubators, technology and financial partners, as well as to funding managers. Services will be expanded to include, among other things, the possibility of leasing flexible space and equipment, expert advisory panels, networking assistance with government agencies and academic institutions, and affiliation to other incubators. Computer software constitutes the main driving force of this incubator, covering CAD/CAM applications in mechanical, electrical, electronics and control applications with analytical and simulation modules.

The main features of the SIRIM technology incubation model, as embodied in its Technology Incubator Programme, are:

(a) Enhancing "smart partnership" involving collaborative activities between government, academic institutions and incubators in order to accelerate the growth of technology based firms;

(b) Implementing the national policy agenda on entrepreneurial development;

(c) Sustaining national visions developed by the government;

(d) Sharing experiences with other third world and developing countries and helping them in the process of technology transfer.

This programme is expected to help establish a technology-based incubation scheme marked by close collaboration among business, science and technology. This should enhance synergy by bringing together available resources and expertise from all sectors of the economy. The repository of knowledge expected to result from this endeavour will be beneficial for the entrepreneurial community.

C. CYBER KOREA 21 VISION

In 1996, the South Korean Government decided that it should prepare for the country's transition to a knowledge-based society as the twenty-first century approached. By March 1997, work had begun on a plan known as "Cyber Korea 21 Vision", built on the Government's Master Plan for Information Promotion (1996-2000). This "vision" emphasized that South Korea would be a creative nation in the knowledge-based society of the coming century, and would be able to compete with advanced countries and attain a standard of living equal to theirs.

In June 1998, the plan was published under Section 5 of the *Framework Act on Information Production*. It consisted of three parts. The first painted a picture of a creative, knowledge-based society, the second dealt with key initiatives and the third developed promotion strategies for Cyber Korea 21.

The basic objectives of this vision were as follows:⁸

- (a) Early establishment of an information infrastructure;
- (b) Increasing productivity and transparency of all economic players, including business, government and individuals, through the utilization of advanced ICTs;
- (c) Promoting new businesses and creating new jobs through the utilization of ICTs;
- (d) Designating competitive telecommunications products and services as key export products.

Table 11 shows the quantitative targets that are to be reached by 2002 in the Cyber Korea 21 vision. A number of initiatives have been planned with a view to making substantial improvements in the social, economic and welfare aspects of South Korean society. Government leadership and massive public investment are key elements in this plan. During the implementation period (1998-2002), resources have been concentrated on three key areas:

- (a) Information infrastructure;
- (b) Wiring government, business and individuals;
- (c) Reinforcing growth in the software and information provider industries.

The South Korean Government, applying market principles in accordance with Korea's World Trade Organization (WTO) obligations, has encouraged private sector participation in the implementation of this plan.

TABLE 11. QUANTITATIVE TARGETS OF CYBER KOREA 21 VISION TO 2002

	1998	2002
Network service speed	33.6 Kbps	2 Mbps
Number of Internet users	3 million	Over 10 million
Number of schools connected to the Internet	1,613	10,400
Number of institutions using digitized public procurement	556	26,000
Market volume of e-commerce	US\$ 47 million	US\$ 3.2 billion
Number of local administrations with electronic information system	4	232
Total number of PCs (number of PCs per 100 persons)	6.63 million (14)	15 million (32)
Information and communications industry's - production value ¹ - export value ¹	US\$ 76.8 billion US\$ 30.1 billion	US\$ 116 billion US\$ 47.1 billion
World ranking in computerization	22 nd	Among the most advanced information societies

Source: Korean Ministry of Information and Communication (1999).

¹ Forecasts by the Korea Information Society Development Institute, December 1998.

⁸ OECD, *Knowledge-based industries in Asia*. <http://www.oecd.org/dsti/sti/industry/indcomp/prod/ind-asia.htm>.

D. BRAZILIAN TECHNOLOGY-BASED INITIATIVES⁹

1. Background

For some time now, experts have identified one weak link of Latin American innovation systems in a relatively ineffective university sector. Universities in the region have typically been teaching institutions having few links with industry,¹⁰ they have been largely dependent on part-time faculty who pursue parallel careers outside the university proper, and they have trained only small numbers of students.¹¹ University reform has been on the policy agenda of many Latin American countries for some time. It has now moved to an unprecedentedly high place on that agenda in view of renewed interest in the “triple helix” of government-university-industry co-operation for economic development.¹²

Brazil has long debated two alternatives in its approach to university reform. One is to rely on broadening access to education and concentrating research on topics relevant to Brazil’s existing industry and agriculture. The other is to build academic institutions based on the latest foreign high tech, adapted to Brazilian conditions.

The direction and outcome of university reform efforts in the country have also been influenced by changes in the more general objectives of industrial and S and T policy. In the 1950s, Brazil went through a period of rapid industrialization as a result of foreign direct investment in heavy industry and infrastructure, encouraged by special treatment and government subsidies. Economic and social instability in the early 1960s led to a military takeover in 1964, and the country remained under military rule until the mid-1980s. During this 20-year period, governmental policies became increasingly nationalistic, emphasizing the development of indigenous industry and human capital, partly through strong protection from foreign competition. Military governments implemented three “Basic S and T Plans”, the third of which, in the first half of the 1980s, singled out telecommunications, chemicals, and petrochemicals as priority areas.¹³

The major economic/financial problems confronting Brazil in the early 1980s hastened the downfall of military rule and brought democratically elected governments into power. Since then, the country has been open to the forces of international competition.

⁹ This section is largely based on a study by N.S. Vonortas entitled *Science and Technology Policy Initiatives in the Americas*, which was prepared for ESCWA in October 2000.

¹⁰ With a few exceptions: in 1984 the Federal University of Paraíba in northeastern Brazil set up a technology park which currently accommodates some 60 technology-based enterprises, many of them spin-offs established by university students. The city of Campina Grande has benefited considerably from the park, whose tenant firms, making everything from display panels to business software, account for nearly 20 per cent of the city’s economy (an estimated US\$ 650 million). Moreover, the yearly average income of local employees is approximately US\$ 2,500, which is double the regional norm (*Newsweek*, 30 April 2001).

¹¹ Needless to say, this is an oversimplification. For an excellent in-depth analysis of universities and university-industry linkages across Latin America, see Judith Sutz, “The university-industry-government relations in Latin America,” *Research Policy*, 29 (2000), pp. 279-290. In addition to the general socio-economic context, Ms.Sutz also discusses both top-down (government-initiated) and bottom-up university-industry initiatives.

¹² H. Etzkowitz and L. Leydesdorff, *Universities in the Global Knowledge Economy: A Triple Helix of Academic-Industry-Government Relations* (London: Cassell, 1997).

¹³ C.J. Dahlman and C. R. Frischtak, “National systems supporting technical advances in industry: the Brazilian experience,” in R. R. Nelson (ed.), *National Innovation Systems* (New York: Oxford University Press, 1993).

2. *Technological Development Company*¹⁴

Technology incubation has won a significant degree of popularity in Brazil as a development strategy.¹⁵ The Technological Development Company (CODETEC), established at the State University of Campinas (UNICAMP) in 1978, was the first incubator project in a Brazilian academic institution.

UNICAMP itself was a very young institution at the time. It was set up in the mid-1970s by proponents of the “elitist” approach to university reform as a research university with close ties to industry. The ultimate goal of the university’s founders was to create a Brazilian equivalent of the Santa Clara Valley, the high-tech region around Stanford University in California.¹⁶ UNICAMP was thus positioned next to the leading commercial and industrial centre of the country, the city of São Paulo, and efforts were made to induce existing R and D laboratories to relocate to the Campinas campus. In the process of emulating Stanford’s park, CODETEC was established shortly thereafter with a view to generating new companies to commercialize research conducted on campus.

In its early phase, CODETEC combined elements of an incubator facility, a technology transfer centre and a venture capital firm. The idea was for university faculty to bring over ideas emanating from their research, to be further developed into marketable technologies and viable businesses by the institution. That phase also coincided with the second Brazilian “Basic S and T Plan” which, influenced by the global energy shock, emphasized alternative energy technologies. This focus affected the nature of research on UNICAMP’s campus, making alternative energy the top priority, followed by telecommunications (optical fibre and semiconductor lasers). This, in turn, affected CODETEC’s focus areas: most ideas brought to it for commercialization related to alternative energy sources and technologies.

Two important events, one local and another national, obliged CODETEC to shift its focus drastically in the early 1980s. First, in 1979 UNICAMP fell into a deep institutional and financial crisis, ending up with the loss of many of its best faculty members, especially those who had been recruited from abroad. For an organization like CODETEC, this was double jeopardy: the best minds responsible for the ideas on which it depended were leaving campus, and the university leaders’ attention was diverted to the problem of survival, leaving CODETEC in obscurity and great danger. Second, about the same time the Brazilian economy entered a deep recession that put an end to a long period of rapid development. National industrial and S and T policies turned more protectionist than ever before, raising tariffs and encouraging substitution of local for foreign products. Specific areas, such as medicine, plus chemicals, petrochemicals and telecommunications, were targeted for support.

In response to decreasing demand for its services from university faculty members, CODETEC changed its strategy extensively to reflect national industrial policy. Supported by a large contract with the State Medicine Centre (CEME), CODETEC found a niche as a developer of products for Brazilian chemical and pharmaceutical firms. Under a highly protective regime, the role of CODETEC changed from technology transfer from UNICAMP to the reverse-engineering of foreign products in preparation for domestic production. This was CODETEC’s import substitution phase.

With the advent of civilian government in the mid-1980s and the resumption of foreign competition, many of the protected businesses disappeared. CODETEC realized that it needed to change strategy once more. This time, it opted for upgrading to products that were more complex and difficult to produce. In addition, rather than simply reverse-engineering products for others, CODETEC decided to add more value

¹⁴ This section is based on H. Etzkowitz and S. N. Brisolla, “Failure and success: the fate of industrial policy in Latin America and South East Asia,” *Research Policy*, 28 (1999), pp. 337-350.

¹⁵ Business incubation has, of course, been a popular development strategy in many other emerging economies. See R. Lalkaka, *Lessons from International Experience for the Promotion of Business Incubator systems in Emerging Economies* (Vienna: UNIDO, 1997) for a summary of experiences.

¹⁶ In the past quarter of a century, UNICAMP has become one of the major universities in the country, accounting for a large share of all research conducted in Brazil.

by developing and marketing fine chemicals and pharmaceuticals itself. The next step was for CODETEC to go into manufacturing, reasoning that it could do so on the basis of its installed reverse-engineering machinery.

At that critical moment in the organization's history, two key people passed away: the head administrator and the chief chemist. Inability and delays in replacing its leadership led to the loss of critical government funds, bringing the organization to its knees. Following a failed attempt to privatize, CODETEC went into receivership.

It is an open question whether the fall of CODETEC was really the outcome of this sudden and unfortunate event. Coming at a crucial moment, that event may simply have brought deeper problems to the surface and hastened the inevitable. One set of problems may be related to the nature of CODETEC. The organization was set up in times of plenty (the last stages of the Brazilian "economic miracle") and operated first under university protection, promoting technology transfer from the university, and then under government protection, supporting import substitution policies. CODETEC had never really proved itself in the market. The final step of turning itself into a company to develop, manufacture and sell fine chemicals and pharmaceuticals in the open market, exposed to international competition, was the boldest it had ever taken in its history, and there was no evidence that it would have been likely to work.

3. "Re-engineering" engineering research and education¹⁷

In the mid-1990s, the Agency of Studies and Projects Financing (FINEP) of the Brazilian Ministry of Science and Technology announced a programme for Engineering Development (PRODENGE). The programme aims at fostering (a) the modernization of engineering education and (b) co-operative research networks through its two subprogrammes: Re-engineering Engineering Education (REENGE) and Co-operative Research Networks (RECOPE). Both subprogrammes involve university-research institute-industry co-operation.

All stakeholders in the development of engineering in the country, including entrepreneurs, professional engineers and their associations, scientific leaderships and university authorities, have been involved in the design and implementation of the programme. A Steering Committee headed by an appointed General Coordinator and supported by FINEP staff co-ordinates and manages the programme at the national level. FINEP has established partnerships with the National Council of Scientific and Technological Development (the country's oldest and most important research promotion body), the Ministry of Education and Sports, and the Co-ordination for the Development of Higher Education Personnel in order to facilitate the delivery of funding packages, including research grants, scholarships, fellowships, support for consulting activities and business loans. FINEP has also obtained a loan from the Inter-American Development Bank, with the obligation to find matching resources for the support of the programme.

A budget of \$35 million has been designated for the first four years of REENGE. While not substantial when considered in relation to the large number of schools involved,¹⁸ the resources have reportedly served as a catalyst for change by creating a venue for discussing the modernization of engineering teaching. Several workshops on engineering education have been organized for heads of engineering colleges to discuss all aspects of engineering education modernization. In addition, a call for proposals has been announced for selecting colleges to be funded by REENGE. Forty-three colleges of engineering have been selected to engage in re-engineering their undergraduate programmes. They have formed regional coalitions to exchange experiences and share educational experiments.

¹⁷ This section is based on W.P. Longo, I. Rocha and M. Hortencia da Costa Telles, "Reengineering' engineering research and education in Brazil: co-operative networks and coalitions," *Science and Public Policy*, 27, 1 (2000): 37-44.

¹⁸ There are more than 120 MA degree programmes and more than 60 Ph.D. programmes in engineering, qualifying approximately 7,000 and 3,000 students respectively every year. In addition, some 136,000 undergraduate students enroll in engineering programmes yearly.

The results, which have been deemed generally successful, include several newly developed products such as ten mini-baja racing cars, two soccer games with robot players, a pilot plant for extracting rosemary oil, an automated CD library and an energy-efficient house.

RECOPE represents the first large-scale effort to organize co-operative research networks in Brazil. It organizes networks for priority research themes, including both long-range research in strategic subjects and shorter-term, specific problem-solving research projects. An academic committee was first given the task of selecting research themes. It did so by conducting a national survey, inviting submissions from individuals and organizations, and by promoting four national seminars. Using the selection criteria of (a) improving the competitiveness of Brazilian products and services, (b) addressing social problems and (c) having a broad spectrum of applications, it finally selected the following subjects:

- (a) Industrial automation;
- (b) Computer science applied to engineering programmes;
- (c) Advanced processes for metal-mechanics transformation;
- (d) Transportation engineering;
- (e) Agri-business;
- (f) Water resources planning, management, and engineering;
- (g) Basic sanitation, including waste management and sewage;
- (h) Technological education, including continuing and distance education and training.

The next step for networks in long-range research themes involved an invitation for expressions of interest in addressing each of the priority research themes. Following the selection of the best of these by committees of ad hoc referees, conventions of all qualified groups were arranged in order to set up partnerships and organize co-operative networks. The networks are organized as “business units” in order to offer scientific and technical services to companies and other clients including government institutions and NGOs. Four to five projects per network were initially defined for collaborative development. Participation of firms is welcome but not necessary. If firms join the networks, they must share the costs of the project that addresses their specific needs.

For networks on specific problem solving, the call for proposals invited projects on topics chosen by the applicant. Company participation was now mandatory. At least one firm was required to participate in a network and share the research costs. Fourteen projects were selected, including projects in off-shore technology, industrial use of mining and steel plant waste, biomass technology, catalysis technology, heavy electrical power systems, welding automation and others.

In addition, PRODENGE has established partnerships with State R and D agencies to co-fund on a 50 per cent basis joint co-operative projects of local priority. The agencies of Rio de Janeiro, Minas Gerais and Bahia have signed agreements and are currently implementing networks. Additional agreements are being negotiated.

The first evaluations of RECOPE by FINEP reportedly indicate positive results. Over and above the specific technical outcomes, however, the most valuable result of this exercise is deemed to be the dissemination of the network culture among universities, research institutes, and industry.