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Management of Technology and Technological Change in Canada: Learning and Teaching Innovation and Competitiveness in a Time of Turbulence and Uncertainty

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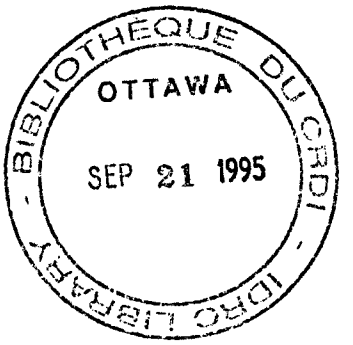

1. Background

Management of Technology (MoT) is emerging as a field of practice, scholarship, teaching, and policy attention at a time of unprecedented concern about Canada's economic future. While overall economic growth in Canada throughout the 1980s was among the highest of the G-7 countries, the economy exhibited persistent problems of low productivity growth and sluggishness in channeling investment into high value-added activities. The current recession has hit Canada hard. In 1991, the Canadian economy contracted by 1.7%. This poor economic performance raised the already high levels of unemployment in the country and increased the already high level of stress on the provincial and Federal governments, exacerbating the ongoing crisis of the Canadian Federal political system. By the beginning of the 1990s, the net public debt/GDP ratio had climbed to nearly 50% - up from 10% only ten years earlier.

How should competitiveness be sustained? Policy makers are bombarded with advice on this issue from industry spokespersons, consultative bodies, and management gurus. Often the central message is that Canada has to get serious about moving up the technology ladder. The Prime Minister's National Advisory Board on Science and Technology informed him in 1991 that:

> Canadians will not succeed in meeting international competition, and will therefore face a declining relative standard of living, unless we become much more adept in applying science-based technology to create a continuous flow of innovation and productivity growth. There is no more serious challenge facing Canada today (NABST, 1991a:2).

The policy question is how to create and sustain competitive advantage through innovation in a small, wide open economy. The issues on the competitiveness agenda range from human resources, science, finance, and policy processes, to cultural values and rules of international trade (SCC, 1992). Another issue, the one we address in this paper, concerns the kinds of skills and attitudes needed to manage technology throughout the national system of innovation. Most obviously, firms require improved innovation management skills, but complementary skills are also required in the variety of public and private institutions that support technical change, in private investment institutions, and in the collective arrangements of innovation system actors such as industrial, scientific, and technical associations. Adding complexity to the issue of how to engineer comparative advantage is the growing interpenetration of the competitiveness and the environmental sustainability agendas.

What is the MoT agenda, and who sets it? In Canada, the MoT agenda is multiple, and diverse actors are tackling issues of management of technical change from a wide variety of disciplinary and institutional standpoints. Generally speaking, however, MoT promises to provide the kind of competence that Canada requires to develop a more productive, higher value-added, sustainable economy. This paper identifies and explores issues in the development of technology management capability in Canada in the university, private, and public sectors, and situates technology management in the context of the exponentially increasing Canadian debates about innovation for economic and social development. In the final section we address the question of where this might take the field of management of technology in Canada.

1.1 The Canadian "National System of Innovation"

Canada is a continent-spanning federation of about 26 million people with a 1989 GDP of C$ 650 billion.[1] Its economy is highly differentiated by region. Manufacturing is concentrated in Ontario

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[1] The value of the Canadian dollar in recent years has been approximately US$.75 to US$.80.

and Quebec; the prairie's economy is based on agriculture; fisheries, mining, and forestry dominate the north and the coasts. Canada is also a significant energy producer.

Approximately 30% (1989) of Canada's GDP is generated through international trade. Of the G-7 countries, only in Germany does international trade contribute a higher proportion of GDP. Canada is highly integrated into the North American continental economy. The United States and Canada have the largest bilateral trading relationship in the world, and about three-quarters of Canadian foreign trade is with the United States. Much of this is intra-firm trade. Canada also has one of the highest levels of foreign ownership of industrial assets of any advanced country. Rates of foreign ownership are about 45% in manufacturing overall, ranging up to 75% in transportation equipment, 72% in chemicals and chemical products, 67% in petroleum and coal, and 90% in rubber products (Porter, 1991: 15).

Canada is a relatively decentralized federation and significant barriers to inter-provincial trade exist. The country is organized politically along east-and-west lines, but economically along north-and-south lines. This accentuates sensitivity to issues of wealth redistribution within the Federal system, while making the definition of national economic strategy relatively difficult (Leslie, 1987). As one observer has commented of Canada's peculiar political-economic structure:

> Canada is a bundle of paradoxes. Its economic development has been uneven because of external and internal factors. It is both underdeveloped and overdeveloped, a resource hinterland and an advanced manufacturer, capital rich and capital poor (Clement, 1977: 7).

Overall, Canada makes a comparatively modest effort to upgrade its technological and scientific capability. Canada's gross expenditures on research and development/gross domestic product (GERD/GDP) ratio has hovered around 1.35%-1.4% since the late 1970s. In 1989, Canada spent about C$ 8.3 billion on R&D. Of this, the business sector funded about 42% and performed about 56%. Industrial R&D spending is concentrated in a few very large firms. In 1987, firms spent C$ 4.1-billion on R&D; 37% was concentrated in the top ten performers, and half in the top 25 performers (ISTC, 1990a: 24). The higher education sector funded about 9% and performed about 23% of Canada's GERD, while the Federal government funded about 30% and performed about 17%. Provincial governments, foreign actors, and private not-for-profit organizations are other, smaller components in the Canadian innovation system.

In Canada, the Federal government has historically played the role of "systems integrator" of the national innovation system. National research capability was overwhelming based in Federal agencies and organizations until the 1960s. Federal policies, programs, and scientific and technical institutions are the single largest component in the national system of innovation.

The most important Federal outlays in support of industrial innovation are direct funding of public-sector R&D and technical services, direct funding of research in the higher education sector via three scholarly granting councils, significant but declining support of the recurrent costs of universities, some support of industrial R&D through specialized programs, indirect support for industrial R&D through relatively generous fiscal incentives, and a variety of programs supporting labor force training and adjustment.

The Federal government spent C$ 5.05 billion on S&T activities in 1989-90. About 59% of these expenditures are intramural. In 1990, there were 290 Federal scientific establishments in all regions of the country. They represented more than 20 Federal departments and agencies and ranged in size from one person-year to over 4,000 person-years. Nearly 34,000 person-years were allocated to Federal S&T activities in 1989-90 (ISTC 1990c). Given the prevailing environment of fiscal restraint in Canada, few expect growth in the Federal R&D sector (Anderson and Davis, 1993).

Fifty-three Canadian universities award bachelor's degrees in the sciences, and thirty-two award bachelor's degrees in engineering (Kavanaugh, 1993). Canada produces about 14,000 scientists, 7,000 engineers, and 1,200 Ph.D.'s a year. The Federal government is the principal supplier of financial resources for university research. In 1992-93, the principal agency that supports university research, NSERC [Natural Sciences and Engineering Research Council], spent about $C 445 M on university research. In Canada, education falls under provincial jurisdiction. Federal support for recurrent costs of higher education is being phased out.

Most observers agree that Canada's overall technological effort is too modest, and R&D expenditures too heavily dependent on the public sector, to advance Canada's aspirations to remain an advanced economy. In 1988, the Prime Minister's National Advisory Board on Science and Technology compared Canada's performance on ten key indicators of scientific and technological effort with those of major competitors (the United States, Germany, France, Sweden, the United Kingdom, the Netherlands, and Japan). On two indicators (advanced degrees awarded by population and government funded R&D as a percentage of GDP) Canada was in the middle. On three indicators (government funded R&D as a percentage of GDP, domestic patents granted per 100,000 population, and higher education R&D as a percentage of GDP), Canada was second lowest. On five others (gross R&D expenditures as percentage of GDP, industry funded R&D as percentage of GDP, international patents granted by population, scientists and engineers in labor force by population, and number of technology-intensive industries with a positive trade balance), Canada ranked lowest (NABST, 1988: 5).

Canada has developed strong technological capability in certain areas, some of which were fostered by governments as instruments of national development: railroads in the nineteenth century, and telecommunications, avionics, and some energy technologies in the twentieth. However, in most industries Canada is a "follower" country; "Canadian technological strategy has been that of a latecomer, mostly imitative and defensive" (Niosi, 1991: 91). Canada, like other "small countries," is an importer of technology through purchases of machinery, services, R&D, and skilled manpower (Dalpé, 1988). Foreign direct investment is an important channel of technology transfer into Canada. Subsidiaries and affiliates of transnational companies use relatively current production technologies. However, manufacturers in Canada take up improved fabrication, assembly, and materials handling technologies more slowly than their American counterparts (APRO, 1992).

In an avalanche of reports and studies, Canadian competitiveness has been dissected and debated.[2] Arguably the most influential and widely visible report was one commissioned from the American business strategist Michael Porter by the Minister of Industry, Science and Technology and International Trade, and the Business Council on National Issues, a private lobby for the business sector. Although the Porter report covered much familiar territory, it usefully applied the famous Diamond analysis to the Canadian system of industrial innovation.[3] Being of American origin, it also enjoyed a degree of credibility unavailable to Canadian actors. When it emphasized to the Canadian political and business elite the special significance of science, technology, education, and innovation for international competitiveness, many Canadian observers were pleased.

The Porter report, like many before it, argues that Canada is at a crossroads in the new competitive environment (Porter, 1991). Five trends are described as being indicative of underlying weaknesses: 1) low productivity growth - since the late 1970s, "total factor productivity growth - i.e. output growth unexplained by additional labour and capital inputs - has been almost zero" (OECD, 1992:51); 2) relatively high unit labor costs; 3) persistent high unemployment; 4) lagging

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[2] Forty-five recent reports and studies are described in Prosperity (1992c).

[3] In so doing, it shed light on one of the most peculiar dimensions of the Canadian national system of innovation: significant parts of this system are located in the United States.

investment in upgrading skills and technology; and 5) a macroeconomic climate that does not encourage productive investments (Porter, 1991).

The report observes that Canadian exports are concentrated in "clusters" of distinct industries. With the exception of some semiconductor and computer firms, the exported upstream industries are in natural resources: materials and metals, forest products, and petroleum and chemicals. Among so-called "industrial and supporting functions industries," which tend to be technology-intensive, Canada's exports are concentrated in transportation industries (mainly automobiles and avionics). Canada's automotive industry is the result of a 1966 production-sharing agreement with the United States. Among final consumption goods and services, Canada's exports are concentrated in the food and beverage industries (Porter, 1991). The picture is the well-known one of an economy over-specialized in exports of unprocessed or semi-processed natural resources and failing to establish itself in a range of higher value-added economic activities (see Crane, 1992: chap. 5, and Gertler, 1991).

1.2 S&T Policies in Canada

We turn now to a very brief analysis of Canada's S&T policies, with a view to describing how these policies are moving to address issues outlined above. This task is not easy because in addition to the Federal government's policies and programs in support of industrial innovation, all provincial governments have policies and programs, some of which (e.g. those in Quebec, Ontario, Alberta, and British Columbia) are extensive and long-standing. Furthermore, like most other North American cities, Canadian cities and metropolitan areas are developing initiatives designed to stimulate and foster innovation. Our discussion focuses mainly on Federal policies.

Of the three policy "trails" to Canadian innovation policy (i.e. science policy, trade policy, and industrial policy; Doern, 1990), the present Progressive Conservative Federal government, which came to power in 1984, has been mostly concerned with trade policy and macroeconomic policy. Industrial policy is officially frowned upon. At the Federal level, science policy is a minor dossier that is looked after by a junior minister of state. In provincial governments, science policy is usually located within ministries of higher education.

The Conservative Government's medium-term economic policy, announced in 1984, had two basic objectives: one was to "create a stable and predictable domestic macroeconomic environment for the private sector" (OECD, 1992: 32) through reduction of fiscal deficits and controlling inflation. The other objective was to "promote economic growth through the implementation of structural policies" (OECD, 1992: 32), mainly through trade liberalization and privatization. Neither of these economic policy objectives referred specifically to science and technology, but both had implications for the kind of innovation policy regime established since 1984 in Canada.

No major science and technology initiatives have been launched by the Federal government since the InnovAction program was announced in 1988. Under InnovAction, which had a budget of about C$ 100 million per year for four years, five themes were pursued: fostering innovation and technology diffusion, developing capacity in three groups of strategic technologies (biotechnology, advanced materials, and microelectronics), improving the effectiveness Federal S&T efforts, building human resources, and promoting an "S&T culture" in Canada. In an associated initiative, in 1989 the Federal government held a national competition under the Networks of Centres of Excellence program. This program provided support for inter-institutional groups of university and industry researchers, mainly in advanced technologies.

Many programs, instruments, and incentives to stimulate industrial innovation currently are in place in Canada. These include one of the most generous R&D tax incentive regimes in the world, applied research assistance delivered through national and provincial industrial extension systems,

special R&D support programs in such areas as defense, artificial intelligence, and strategic technologies, and regionally specific technology development funds in some provinces.[4] In 1989-90, the Federal government spent about C$ 2.7 billion to assist non-agricultural business, but of this regional development assistance accounted for 41% of the total and energy and resource development assistance accounted for another 27%. Industrial or technology program expenditures accounted for 23%, or C$ 627 M, but of this defence industry assistance represented fully 40% percent of expenditures. The trend is to reduce direct support to industry, to make a sharper distinction between industrial and regional development assistance, and to increase the volume of repayable assistance (Davis, 1993).

The Canadian policy style does not favor general indicative planning in which targets, measures, or goals are put forward. The Canadian political system lends itself primarily to de facto, implicit S&T policy making. It rarely defines explicit objectives such as market share or R&D spending targets. Canadian S&T policy relies on a great deal of consultative processes and consensus building. In addition to its process orientation, Canadian S&T policy tends to concentrate on providing infrastructure, an appropriate environment, and discrete incentives to induce desired changes in behavior in industry and science. Universities and public labs, because they are accessible to public policy instruments and dependent on public financing, are attractive targets for attempts to create surrogate industrial research activities (NABST, 1988: 9; SCC, 1992: 74-76). Most Canadian policy initiatives not targeted on the university sector involve promotion of consortia and strategic alliances in advanced technologies, focusing the activities of public laboratories (OECD 1990, pp. 123-128), and promotion of concerted action among innovation system players (Davis, Alexander and MacDonald, 1990). Some indications exist that the Federal government is considering strengthening institutions and incentives favoring technology acquisition and diffusion (NABST, 1992).

In 1991 the Federal government launched a "Prosperity Initiative" (so called because of the public's perceived resentment of issues of "competitiveness"), an attempt to create consensus in Canada about actions to promote economic and social well-being. The Prosperity Initiative was steered by a group of eminent persons from the private and higher education sectors, and it supervised the production of many background reports and undertook extensive consultation with the public, industry groups, and government clients in dozens of roundtables and workshops. A Task Force in Science, Technology and Related Skills also conducted consultations and advocated a course of action (Prosperity, 1992b). The Prosperity report puts forward 54 recommendations in an action plan. In general, recommendations fall into 8 classes of initiatives (Prosperity, 1992a):

- collective action (a National Quality Institute would launch "a coordinated national effort to adopt a quality approach in all areas of Canadian society);
- education and training (many proposals);
- regulation of government (as in the proposals to independently review tax and fiscal policy, assess the impact of government on competitiveness, etc.);
- administrative coordination (consolidation of government programs of assistance to industry);
- tax and fiscal measures;

[4] For a description of several of these incentives and programs see Botham and Giguère (1993).

- infrastructure (a broadband electronic network, a Centre of Excellence for Sustainable Development);
- legal measures (harmonization of laws regarding investment, etc.);
- persuasion (establish a communications campaign to convince Canadians that learning is necessary, etc.).

Many of the recommendations are addressed to actors other than government (especially universities, communities, industry associations, firms and trade unions), and few recommended initiatives are predicated on substantial increases in public spending.

Roobeek (1990: 230) observes that in industrial countries in the past decade, "technology policy hangs in the air instead of being firmly rooted in an overall restructuring policy." Canada is perhaps moving towards a more comprehensive restructuring policy in which S&T and innovation policy are elements. This may be something of a departure from the neoliberalism of the 1980s, which was concerned primarily with controlling inflation, interest rates, and public spending. The attempted restructuring involves experimenting with a new style of political action emphasizing mobilization of Canadians through consultation and persuasion, with modest doses of government financial commitments.[5] It represents an attempt to stimulate institutional and social change. The primary lesson it contains is that successful adjustment to marketization is not a passive process. However, the basic model of economic development upon which Canada has depended - export-led growth with a specialization in staples and some managed sectoral trade - is not being put into question.[6] Furthermore, after the Minister for industry, science and technology announced his decision to leave politics, what remained of the Prosperity Initiative was disbanded, and no serious follow-through has occurred. Plebiscitary technology policy has not been notably successful in Canada.

Environmental sustainability is another S&T policy issue of growing importance. The Canadian government has begun to increase the salience of environmental initiatives within its broader political and economic policy positions. The assumption is that there is a domain of compatibility between economic growth and environmental sustainability. The most notable aspect of Canadian environmental policy is the 1991 Green Plan, a six-year, C$ 6 billion coordinated set of initiatives in pursuit of environmentally sustainable development. Many initiatives undertaken within the framework of the Green Plan have an S&T dimension. Among those are a C$ 50 million fund for training the next generation of environmental scientists; C$4.5 million Canadian Global Change Program; and the Environmental Innovation Program, which makes $1.7 million available in 1992-93 to support extra mural R&D to attain Green Plan goals.

The conclusion of a trade agreement with the United States in 1988 and the impending signature of an agreement in 1993 with the U.S. and Mexico was the culmination of two decades of debates between "nationalists" who argued that the goal should be to foster Canadian-controlled firms able to use technology competitively, and "continentalists" who favored enhancing market mechanisms to drive Canadian industrial productivity.[7] Doern notes:

> The free trade initiative was built...on the proposition that Canada's manufacturing sector faced a serious productivity gap that could only be addressed by the cold shower of being

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[5] The preface to the Prosperity Initiative action plan urges the citizen to read the plan, discuss it with friends and colleagues, and "wherever you can support this plan with personal action, we urge you to take that action" (Prosperity, 1992a: i).

[6] On the limits of this model of development see Phillips, 1991.

[7] On this debate see Blais (1986).

> exposed to full competition and by obtaining more secure access to its biggest market, the United States (Doern, 1990: 56).

The Canada-U.S. agreement limits signatories' latitude to implement policies of economic nationalism which, in Canada, are "essentially, policies supporting indigenous manufacturing industry at the expense of resource industries, and [policies] supporting Canadian capital against foreign capital" (Leslie, 1987: 13). In addition to establishing trade rules for standards, intellectual property, rules of origin, and dispute settlement, the agreement restricts the signatories' latitude to screen investments and impose performance requirements such as R&D spending targets or local procurement measures (Davis, 1993). No agreement was reached regarding the definition of countervailable subsidies. The Federal government is moving away from spending money on industrial development subsidies. Increasingly, Canadian S&T policies for industrial innovation will focus on the research, education, and training end of the innovation spectrum, on the one hand, and on creating an appropriate infrastructure and institutional and fiscal environment for innovation, on the creating an appropriate infrastructure and institutional and fiscal climate for innovation, on the other (Davis, 1993).

This is the policy context in which the issue of management of technological change is being discussed in Canada. Management of technological change within the firm is viewed as part of the larger challenge of social innovation. All social and economic actors are being asked to innovate. Improved management skills presumably are required throughout the national system of innovation, including enhanced skills and deepened understanding of industrial innovation among those who are not labeled "technology managers."

"Innovation management" therefore overlaps MoT, which has developed around a research and teaching agenda that is primarily firm-centered and generally focused on problems confronting individuals in technical environments. MoT has undergone a surge of growth in universities and to a lesser degree in the public and private sectors. In the following section we describe emerging patterns of MoT activities in Canada. Later, we examine the arguments and proposals for management skills upgrading put forward in the competitiveness debate in Canada.

1.3. Definition of the MoT Challenge

The most thorough review of research on managing technological change in Canada was prepared in the late 1980s under the auspices of the Social Science Federation of Canada with the financial support of the Social Sciences and Humanities Research Council (SSHRC). The Federation's report adopted a quite broad view of "management of technology" to include science and technology (S&T) policy, management of innovation, innovation and the labor process, industrial policies and strategies, the geography of innovation, standards and standards writing, technology assessment, and risk management (Salter and Wolfe, 1990). From this review a list of current research issues and topics on management of technical change was drawn up (see Table 1) and four "paradigms" of MoT research identified:[8]

[put table 1 here]

- The "theoretical" paradigm is "perhaps the best developed" of the four. In it participate scholars from all social science disciplines in the "the study of the relationship of technology to society." This paradigm is populated by researchers who view themselves as social critics and philosophers rather than social scientists.

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[8] The following description of the four MoT paradigms is based on Salter (1990), pp. 18-22.

- The "labor process" paradigm "originated in the broader literature concerning the transformation of the labor process under the conditions of modern industrial production." Originally largely Marxian in orientation, research in this paradigm is taking a utilitarian turn as methods are developed to facilitate the introduction of new technologies in the workplace and mitigate their adverse impacts.

- Within the "social science" paradigm researchers produce work along disciplinary lines primarily for scholarly (rather than practical) use. The research is largely empirical, non evaluative, and noncommittal with respect to the value of technology.

- The "business paradigm" is described by a frequently-cited definition of the MoT field: MoT "links engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization" (NRC, 1987). The key premises of this paradigm are that 1) scientific and technical disciplines must join forces with management disciplines and that 2) the goal of this collaboration is to improve the performance of the organization (generally, the firm).

Most social science disciplines and many humanities disciplines are increasingly concerned with the significance and origins of technical change and its relation to social structure and cultural values. However, the business paradigm, much more than the other three, has succeeded in establishing itself as the growth point of MoT.

In the remainder of this chapter we focus mainly on MoT of the business paradigm variety, although we shall also have something to say about a growing overlap between S&T policy issues and MoT issues. We review recent initiatives in the university, public, and private sectors concerning teaching, training, research, or consulting activities in MoT, and we identify how issues of innovation management skills arise in the S&T policy debates and how MoT might evolve to deal with issues of environmental sustainability.

2. Organization of MoT in Canada

MoT first appeared as a significant issue on the Canadian science and technology policy agenda in the late 1960s. The Senate Special Committee on Science Policy (the Lamontagne Committee), in its comprehensive review of science policy, observed that there was an "urgent need to improve the training of R&D managers and to do more research on the R&D and innovation processes" (Lamontagne, 1973: 803). The initial Lamontagne policy report recommended that a committee comprised of representatives from the Ministry of State for Science and Technology, Canadian management schools, and the Canadian Research Management Association develop a training program for R&D managers and research program on "the organization of R&D activities and of innovation strategies." Two research centres were to be identified in Canada to carry out the research and training, and a scholarship and research funding program was to be established (Lamontagne, 1972: 529). However, subsequent consultations with industry and professional groups revealed a strong preference against the establishment of scholarships for training R&D managers in favor of continuing training and fora for practicing R&D managers, fellowships for experienced (i.e. mid-career) managers, and collaborative training with industry (Lamontagne 1973: 803).

The research funding component was implemented in 1974 by the Department of Industry, Trade and Commerce in the form of a Technological Innovation Studies Program. Between 1974 and 1985, when it was eliminated, this program funded 103 studies of innovation in Canada and

distributed as many as 800 reports per month to interested parties (Clarke, 1990). The program was also intended to award scholarships and fellowships in management of technological innovation or technical entrepreneurship, but none were ever awarded. However, the research funding component of the program played a critical role in seeding MoT research capacity in Canadian universities.

In 1979 the Canadian Advanced Technology Association, the Innovation Management Institute (now defunct), and the York Enterprise Development Centre sponsored a national workshop on technological innovation management education (Clarke et al., 1979). Included in the workshop's background material were the results of a survey of perceived educational needs, and examples of university course curricula. The workshop identified issues for MoT education and training:

- MoT encompasses management of technological innovation and technical entrepreneurship.
- Traditional engineering and science courses do not provide adequate training to work in technology companies or to engage in entrepreneurial activities.
- Entrepreneurs can and should be provided with MoT skills to enhance their success rate.
- University MoT courses should be made available to science students, engineering students, and business students.
- An introductory or overview MoT course should be provided and perhaps be made compulsory.
- Case material, contact with "live" entrepreneurs, and audiovisual teaching approaches were advocated.

Throughout the 1980s, Canadian management and engineering schools established courses and occasionally programs in management of technology (see below). MoT was given a boost in visibility within the university and business communities through two national workshops on Management and Technology that were held in Canada in 1985 and 1988. These workshops brought together deans of faculties of management and engineering with corporate executives. Participants readily agreed that international competitiveness required new management skills, that the provision of these skills should be a lifelong process, that more research in MoT was necessary, that MoT implied more than managing hardware, and that providers of education and training should be as responsive as possible to industry needs. The workshops successfully disseminated information about university activities in MoT and about current views on MoT. However, the workshops did not generate impetus for cooperation among MoT actors in Canada. The second national MoT workshop produced a plethora of recommendations but no focused agenda (see MTI 1988). This lack of cooperation and focus may in part be attributable to rivalries among management schools and between management and engineering schools which appeared to hinder concerted effort to develop MoT in Canada.

More recently, Québec's Conseil de la science at de la technologie (Council for science and technology) commissioned a report on the current and future needs for management of technology in that province. The report, "La Gestion de la Technologie: Un choix ou une nécessité?" was prepared by Louis Lefebvre, Élisabeth Lefebvre and Anne Le Luel of the École Polytechnique in Montréal. The report is expected to be released in the summer of 1993.

2.1 Public Sector Strategies

The Canadian public sector is involved in MoT education, research, and capacity-building in a number of ways. As we show later, many of the MoT initiatives in the university sector and some in the business sector draw on public support at some stage. In addition to their concerns to stimulate MoT teaching, research, and conferencing activities in the business and university sectors, some Canadian government agencies are strengthening their own capabilities in MoT. Industry, Science and Technology Canada (ISTC), the flagship Federal S&T agency, offered a course of six MoT training modules to staff across the country in 1990-1991. The rationale was that:

> Understanding the impact of technology management is important to the effectiveness of ISTC managers and officials, particularly those engaged in the day-to-day delivery of programs, services and counseling to corporate clients. Helping business to recognize the importance of managing technology will be an essential part of the ongoing role of ISTC sectoral and regional officials (ISTC, 1990b).

Each module was a stand-alone training package at the first-year MBA level targeted on ISTC managers and officers in the regional offices, sector branches, policy directorates, and in the regional service bureaus, as well as general and senior managers from industry. Training for each module lasted three days. The first module provided an introduction to the management of technology. The other modules provided instruction in technology and business strategy, advanced technologies for manufacturing and service industries, strategic alliances and partnering, new product and process development, and international marketing.

A second issue concerns the ways that governments become directly involved in the provision of management of technology services to firms. Canada has a complex public infrastructure, supplied by the Federal, provincial, and local governments (sometimes in collaboration with educational or industrial organizations), to deliver technical support to firms. The two largest components are the National Research Council's Industrial Research Assistance Program (IRAP, an industrial extension network of about 160 offices across the country), and the provincial research organizations (PROs), which offer applied research and technical support services. Many other technical support institutions have local, sectoral, or dedicated technology transfer functions. Few of these institutions combine technical consulting with services addressing managerial and organizational problems related to competitiveness.

The Canadian federal and some provincial ministries of industry, however, have programs that support part of the costs of technology diagnostics, business planning, strategic planning, or evaluation of firms' technology implementation strategy. Examples of Federal services are the Manufacturing Assessment Service, the Advanced Manufacturing Technology Application Program, Interfirm Comparisons Service, sector campaigns, a Manufacturing Visits Program, Workshops on Informatics for Senior Executives, and Canadian Awards for Business Excellence (NABST, 1992: A2). Typically these management support services are delivered through consultants.

2.2 Academic Strategies and Programs

In the second half of the 1980s the teaching of Management of Technology spread rapidly throughout the Canadian university community. A recent survey revealed that there are at present more than 70 courses related to Management of Technology available at 25 Canadian universities (Clarke, 1992). A similar survey five years ago found less than 50 courses at fewer than 20 universities (Clarke and Reavely, 1987). Most of the growth in MoT courses in Canadian

universities occurred between 1987 and 1990; little changed between 1990 and 1992 (CAC, 1992: 26). At present about two-thirds (i.e. 45) of the courses are offered by about one-third (i.e. 8) of the universities: these institutions represent the highest concentrations of MoT teaching activity in Canada. The universities are: Alberta, Calgary, Carleton, École Polytechnique de Montréal, Ottawa, Université du Québec à Montréal, Toronto, and Waterloo.

In addition, the University of British Columbia has recently launched an MoT program, and Simon Fraser University, which offers an engineering extension program in technology management, has offered MoT courses in collaboration with University of Waterloo and is developing plans to increase the number of graduate courses offered in MoT.

Some of the principal university-based groups and institutions active in MoT are described below.

The National Centre for Management Research and Development (NCMRD) was established in 1984 at the University of Western Ontario in London, Ontario. The Centre benefits from support from the Federal Department of Industry, Science and Technology. The Centre has two roles, to "stimulate and provide direction for management research being conducted at both the Centre and other institutions," and to "disseminate research findings to the management community." NCMRD carries out or sponsors research in a number of areas, including management of technology and innovation. The Centre has a discretionary budget with which to fund research.

The Centre de recherche en développement industrielle et technologique [Research Centre on Industrial and Technological Development, CREDIT] and the Centre de recherche en évaluation sociale des technologies [Research Centre on Social Assessment of Technology, CREST] were established as interdepartmental research centers by the Université du Québec à Montréal (UQAM) in 1986 with support from the Quebec Ministry of Higher Education, Science and Technology. CREDIT links researchers from various departments in UQAM and other universities (Ecole Polytechnique, Laval, Sherbrooke, Montreal, and Carleton). Its researchers have investigated a broad spectrum of problems in S&T policy, industrial economics, and management of technology. CREST links researchers from UQAM, McGill, and Ecole Polytechnique. Its researchers have focused on the processes of technological innovation and their interaction in labor, management, and production environments; the acquisition of knowledge and skills; and the sociology of scientific and technical controversies. UQAM has recently amalgamated CREST and CREDIT.

The Research Centre for Management of New Technology (REMAT) was established at Wilfred Laurier University in 1985. Funded by a membership of over 350 small and medium-sized firms, REMAT seeks to help Canadian managers acquire and implement new technology, to provide a forum for industry, governments, and labor to resolve problems related to technology in the workplace, and to develop practical research programs to improve the capability of Canadian managers to deal with new and emerging technologies. REMAT hosts a monthly Technology Forum for senior executives, a series of seminars and workshops on a wide range of topics (for example, supervision in a technology environment, quality management, etc.), and occasional conferences (for example, Technology and Waste Management). It also conducts an annual survey of technology, offers a technology auditing service, maintains a bibliographic data base on implementation of change in technological environments, and conducts contract research. Wilfred Laurier University has offered a Technology MBA since 1986.

The most intensive initiative to strengthen Management of Technology in Canadian universities was the establishment in 1990 of a program of "Chairs in the Management of Technological Change," funded by two of Canada's national granting councils for academic research: the Natural Sciences and Engineering Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC). A competitive program of MoT chairs funded under a matching-grant formula was developed jointly between SSHRC and NSERC. The granting councils match private contributions in establishing the chairs. This ensures industry support of and commitment to the

chair program. The objective of the NSERC-SSHRC program is to encourage study, teaching, and training in the management and facilitation of technological change. According to the councils, the program addresses the problem of maintaining living standards and creating employment in the face of global competition: "the driving force in global competitiveness is technological change." According to published reports, the five year commitments from the two councils total $4.61-million, or an average of $.922-million per year (Caughey, 1993:2).

By the end of 1992, eight chair proposals had been approved in the first two rounds of competition. NSERC and SSHRC have approval for two additional rounds, for three chairs each, and the first of these is underway. The eight existing chairs are as follows:

The University College of Cape Breton, Nova Scotia, has created a chair entitled "Environmental Technology in Non-Urban, Resource-Based Industries" located in the Tompkins Institute for Human Values and Technology. The industrial sponsors are the Nova Scotia Power Corporation, Sydney Steel Corporation, and the Cape Breton Development Corporation. This chair's research program will examine industrial innovation in resource industries in non-metropolitan regions with regard to their competitiveness and environmental sustainability.

The École Polytechnique de Montréal has two chairs, both located in the Department of Industrial Engineering. The first, called "Technology and International Competitiveness," is co-sponsored by Jarislowski, Fraser & Co., the Quebec Government, and a consortium of consulting engineering and manufacturing firms. This chair will support research on concurrent engineering and strategy formulation. The second chair, entitled "Choice and Management of Technological Projects," is sponsored by Bell Canada. It will examine problems related to the choice of technological orientations, the development and implementation of management methods appropriate for technology projects, and the concept of "optimum timing" in applying the results and marketing of the products generated by innovation and R&D.

The chair at the Université du Québec à Montréal is called the "Hydro Québec Chair for Research in Management of Technology." Located in the Department of Administrative Sciences, the chair concentrates on analyzing management challenges facing Canadian industry. It will "promote reflection and dialogue between researchers and managers with a view to promoting technological innovation and stimulating entrepreneurial spirit in the high technology sectors."

Carleton University's chair, located in the Business School, is entitled "Managing Technological Change in Manufacturing." The chair examines "the role of manufacturing in the front-end of the product development cycle, the establishment of manufacturing as a core competency of a firm, and the creation and management of external linkages anchored on manufacturing for competitive advantage." The industrial sponsors are Gandalf Technologies, Lumonics, Mitel, and Northern Telecom. A Research Centre in High Technology Management established in 1984 with provincial support within the Carleton University Business School has since closed.

The Chair at Queen's University is called the "NSERC/SSHRC Alcan Chair in Management and Technology" and is located in the Business School. The sponsor is Alcan, Ltd. This chair was originally established in 1986 as an NSERC industrial chair and then worked into the NSERC/SSHRC program. The chair's work focuses on management of R&D functions, technical entrepreneurship, commercialization of university-based research, and strategies for high technology firms.

The Chair at the University of Toronto is called "Management of Technological Change in the Financial Services Industry." This chair is shared by the Faculty of Management and the Faculty of Engineering. The industrial sponsors are the Royal Bank, the Toronto Dominion Bank, and Stentor Alliance (formerly Telecom Canada). This chair emphasizes research on the management of

computer and communications technologies in the financial services industry. It also forms the core of a new Centre for the Management of Technology and Entrepreneurship.

Simon Fraser University and the University of Waterloo share a Chair called "Management of Technology: Innovation and Change." The industrial sponsors are Bell-Northern Research and British Columbia Telephone Company. The research program is aimed at finding ways to reduce the time it takes to formulate and successfully market technologically advanced products and services. The research looks at multidisciplinary formulation teams and their management. This chair is also interested in use of wide-area network links and teleconferencing for teaching and research collaboration, and direct electronic links have been established with some of the MoT chairs at other universities.

In addition to the chairs program, SSHRC supports academic research on MoT under two strategic grants program themes, "Science and Technology Policy" and "Managing for Global Competitiveness." Both program themes were established in 1989, but earlier, somewhat analogous themes ("Managing the Organization in Canada" and "Human Context of Science and Technology") were initiated in 1983. Through these programs a total of $2.7-million was awarded in 1992 (Caughey, 1993). NSERC also supports research in the discipline of management science ($36K in 1992), and research whose 'primary area of application' is management science ($747K in 1992). If we include the SSHRC scholarships in science policy ($150K in 1992), the two councils currently distribute just over $4.7-million per year in studies broadly related to management of technology, innovation, entrepreneurship, and science and technology policy.

This sketch of MoT initiatives in Canadian universities illustrates the growing interest in MoT teaching and research in Canada. Canadian researchers from academia, industry, and government actively participate in key North American MoT conferences. At the PICMET conference in Portland in 1991, Canadians authored or co-authored 23 papers of the 278 presented. The Third International Conference on Management of Technology, held in Miami in 1992, also included a large contingent of Canadian MoT researchers. Canadians authored or co-authored 24 of a total of 147 papers. In each conference, the most popular theme for Canadian presenters was R&D management.

The above sketch also illustrates the importance of public and private sponsorship in establishing academic institutions supporting MoT teaching and research. Before the 1980s, MoT activities in Canadian universities were scattered throughout faculties of business or engineering. Two kinds of university-based institutions were created in the 1980s: centers and chairs. The centers usually begin with university and government support, and then seek to enlarge private sponsorship through membership fees or the sale of services. This movement to secure university-based MoT centers through enlargement of private support has had some successes but growth appears to be slow. The MoT chairs program, which resulted in the reinforcement of capacity very quickly, was designed from the beginning to require private sponsorship.

No university-based networks, associations, or organizations for MoT exist at the national level in Canada. A proposal for a Technology Innovation Management Network submitted to the Federal government's Networks of Centers of Excellence Program in 1989 was not successful. By way of comparison, in Britain, the JUPITER consortium (Joint Universities and Polytechnics Industrial Technology Education and Research) provides a network of courses offered by participating educational institutions, including the Short Course Compendium and Training Guide in Technology Management.

One pan-Canadian initiative deserves mention. This is the Technology Management Case Competition, the first such case competition in North America, launched in 1990 by the Business and Engineering Development Association and coordinated by the University of Ottawa. This

competition is open to students from Canadian universities and is supported by a consortium of private and public sponsors. Each university can field one team of four members, of which at least one member must be a business student and one an engineering student. The cases "center on a major business and technology problem faced by Canadian company." Registered teams receive the case by fax and have five hours to prepare a solution in the form of a recommended strategy. Winning teams receive honors and prizes. In the first competition, nineteen teams from twenty-one universities participated.

In April 1993, the first meeting of what may become a Canadian MoT network took place in Montréal. Attendees included the NSERC/SSHRC "Chairs in Management of Technological Change" as well as numerous other researchers, research administrators and technology managers from industry. A committee was struck to examine the best approach for Canadian participation in the International Association of Management of Technology (IAMOT).

We have searched for reliable information about the market for graduates of MoT programs in Canada. Abbott's 1988 study suggests that employers prefer on-site or customized MoT training, and that they do not value MBA graduates, especially young ones who are viewed to have unrealistic expectations about what they can contribute to a firm. The best candidates for MoT training, in the view of these employers, are people with a strong technical background and five to eight years of work experience. Davis and Tiffin (1992) found that few executives were aware of the field of MoT. Their survey of executives' perceptions of technology management problems identified five distinct viewpoints, each reflecting an understanding of how technology contributes to a firm's competitiveness and each representing a market segment with specific requirements for MoT skills, knowledge inputs, and services. They called the viewpoints *dependent optimization, independent product innovation, global innovation, potential growth-driven innovators*, and *technological entrepreneurship.*

2.3 Private Sector Organization for MoT Training

Concurrent with the wave of interest in MoT in universities have come numerous initiatives to establish income generating MoT activities in the private sector. A private market for technical management services and educational events is developing in Canada, although we have not yet located a reliable survey of this market and its suppliers.

The most important institution in Canada offering MoT services on an income-generating, not-for-profit basis was the Management of Technology and Innovation Institute, MTI. This Institute was established in 1987 at McMaster University in Hamilton, Ontario, as a national centre with sponsorship from the Federal government, McMaster University, and a number of firms. In 1989 corporate sponsors were Atomic Energy of Canada, , H.L. Blachford, Domtar, Fell Fab, GM Canada, IBM Canada, Lumonics, Northern Telecom, Nova, Ontario Hydro, ORTECH International, Stelco, Westinghouse Canada, and Zepf Technologies. MTI closed its doors in December, 1992, heavily in debt. MTI was an independent organization "developed in response to the crisis in international competitiveness and technology exploitation faced by Canadian industry" and "dedicated to helping Canadian companies compete successfully through more effective use of their technological and human resources" (MTI, 1990). MTI offered workshops, conferences, training seminars, and consulting services. The training services and seminars were offered in major cities throughout the country. In its Fall, 1990 program MTI offered a lineup of 12 seminars.[9] Additional on-site seminars and custom corporate services were available on demand.

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[9] The seminars were: "Made In Canada: Using Manufacturing to Gain a Competitive Edge," "Winning at New Products," "Effective Technology Transfer," "Bridging the Authority Gap: Influence Strategies for Project Managers," "The Management of Technology" (a special seminar for CEOs and executives), "Building Blocks for Teams: How to Lead Effective Groups," "Development of First-Line Supervisor," "Effective Employee Suggestion

MTI had a small in-house staff. Its strategy was to keep overheads low by using university teaching staff from around the country in the seminars and workshops it offered. MTI also hoped to generate income through the preparation and sale of MoT audiovisual teaching material. MTI was expected to recover costs and eventually become largely self-supporting through sales of memberships and services. MTI's failure, even when benefiting from access to top university-based MoT researchers and significant corporate, government, and university sponsorship, suggests that there is a limited market in Canada for MoT training services targeted on mid-level decision makers.

A number of Canadian consulting firms, large and small, are offering research, educational, and project management services in MoT and S&T policy. Stargate Consultants of Ottawa conducts studies of innovation and innovation policy, performs evaluation of R&D programs, and offers management training programs in R&D management, technological innovation, and technical entrepreneurship. Pallister-Tiffin Technology Management, recently deceased, was a dedicated MoT management consulting firm based in Calgary and specializing in advanced technology firms and firms in the resource sector. Terracy, in Vancouver, provides an international management and consulting service in advanced technology, venture management and business development, with a focus on creative innovation and environmental efficiency. Hickling, with offices in Ottawa, Toronto, and Washington, offers a wide range of technical management and S&T policy services, including decision analysis, human resources management, technology assessment, environmental technologies, and management of technology. Policy Research International and Cognetics, based in Ottawa and Vancouver, respectively, are active in S&T policy and MoT projects in developing countries. Nordicity/NGL, Doyletech, and RockCliffe Research and Technology are three well-known Ottawa firms that offer services in S&T policy analysis, economic development, project management, and investment management. Other consulting firms known to have interests and activities in MoT and S&T policy are Prospectus, Policy Impact Associates, Clarkson Gordon, Arthur D. Little Canada, Ernst and Young, Peat Marwick, the Canada Consulting Group, and SECOR. The national profile of private suppliers of MoT service has never been established. The Québec Council of Science and Technology examined the availability of private technology management services in the province. It found that of 1059 management service firms in operation, 95% were in informatics and office automation. Less than 4% offered services in the domain of industrial planning (CSTQ, 1990: 111).

Only one private think-tank in Canada has developed a major stream of MoT activities and services. This is the Conference Board of Canada, a not-for-profit organization established in 1954 and affiliated with similar organizations in the United States and Europe. The Conference Board of Canada's mission is to be "the leading independent applied research institution dedicated to enhancing the performance of Canadian organizations within the global economy." The Conference Board of Canada has more than 700 associates (i.e. member organizations) from across the spectrum of industries and organizations, and it provides access to more than 3,000 associates through its American and European affiliates. It publishes the Canadian Business Review and it pitches its services at business executives. It conducts research and undertakes economic forecasting and analysis on public policy, certain business sectors, organizational effectiveness, and international business issues. It communicates the results via conferences, speakers' programs, roundtables, newsletters and executive summaries, bulletins, and reports. Since 1983 the Conference Board of Canada has had a Management of Innovation and Technology program with the following activities:

Systems," "Profit from Information Technology," "Managing Development Projects," "Managing Strategic Change in Continuous Operations Industries," and "Meeting the Technology Challenge: from Initiative to Implementation."

- the Council for the Management of Innovation and Technology is a forum for senior corporate executives to discuss strategic issues concerning technology management. About forty companies are members.

- the Research Managers' Forum focuses on the needs of intermediate research managers with day-to-day R&D management responsibilities. Approximately fifteen companies are members.

- the annual Conference on the Management of Innovation and Technology has taken place since 1988 and is open to non members. It focuses on "key factors affecting the successful integration of innovation and technology in business operations."

- occasional seminars and workshops, such as a series on Technology Management and Environmental Imperatives.

- an annual survey of members' attitudes and spending intentions regarding R&D.

- publication of occasional research reports. Recent ones have focused on Canadian R&D tax incentives, excellence in the management of innovation, competitive intelligence gathering, and human resources for technology managers.

The International Innovation Institute is a recent addition to the group of private actors in MoT in Canada. The International Innovation Institute is based in the Banff Centre for Management, a private, not-for-profit education and conference organization in Banff, Alberta. The Institute is a "global network of individuals (public and private) committed to understanding processes of innovation and applying this knowledge to the reshaping of their organizations." The mission of the Institute is to "assist organizations in restructuring themselves and in reshaping the attitudes, knowledge, and skills of their members in order to nurture high performance in a global, knowledge-based economy." Through networking, conferencing, and educational activities the Institute "offers senior managers a new 'window on the world.'" The Institute conducts action research and organizes courses and programs on innovation-driven economies, workplace learning, self-managing teams, managing human resources, effecting change, competitive strategies for advanced technology firms, and preparing organizations for strategic alliances. It also is one of the few applied management education initiatives in Canada to tackle issues of managing innovation at the interorganizational or societal level. Initiatives include direction of a multi-stakeholder group to produce a strategy for economic development in Alberta, organization of roundtables on learning and the new economy, and a series of activities on "developing a collaborative culture."

2.4 Mechanisms for Interaction

As indicated previously, Canadian S&T policy is talking about reinforcing the set of institutions that support technical change in order to accelerate the diffusion of improved technologies throughout the economic sector. This raises the issue of the degree to which the improvement of a firm's technological capability requires complementary improvement in the firm's management capability, and how the acquisition of that management capability can be ensured. Answers to these questions depend on how MoT is defined and on how organizational learning processes can be facilitated.

At one end of the spectrum of MoT activity are the many sharply-focused technology management techniques and training modules that are readily available on such subjects as leadership in

technical teams, project management, R&D management, procurement, etc. We will call this "technical MoT." Training in technical MoT is targeted on line managers or middle managers. However, as we shall see in the next section, Canadian opinion attributes failure to attain competitiveness to a combination of technical deficits and management deficits at the senior level, with the key bottlenecks not in the technological stream but in the organizational-managerial stream (De Vos, 1990: 20). The challenge of technological change is increasingly regarded as one of integrative management: "the integration within a company ... of increasing numbers of functions and resources, both technical and organizational" (De Vos, 1990: 11). The integrative approach to MoT "is a way of thinking," not merely a collection of techniques, and it is "not easily understood, let alone taught." The integrative task is "not only the main challenge [of managing technical change] but also the most difficult to achieve, and it is the area where most companies fail and where good MoT teachers or consultants are the scarcest" (De Vos, 1990: 11). The more holistic and integrative the management task, the more it must involve senior management in interaction with all elements in the organization as well as with outside stakeholders.

In Canada most MoT services to firms, publicly or privately delivered, are of the modular, narrowly technical variety. The only current integrative management practices are business planning (i.e. strategic planning) and total quality management.[10] De Vos (1990: 13) advocates that integrative MoT services be grafted onto business planning or TQM activities. Some countries are approaching the delivery of MoT services to business via the integrated planning route. Australia, through its National Industrial Extension Service's World Competitive Manufacturing program, requires firms desiring technical assistance to undergo a three-day integrative business planning exercise. At the other end of the spectrum, West German agencies focus first on the product or technical problem, eventually embracing broader management practices in some cases. In one U.S. state, government-stimulated improvement of management of technological change in firms is regarded as a two-tiered task. One tier concerns the vast majority of firms, which seek technical assistance and technical MoT services for modernization and incremental improvement of performance. The second tier concerns firms with high growth potential in a strategic area ("foundation firms"); these firms are invited to anticipate and confront the organizational and technological challenges to their growth and competitiveness. Sometimes technical assistance relating to the automated production needs of the firm is used as a "hook" to draw some firms into an integrative reformulation of competitive strategy (De Vos, 1990: 16).

We must emphasize the special organizational requirements for successfully delivering technical MoT and integrative MoT services to firms from public technical support agencies. Technical MoT is relatively inexpensive, easily disseminated in modular form through diverse kinds of media such as distance education or videos, is targeted on line and middle managers, and appropriate for incremental modernization of large numbers of firms. Integrative MoT is a form of firm-specific support. It implies substantial interaction between delivery agents and firms. It requires a great deal of commitment and involvement of senior management. Because it is highly customized, it is expensive to deliver. Furthermore, since it can only work on firms that are already dynamic, it amounts to investing in "winners" (De Vos, 1990). Finally, integrative MoT requires a very special skill set on the part of delivery agents. Public officials, academics and most business consultants do not have these skills. This implies the necessity of recruiting and training a corps of dedicated delivery agents.[11]

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[10] A statement of TQM's principles shows why it is integrative. TQM is led by top management; it is customer-focused and aims at continuous improvement to attain long-term company goals. It involves everyone in a search process for win-win solutions. It is prevention-oriented, systematic, and methodical; it is based on management by fact, and it promotes the view that companies are responsible to society (Hutton, 1992).

[11] According to De Vos (1990: 38), the ideal teacher-consultant for delivering integrative MoT services has a technical degree, graduate business education, several years experience in technical management and other business experience, good communication and facilitation skills, may be a generalist with depth in one or two core disciplines, has rational and intuitive problem solving capabilities, inspires cooperation, can listen and synthesize

It is likely that quite a few public and academic actors are offering MoT-related technical and management services to firms. No reliable inventory of this activity exists. One example among many is the Ottawa-Carleton Research Institute, a creation of universities, community colleges, businesses, and local economic development agencies in the Ottawa region. OCRI represents an innovation-oriented confederation of actors that jointly promotes scientific, technical, and management courses at the metropolitan level. OCRI provides information on a range of technical and management training offered in the Ottawa region.

2.5 Summary Profile

Universities, governments, and the private sector have taken a variety of initiatives to develop and disseminate MoT skills and information to constituencies in Canada. The first wave of initiatives took place mainly in universities. A second wave of difficult-to-document initiatives concerns the development of a private market for MoT services. In a third wave that has yet to gather much momentum, public agencies are considering ways to diffuse MoT skills widely throughout the business sector.

The initiative to define the MoT agenda in Canada is currently in the hands of at least five separate groups. One is represented by the engineering and management schools, which compete with each other for resources to sustain teaching and research programs in MoT and other fields. The second is the international MoT scholarly and practitioner community, which is based in professional associations and in management and administrative disciplines. In the third group are governments, which occasionally fund programs in MoT and are considering ways to deliver technology management services to firms. In the fourth group are firms that use MoT skills or services and occasionally support MoT initiatives in-house or in universities. The fifth group is represented by interest groups and policy advisory bodies who compete to articulate a competitiveness agenda. A significant feature of this agenda is that it increasingly identifies management deficits as a problem requiring remedy.

3. Prevailing Influences on MoT

When MoT was first identified as a Canadian S&T policy issue two decades ago, it was viewed primarily as an R&D management problem to be addressed through formal training and a university-based research program. MoT was thereafter largely ignored in Canadian S&T policy debates until the late 1980s.

It is curious that management deficiencies were among the last factors to be considered in the Canadian competitiveness debate. Researchers, universities, workers, bureaucrats, the political system, government labs, the tax system, public attitudes, banks, foreign firms, small firms, the resource sector, history, and teachers were all fingered as the weak links in the national system of innovation before the skills, attitudes, and competence of managers became an issue. In the late 1980s, however, the tables turned. In a 1988 report on globalization and competitiveness, the Science Council of Canada was one of the first to put the competence of managers at the center of the innovation policy agenda:

> Improving the scope of governmental support will not in itself be much help...when Canadian managers place so little emphasis on technology and innovation. Canada's most immediate S&T problems are the inability of many of its managers to develop and apply

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well, has linkages with an investment firm, has experienced and overcome failure, and is either around 35 years old or is an older person with about 25 years of experience.

> technology to make a profit, the low rank within managerial hierarchies for those with technological expertise, and relatively poor rewards for these people. [...] [F]ew Canadian companies integrate technology into their strategy formulation process. Too frequently major technological choices are treated as tactical rather than strategic decisions. Or they are viewed largely in isolation, as the concern of the R&D department....The proper exploitation of technology must move to the top of the agendas of Canada's directors and senior executives....(SCC, 1988: 11,12).

The idea that managerial incompetence is at the root of uncompetitive firms has since become firmly established in the policy debates. A 1992 NABST report on technology diffusion in Canada observed that:

> the critical factor governing whether a firm remains competitive is the awareness and commitment of the senior managers of that firm. Too often, these managers are not aware of the pace of change in competitive firms around the world. They do not take advantage of the support infrastructure and programs which are available to them. They react too late, if at all, to the opportunities of better technology and to the need to change management concepts and procedures to permit their firms to reach quickly and responsively to market demands and challenges. This lack of awareness and motivation has been identified as the most serious impediment for [sic] technology acquisition and diffusion in Canada (NABST 1992

The report of the Prosperity Initiative's consultations on financing innovation provides an even harsher assessment of Canadian management. It observes that "in all quarters, Canadian management was indicted for its overall lack of vision and poor leadership." The indictment blames public, private, labor, and academic management for behaving according to a "herd mentality" and thereby becoming "blockers and followers," "risk averse, conservative, cautious, ill informed, and insular" (Prosperity, 1992d: 17,29).

These are strong words, delivered by messengers that governments cannot easily silence. They reflect what is probably widespread frustration with Canada's performance, institutions, and leaders. The deluge of reports, briefs, and consultations on Canada's competitiveness has produced a wave of diagnoses of problems and recommended remedies. In Table 2 we list recent ideas and proposals regarding the improvement of innovation management skills. The proposals concern training methods and arrangements, partnerships, new forms of policy making, recognition and incentives, and new principles.

These proposals represent an agenda for profound change in Canadian management styles, activities, and institutions. They also represent quite divergent diagnoses of problems, thereby generating an agenda that is incoherent. For example, how do we reconcile the call for more cooperation but less herd mentality, better inter-institutional linkages and greater institutional accountability, or more highly selective skills training and holistic, visionary leadership? Contradictory management desiderata are a reflection of our turbulent times. If there is an emergent innovation management paradigm, it is that of the "learning organization" which adapts, survives, and grows through nimbleness and intelligence. Characteristics of learning organizations are: they reward critical thinking, initiative, and risk taking; they have clear and committed leadership; employees are empowered and highly involved; communication and feedback are high; a bias for action and results exists; customers are the focus of attention; flexibility and other enabling organizational designs are experimented with; continuous learning and development opportunities are created; inter-firm learning is a source of strategic advantage (III, 1992). This is one part of the vision, against which must be set Canadian managers' day-to-day preoccupations with productivity.

The other part of the vision recognizes that management of technological change and innovation is an essential element in competitiveness but sees competitiveness in the coming decades to include global environmental considerations as well. For example, it has been suggested that environmental impact rulings could become one of the major non-tariff trade barriers of the future. The open Canadian economy stands to be particularly affected by such changes. The Canadian fur and timber industries are already feeling the impact of this sort of tactic. In the twenty-first century we will see competitiveness move from concern for being 'better, cheaper' to being 'better, cheaper, greener.' Changes in corporate goals, and possibly entire product lines will require dramatic shifts in thinking, at all levels of the economy.

Some of those shifts in thinking are already apparent among businesses. Pilko & Associates reports that in one recent survey of 200 senior executives in the US, 90% said that environmental considerations were part of their strategic planning process. DRT International surveyed 250 European companies and found that almost three quarters has specific plans to improve environmental performance. A 1991 report from the Canadian Federation of Independent Business states that 99% of their members are concerned about the state of the natural environment, and that 60% have made, or are about to make, significant changes to their businesses to respond to environmental concerns.

As an example of how MoT might become involved in environmental issues, we can look to the link between "quality" and "environment" underway at the Canadian Standards Association (CSA). The CSA has been working to develop environmental management systems that draw on the structure of and are compatible with the ISO 9000 series of Quality Management Standards (CSA, 1992). While 'quality' is a term currently in vogue, there is a growing recognition that it is more than just an idea, but it is a force in business that is here to stay. Part of the reason for this is the link between quality and life cycle analysis.

While we now speak of product life cycles in terms of formulation, development, and deployment, an alternative view is to look at the environmental life cycles for products. This approach examines the environmental cost over the entire life of the product, from resource stage to final disposal. In this conception products and services are viewed as systems with inputs (raw materials and energy) and outputs (waste and usable products). Within the system there are six stages: 1) raw materials acquisition; 2) manufacturing, processing and formulation; 3) distribution and transportation; 4) use, re-use, and maintenance; 5) recycling; and 6) waste management. Recent work suggests that the two approaches (product life cycle and environmental life cycle) are merging to some extent. Ottman has described how "companies must integrate environmental planning into their overall business strategy" (Ottman, 1992) and Casey gives some examples of companies that have taken the lead in reducing packaging for their products and "reaped significant benefits" (Casey, 1992).

According to the ISO standards, quality has four facets, 'definition of product needs,' 'product design,' 'conformance to product design,' and 'product support.' MoT specialists will be called upon to assist in the design, manufacture and distribution of product and service systems that meet the quality demands of the modern consumer, which will include the environmental impact during all of the six stages. Whether this means products that last longer or are easier to recycle will depend on the circumstances, but we can be assured that quality demands will not lessen and they will continue to extend forward and backward from the usual conception of product life cycle.

Proctor & Gamble (P&G) is one company that has taken the 'Total Quality Management' route to environmental responsibility. Their chairman of the board and chief executive, Edwin L. Artzt, was recently quoted as saying "We have a global challenge to lead the improvement of how we operate—not only in business but also in education, government, medical care, and the environment—so that we put the resources we have to their fullest and wisest use" (Fortune, 1992). P&G is a participant in the Global Environmental Management Initiative (GEMI), "a group of

20 leading companies dedicated to fostering environmental quality worldwide, [where it is] a pioneer in the application of total quality management principles to environmental improvement" (ibid.).[12]

In many cases the response to a sustainable development imperative will be a technological one. Northern Telecom, for example, has led the way in producing electronic circuits without the use of chloroflourocarbons (CFCs). Not only is this a leading stance environmentally, but it is resulting in dramatic savings (Business Council for Sustainable Development, 1992; Schmidheiny, 1992). New materials are allowing goods to be delivered with less packaging and more easily recyclable. Even transportation and distribution systems are being modified to handle goods that are less 'packaged' than before. Managing technology is fundamentally a skill in managing change. It makes sense, therefore, that as corporations move into an era of dramatic and fundamental changes they may turn to the experts on managing change, MoT researchers. We must be ready to meet that challenge.

Corporations in the 21st century will find it essential to be able to innovate and operate competitively while at the same time operating in an environmentally responsible manner. The Canadian government and some Canadian corporations have recently taken several strong initiatives in the area of environmental stewardship and sustainable development. MoT research which ties innovation and management of technological change to sustainable global competitiveness will go a long way to ensuring that Canada and Canadians remain healthy and prosperous into the next century.

In summary, there is no simple answer to the question of what are the sources of influence on MoT in Canada. There are many sources of influence. These we review below.

MoT has fuzzy boundaries, and definitions of the content and contours of the field vary. However, the center of gravity is clearly in the engineering and administrative disciplines. As we noted earlier, of all three institutional sectors, academic MoT activities are the most highly visible and have received the largest portion of public financial support devoted to development of MoT in Canada. Academic traditions and the approaches of the various management and engineering disciplines that make up the core of academic MoT in Canada largely determine the vocabulary and outlook of the "business paradigm" of MoT. In Canada, through the creation of MoT university chairs and new programs devoted especially to the development of business-paradigm MoT research and teaching, funding agencies and universities are primarily mobilizing engineering and administrative disciplines in pursuit of practical solutions to problems encountered within firms. Other social science disciplines offer competing paradigms, but these rarely interact with mainstream "business paradigm" MoT. Furthermore, the Canadian style of "business paradigm" MoT practice and scholarship is not easily distinguishable from "international" MoT, which is primarily based in North America and (to a lesser degree) Europe.

Most commonly, MoT teaching and research programs have been established in management or engineering faculties. Stand-alone MoT institutions in the university environment are rare.

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[12] In an advertisement accompanying the article, P&G states: "Total Quality Management is not just blue sky. It can also be cleaner air, clearer water and greener earth. Making our world a better home for people today, and for future generations, has become an important concern of consumers, customers and communities all over the world. Here and overseas, industry is starting to move away from merely meeting governmental regulations and toward a process of continuous environmental improvement. That's why the application of Total Quality Management to the environment has created so much interest in the business community. At Proctor & Gamble, we are learning how to use TQM to develop practical new solutions to environmental issues related to our processes, products and packaging. We're eager to share our experiences with others who want to contribute to progress in achieving environmental goals."

Canadian MoT shares the firm-centered bias that is characteristic of North American management disciplines. MoT appears most accessible and relevant to certain medium and large firms, and to small technology-intensive firms.

A great deal of MoT activity takes place that is difficult to compile, either because it is wrapped into other activities (for example, promotion of advanced manufacturing technologies) or because it is distributed as sharply-focused improved management techniques (for example, total quality management, design, or marketing), often through organizations that do not label themselves as active in MoT.

Although its center of gravity is in the administrative and engineering disciplines, business-paradigm MoT is largely problem- or issue- oriented, without restricting or explicitly favoring particular disciplinary approaches (see the examples in Adler, 1989). The popular international MoT conference held biannually at the University of Miami includes in its purview papers on S&T policy, processes of technological innovation, strategic planning, technology transfer, R&D management, entrepreneurship and new venture management, product and process innovations, technological innovation in organizations, quality and productivity issues, MoT in manufacturing and the service industries, managing information technology, human and social issues, education and training issues, economic analysis of innovation, and MoT methodologies. The conference draws participants from a variety of disciplines. However, the tenor of the conference is closer to that of engineering management than to social science-based administrative disciplines.

It is important to emphasize that even "business paradigm" MoT contains a wide variety of activities of varying content and styles, ranging from highly integrated strategy-oriented teaching and research to quite narrowly-focused technical problems with a management dimension. As De Vos has observed,

> Somewhere between these extremes are blends of MoT material with the more established teaching disciplines, such as engineering (including automated design and manufacturing), information technology, organization theory, research management, innovation, marketing, total quality management, business policy, and so forth. (De Vos, 1990: 39).

Selective investment in the MoT "business paradigm" in universities has several emerging consequences. One is that problems concerning innovation in environments larger than the firm receive comparatively little attention. Geographers, sociologists, regional economists, and political scientists, rather than researchers in engineering management or business administration, are developing the Canadian knowledge base about innovative environments, for example. Another consequence is that policy issues and problems are underexamined, leaving actors in the policy system to focus on process to the exclusion of content. A third consequence is that uses of technology for purposes that are not immediately economic (for example, problems of health or environmental technologies) are left for others to examine. A fourth consequence is that issues having to do with labor and management-labor relations are not sufficiently brought into the MoT teaching and research stream. A fifth consequence is that researchers working on MoT problems outside the business paradigm are scattered throughout departments, faculties, universities, and regions, with few shared institutional structures or dedicated resources to support their work.

Business-paradigm MoT teaching and research makes an explicit commitment to provide useful and reliable skills to firms, building upon and complementing the engineering or management backgrounds of students. The utilitarian expectations of MoT are very high, although the field is a hodge-podge collection of techniques, approaches, beliefs, research programs, and rules-of-thumb. This is partly because of the novelty of the field and partly because MoT is advancing at three different levels of analysis and aggregation. At one level MoT is a collection of techniques designed to solve relatively narrow sets of problems, such as purchasing, product development, or

R&D management. At a second level MoT attempts to integrate all relevant considerations into a strategic posture, converging with strategic management. At a third level MoT is concerned with organizational and interorganizational learning.

4. Policy Implications

We began this paper with a discussion of managing technology and we end it with the observation that the entire system of public and private management education and practice in Canada is currently being called into question as the country comes to grips with the challenges of competitiveness. Technological innovation, globalization, and economic turbulence are the factors that today's managers must learn to use to competitive advantage. Canadian managers must also grapple with a wide variety of indigenous cultural, social, and institutional factors that may be just noise to traditional management science, but that constitute and condition today's decisionmaking environment.

We have observed that the public, private, and academic sectors are each struggling with the challenges posed by management of technology and innovation. The public sector requires competent program managers and is responsible for ensuring the delivery of useful technology management services to firms, but the primary success of public policy for MoT in Canada has been to create support mechanisms for academic research. The private sector is calling for useful management of technology skills and services, but neither its advisory bodies nor its purchasing behavior permit clear identification of the configurations of management and technical skills that are appropriate at different levels and in different circumstances. The university sector is calling out for increased resources and support for MoT teaching and research, raising expectations about performance and utility that must be met.

It is not possible at present to identify best practices for training technology managers in Canada. Only anecdotal evidence is available concerning training methods and outcomes. Little is known about how Canadian firms use persons with formal training in MoT. Even less is known about the labor market for individuals with various combinations of technical and management skills.

The dominant features of the Canadian innovation management and training system are experimentation and diversity. These features are simultaneously a virtue and a liability because of the contradictory expectations that Canada has of its management training activities. In an age of turbulence and in a country as diverse as Canada, it is understandable that no agency or group has a clear overview of activities and no incontrovertible definition of best practice with respect to management of innovation. There is no sharply-focused Canadian MoT agenda, nor is there likely to be. On the other hand, dispersion of efforts does not enhance the kind of rapid learning, accountability, and demonstrably effective performance that are widely-held objectives.

As we pointed out earlier, conventional wisdom attributes the shortcomings of Canadian innovation not to lack of narrow technical or administrative skills, but to the failure of senior management to turn innovation into competitive performance. If there is an emerging consensus on managing technology in Canada, it is probably that "much of the adjustment which has to occur in Canadian firms is based less on technology and more on the way businesses manage themselves" (NABST, 1992: 23). Firm-level capacity to maintain a dynamic search for best-practice technology requires that management and labor be skilled and motivated, and that an appropriate, coordinated public innovation support infrastructure be provided.

Sustaining international competitiveness in an open, democratic, high-wage country makes an unusual set of demands on social values and the predominant business culture. In Canadian society entrepreneurial values are widely shared: a large majority of Canadians believe that hard work pays off, that ability judiciously applied leads to gain, that wealth creation is not a negative-sum game.

At the same time, Canadians are reluctant to attribute poverty to lack of individual initiative or to social structure (Fletcher, 1992; ISTC, 1992). If Canada develops what has been called a "high growth, low employment" economic trajectory, successful social adjustment to technological change will require a new commitment to develop social and political skills that are not being examined within the predominant MoT paradigm.

It would be foolhardy to predict the evolution, over the next decade, of MoT in Canada. More useful would be to specify desirable features of MoT teaching and practice in the country. We consider that a greater degree of interaction and cooperation among university researchers and teachers in MoT in Canada, including sharing of cases and curricula, would be useful. It would also be useful for MoT teachers and private sector associations to devote greater efforts to describe the kinds of management and technical skills required in industry, and to prepare teaching and research material with greater accuracy. We would like to see Canadian industry increase the strength and quality of privately supplied MoT training and consulting services through the development of a more vigorous market for these services. We would also like to see a more vigorous and comprehensive set of technical and management services provided to firms by public institutions. Finally, we would like the MoT field to become more reflexive, to question itself, its assumptions, its parameters, and its performance with a greater degree of clarity than has been the case until now. We would not like to see any one of the three streams of MoT that we have identified - technical MoT, integrative MoT, and learning-organization MoT - suppress any of the other streams, but we would like to see greater involvement of the social science and the natural science disciplines in MoT teaching and practice. Finally, we suspect that larger management thought and practice will be increasingly concerned with environmental issues. These are likely to engage all three streams of MoT, from pragmatic quality and efficiency improvement that reduce harmful environmental impact to the creation and maintenance of the socially responsible "green corporation," in touch with its social, physical, and biological environment.

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Table 1

Current social science topics and issues in the management of technology in Canada

- the stimulation of innovation and R&D within the firm
- the management of the innovation process
- technology transfer within Canadian industry or from parent or foreign firms
- technology transfer for export
- technology transfer and overseas aid/development
- organizational adoption of and adaptations to new technology
- job classifications and job skills (related to technological change)
- the impact of technology upon the workforce in general and in specific industries
- training issues and policies
- science and technology education
- public education concerning science and technology
- labor-management relations and collective bargaining (as affected by technological change)
- science and technology policies
- industrial strategy
- trade policies
- trade liberalization and its effects on the technological behavior of firms
- standards
- intellectual property issues
- regulatory issues
- technology assessment and risk analysis
- office automation studies
- gender and technology
- spatial aspects of technology
- regional and community development
- decision theory and decision support systems

Source: adapted from Salter (1990: 38).

Table 2: Recent proposals to strengthen management of innovation in Canada

1) Strengthen programs to support the hiring of technically trained people in firms.

   An estimated 70% of Canadian manufacturing firms have no engineers on staff. Some provinces, notably Quebec and Ontario, have programs that subsidize the hiring of technically trained people. Calls are being heard to expand these programs (SCC, 1988; CSTQ, 1990).

2) Firms should increase the influence of persons with technical competence within senior management.

   Canadian firms are urged to modify the composition of Boards of Directors and strengthen the technical capability of senior management to provide better strategic direction with respect to technology (SCC, 1988).

3) Establish alliances and partnerships.

   Large, indigenous technology firms should provide mentorship to smaller companies in the innovation, production, management, and international marketing of products (CIAR, 1988).

   Sponsor and encourage "all forms of partnerships and alliances" (Prosperity, 1992d: 30).

   Train executives as a team (Larson, 1992: 21).

4) Establish new institutional arrangements to provide analysis, generate consensus, guide collective action, fund research, or keep innovation and competitiveness issues in the public eye.

   Recent proposals include the establishment of a Prosperity Council to include representatives of Federal and provincial governments, labor, education, consumers, and voluntary and social groups (Prosperity, 1992a: 62); a Competitiveness Council (Prosperity, 1992b); a Centre of Excellence for Sustainable Development (Prosperity, 1`992a); a Canadian Education Council (ibid.); a Technology Change Centre (ibid.); a Continuous Learning Board (NABST, 1991b); a Management Research Council (CAC, 1992: 46); and "a series of Community-based business support networks or planning councils" (Prosperity, 1992d: 30); a National Quality Institute (Prosperity, 1992a); and a National Business Leadership skills school (Prosperity, 1992a: 30).

5) Improve management training.

   Courses in management of technological change and new product development should be developed and delivered through secondary schools, technical institutes, and universities (Prosperity, 1992a: 20). Firms should collaborate with universities to strengthen their teaching and research capacity in MoT. (SCC, 1988). Faculties of business and engineering should work together to develop graduate and undergraduate courses in MoT (CAC, 1992: 41).

Public funding of university-based management programs should be increased and tied to accountability for improved teaching and research (CAC, 1992: 44-5, 53).

Business faculties and industry should work more closely together to improve the relevance and quality of business education (CAC, 1992: 40).

Federal and provincial governments should fund a program to enable graduate engineers to learn designated foreign languages and study abroad (SCC, 1988: 12).

Companies should maintain internal technology management programs (SCC, 1988). The goal should be to develop "managers with the confidence, knowledge and skills to manage continuous innovation" (NABST, 1991b: 17). Industrial managers should upgrade their skills and those of their employees "through on-going training programs and active collaboration with the education sector" (NABST, 1992).

Universities should improve their continuing education in MoT (SCC, 1988). Canadian public and private organizations should increase commitment to continuing education of managers (CAC, 1992: 44; Larson, 1992).

Public and private organizations should experiment with new ways of educating managers (CAC, 1992: 45).

Provincial governments should establish programs to allow universities to hire domestic or foreign MoT practitioners for short periods (SCC, 1988).

A statement of competence-based qualifications should be developed for Canadian managers and used to redesign post-secondary management and administration programs and in hiring and promoting employees (Prosperity, 1992a: 46).
Courses in the management and use of computers and other information and communications technologies should be prepared for all students in management and administration (Prosperity, 1992a: 31).

Establish programs of mentoring and interchange of managers, executives, labor representatives, and academics to accelerate the diffusion of new management practices (Prosperity, 1992a: 46; NABST, 1991b: 17).

Launch a Total Quality Management education campaign for CEOs and senior management (Hutton, 1992).

Assess the impact of the changing world economy on the future skill requirements of public and private sector managers, and develop and implement appropriate continuous learning programs (NABST, 1991b: 17); CAC, 1992; 48).

Reorganize management education: rationalize sector-specific training; create two career streams, one emphasizing teaching and the other, research; increase cooperative education; functionally integrate business education and public administration education; establish centers of excellence (CAC, 1992: 49).

Business and administration faculties should strengthen student learning of human relation skills (CAC, 1992: 46).

The business community should work with faculties of education to "develop a mindset on the part of future managers of the educational system of the importance of their role in supporting the competitiveness of the Canadian economy" (CAC, 1992: 42).

Public administration education should emphasize best practice (CAC, 1992; 54).

Management education should "reflect a more holistic perspective" encompassing the environmental and social contexts (CAC, 1992; 51).

6) Improve labor-management teamwork.

Adopt labor-management teamwork as "the normal way of doing business in Canada" (Prosperity, 1992a: 31).

Develop and promote models of labor-management teamwork (Prosperity, 1992a: 31) and provide training for such labor-management collaboration for total quality management (Hutton, 1992).

Promote labor-management cooperation "by building national forums for industry associations to pursue common objectives" (Prosperity, 1992a: 31).

7) Management innovation strategy.

Foster corporate innovation through total quality management programs (FSCA, 1992: 17).

Senior management in firms, trade associations, financial institutions, and labor organizations should "make a point of acquiring enough operational knowledge about the strategic management of technological change to provide effective management and vision" (SCC, 1989: 17). Trade associations should help "de-mystify the role of technology in business operations," "nurture greater commitment on the part of CEOs toward employing new technology and managing technology more effectively," and "develop a better understanding of technological innovation in business planning" (CCC, 1988).

Firms "are on the front lines of international competition." The burden is on their managers to understand their competitive position and focus on innovation-driven advantage (Porter, 1991: 77).

8) Recognition and tax incentives

Create "one-time, tax-free rewards for achievement in business excellence" (Prosperity, 1992d: 30).

Provide tax incentives for people to serve on SME boards of directors or advisory committees (Prosperity, 1992d: 30).

Recruit offshore Canadians and expatriate foreigners with tax-free bonuses and incentives (Prosperity, 1992d: 30).

Government should establish new tax incentives and other inducements to promote technology acquisition.

9) Adopt improved management practices

Industrial managers should practice continuous benchmarking, and government programs and private technology centers should actively promote the identification and diffusion of best practice in this respect (NABST, 1992).

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