Science, Innovation and Electronic Information Division

RESEARCH PAPER

CAPACITY TO INNOVATE, INNOVATION AND IMPACT: THE CANADIAN ENGINEERING SERVICES INDUSTRY

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Capacity to Innovate, Innovation and Impact: The Canadian Engineering Services Industry

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This paper presents estimates of the technological and performance indicators, organized into a system of innovation. Knowledge is the strategic asset in this system. The elements of the system are linked together as inputs, outcomes and impacts in order to form a coherent picture of the relationship between technological change and its economic impact. The analysis is carried out at the finest industrial disaggregation level, the 4-digit engineering services industry, in order to determine the effect of unique industry characteristics on innovation activity. Types of innovation are discussed, including the organizational change, as is the novelty of innovation and the innovation diffusion cycle both for innovations adapted from other firms in the country and for innovations adapted from other countries. Estimates of the impact of innovation on sales, exports, jobs and skills are also provided.

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The Science and Innovation Information Program

The purpose of this program is to develop **useful indicators of science and technology activity** in Canada based on a framework that ties them together into a coherent picture. To achieve the purpose, statistical indicators are being developed in five key entities:

- **Actors**: are persons and institutions engaged in S&T activities. Measures include distinguishing R&D performers, identifying universities that license their technologies, and determining the field of study of graduates.
- **Activities**: include the creation, transmission or use of S&T knowledge including research and development, innovation, and use of technologies.
- **Linkages**: are the means by which S&T knowledge is transferred among actors. Measures include the flow of graduates to industries, the licensing of a university's technology to a company, co-authorship of scientific papers, the source of ideas for innovation in industry.
- **Outcomes**: are the medium-term consequences of activities. An outcome of an innovation in a firm may be more highly skilled jobs. An outcome of a firm adopting a new technology may be a greater market share for that firm.
- **Impacts**: are the longer-term consequences of activities, linkages and outcomes. Wireless telephony is the result of many activities, linkages and outcomes. It has wide-ranging economic and social impacts such as increased connectedness.

The development of these indicators and their further elaboration is being done at Statistics Canada, in collaboration with other government departments and agencies, and a network of contractors.

Prior to the start of this work, the ongoing measurements of S&T activities were limited to the investment of money and human resources in research and development (R&D). For governments, there were also measures of related scientific activity (RSA) such as surveys and routine testing. These measures presented a limited picture of science and technology in Canada. More measures were needed to improve the picture.

Innovation makes firms competitive and we are continuing with our efforts to understand the characteristics of innovative and non-innovative firms, especially in the service sector that dominates the Canadian Economy. The capacity to innovate resides in people and measures are being developed of the characteristics of people in those industries that lead science and technology activity. In these same industries, measures are being made of the creation and the loss of jobs as part of understanding the impact of technological change.

The federal government is a principal player in science and technology in which it invests over five billion dollars each year. In the past, it has been possible to say only *how much* the federal government spends and *where* it spends it. Our report **Federal Scientific Activities, 1998 (Cat. No. 88-204)** first published socio-economic objectives indicators to show *what* the S&T money is spent on. As well as offering a basis for a public debate on the priorities of government spending, all of this information has been used to provide a context for performance reports of individual departments and agencies.

As of April 1999, the Program has been established as a part of Statistics Canada's Science, Innovation and Electronic Information Division.

The final version of the framework that guides the future elaboration of indicators was published in December, 1998 (**Science and Technology Activities and Impacts: A Framework for a Statistical Information System,** Cat. No. 88-522). The framework has given rise to **A Five-Year Strategic Plan for the Development of an Information System for Science and Technology** (Cat. No. 88-523).

It is now possible to report on the Canadian system on science and technology and show the role of the federal government in that system.

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1. Introduction

Firms innovate in all aspects of their business to gain or sustain competitive advantage. An innovative financing package may be offered to win a contract. New marketing techniques may be adopted to build customer loyalty. Pricing strategies may be changed to attract new customers and increase market share. The command-and-control type managers may be replaced by inspiring leaders to revitalize the company. This paper is primarily concerned with innovations specifically related to technological advancement, i.e. significant improvements to existing products[1], the introduction of new goods or services and the adoption of more efficient methods of production or delivery. With technology changing at an unprecedented pace and the geographical boundaries of the marketplace disappearing, the competitive advantage more than ever depends upon a steady flow of new and improved goods and services and more efficient methods of production.

In order to compile information on the status of the Canadian industry, Statistics Canada conducted a survey of innovation in the service sector in the spring of 1997. Because of the heterogeneity of service industries, the survey focused on key sectors. Communications, financial services and business services sectors encompassing fourteen industries were surveyed. The sectors were chosen for their unique characteristics in order to understand the effect of industry-specific factors on their propensity to innovate. They are all knowledge-based and information-intensive but differences in industry structures, the nature of their products, the way they organize production and the competitiveness of their markets distinguish them from each other. In the television broadcasting industry, for example, production occurs on a project-by-project basis, with partners often changing with projects. Complex technologies in the financial services industry requiring large investments are developed by a consortium of firms and simultaneously introduced by the members. In professional service industries, it is not uncommon for the branch offices or establishments (as distinct from the firm which is the international standard for innovation surveys) to create intellectual property and introduce innovations suited to their local markets.

The first results from the survey were released in March 1998. Subsequently, studies providing information on broad industry aggregates were issued. While they provided useful insights into the process of innovation, they did not (1) treat innovation as a system and (2) explore the influence of unique industry features on innovation activity. These and other studies based on this survey are listed in Appendix B.

[1] The term product is used to mean a good or service.

In this paper, we present estimates of a system of innovation in which knowledge is the strategic asset and organize the technological and performance indicators into inputs, outcomes and impacts in order to present a coherent picture of the relationship between technological change and its impact on the economy. The main components of the system along with their estimated values from the survey of innovation, supplemented in a few instances by other Statistics Canada sources, are presented in Table A. The analysis is done at the finest available industrial disaggregation level to illustrate the effect of unique industry characteristics on innovation activity. The focus of the study is on the engineering services industry. [2] The first column in Table A shows indicators of knowledge base, knowledge generation within the firm and the various ways in which firms acquire knowledge from external sources. The second column summarizes the outcomes that result from the use of knowledge assets. These are divided into new or improved products and processes offered on the market and intellectual property that can be licensed for commercial use. Performance indicators or impacts are given in the third column. This table is intended to be an easy reference to data in the context of the system of innovation. For reference to the survey instrument, more detailed tables arranged according to the topics in the questionnaire are placed in Appendix A. They also show corresponding data for the business services sector for comparisons. For the purposes of this paper, the business services sector is narrowly defined to cover three industries: computer services, engineering services and the scientific and technical services.

The analysis begins with a brief description of the relevant features of the engineering services industry in the next Section. The rest of the paper follows the outline set out in Table A. Capacity to innovate is the subject of Section 3. Firm's internal capacity and the access to learning and tacit knowledge through networks, alliances and acquisition of other firms are discussed here. In the fourth Section, we examine the extent to which the industry is able to translate its knowledge into products and processes. We focus, in particular, on the aspects related to competitiveness including the propensity to innovate, degree of novelty and the frequency of innovations. The innovation diffusion cycle, with estimates of the lag with which innovations – domestic and adapted from foreign countries -- are diffused after they were first introduced is also discussed here. Another feature of this section is the discussion of the culture of innovation which takes into account the total innovation effort whether it is successful or not, whether it results in an immediate economic benefit or positions the company for future growth. The economic impact of innovation is the subject of Section 5. Contribution of innovation to sales and exports is discussed, as is its effect on jobs, skills and productivity. Process-related outcomes such as improvements in quality, reliability of products and timeliness are also included. The paper concludes with a summary of the main findings.

[2] 1980 Standard Industrial Classification code 7752. NAICS has replaced the 1980 SIC since the survey was done but the engineering services industry is little affected. The corresponding NAICS code is 541330. For international comparisons, the equivalent industry in the United States has the same code, NAICS 541330. ISIC and NACE roll up engineering services industry with architectural and scientific services in codes 7421 and 74.20 respectively.

Table A: Components of the System of Innovation: Engineering Services Industry

(Figures pertain to number of firms and are shown as % of all firms in the industry, unless otherwise stated)

Capacity to innovate		Outcomes		Impacts	
Tacit Knowledge		**Products and Processes**		**Overall indicators**	
- Knowledge intensity (% of workforce)				% contribution of	
- Professionals	55.7	Innovation Rates		innovations to	
- employees	46.6	New products	30.2	industry	
- partners & principals	2.2	New processes	26.2	- sales	16.4
- consultants	6.9	Organizational		- exports	20.0
Of professionals:		Change	15.6		
Bachelor's degrees	71.0	New product, new process		All the following data	
Master's degrees	24.0	or organizational		are % of innovators:	
Doctorate degrees	5.0	change	40.7	Impact on Jobs:	
- Technicians & technologists	30.4			- Increase	32.4
- Administration & support	12.8	Innovation Rates		- Decrease	4.0
- Formal training programmes	11.3	- Exporters	73.0	- Neutral	63.5
- Movement of workers (jobs created +		- Non-exporters	32.3		
jobs destroyed)*100/total jobs	26.0	- Internet users	76.6	Impact on Skills:	
Knowledge generation		- Non-Internet users	19.7	- Upgraded	37.4
R&D intensity (R&D expenditure as		- Knowledge-intensive firms		- Downgraded	2.1
% of GDP)	8.4	- R&D performers	98.1	- Neutral	60.5
Propensity to perform R&D	15.3	- Non-R&D performers	23.1		
- regularly	10.2	- Newly acquired firms	60.8	Increase in	
- occasionally	5.1			productivity	
R&D alliances	13.7	Novelty of innovation:		- of innovators	30.6
Knowledge acquisition		(% of innovators)		- of clients	33.9
R&D collaboration with		- Quality improvements			
- Clients	4.9	or cost reduction	63.2	Improvement in	
- Universities	3.5	- New product	28.1	employee motivation:	
- Government research labs.	3.6	- New line of products	15.0	-Firms making org.	
Collaborative innovation projects	10.6	- Breakthroughs	3.8	change	27.4
Mergers & acquisitions	2.3			- Other firms	21.1
Networks (% of innovators)		**Intellectual Property (IP)**		- All firms	23.5
- Clients	70.3	Firms using IP protection			
- Competitors	41.7	instruments:		**Process-related**	
- Consultants	21.8	- Any instrument	21.5	**indicators**	
- Govt. information Progs.	20.2	- Patents or copyrights	12.3	Quality:	
- Universities, etc.	32.8	- Trade secrets	8.8	- Flexibility in	
- Conferences and journals	40.2	- Trademarks	6.6	meeting	
- Social gatherings	11.8			demand	53.1
Acquisition of Embedded knowledge		**IP assigned by firms**:		- User-friendliness	
- Machines		(as % of firms using IP		of products	35.0
- Acquired the right to use of IP		protection instruments)		- Product	
- from domestic firms	5.8	- to domestic firms	12.7	reliability	44.9
- from foreign firms	1.8	- to foreign firms	3.8	-Safety	27.9
Internet Technology	62.3			Timeliness	43.4
Leadership and management style				Accessibility	24.2

2. Some Features of the Engineering Services Industry

The engineering services industry is comprised of firms primarily engaged in applying principles of engineering in the design, development and utilization of machines, materials, structures, processes and systems. It offers services ranging from feasibility studies to design and commissioning or the start-up of the operation of projects. Most firms are pure engineering services firms. Very few offer full service packages. Only 10 per cent of the firms earned any revenue from BOOT (build, own, operate and transfer ownership) and 12 per cent from BOT projects in 1999; however, 67 per cent of the firms offered design/build service packages. Revenue shares of these services were much smaller (ACEC 1999). This is partly a reflection of the industry's skewed structure tilted towards the small firms which must form coalitions or consortia if they want to offer full service packages.

Consistent with the industry structure and dominance of pure engineering services, transactions tend to be small in size. In 1999, one-fourth of the contracts received by members of the Association of Consulting Engineers of Canada were valued under $5,000 while only 18 per cent were above $100,000 (ACEC 1999). Once the activities of non-members, who are typically small firms, are taken into account the small contracts would have a larger share.

Notwithstanding the large number of small firms and small contracts, the engineering services industry has an important position in the economy. In 1996, it earned $5,456 million in fees[3] (Statistics Canada, 1996). It ranks fourth largest in the world, with the United States dominating. The other major players with which it has to compete in international markets are the United Kingdom, The Netherlands, Germany and France (Industry Canada, 1997). Canadian firms exported $1,109 million worth of services in 1996, but the actual exposure to international markets is much greater when the work performed by foreign subsidiaries, excluded by the export data, is included. Their contribution can be significant as they are estimated to account for 21 per cent of the total workforce working for the Canadian engineering services firms in Canada and foreign countries (ACEC 1999).

The industry is at the leading edge towards the development of knowledge-based industries. This stands out in a number of ways. First, workers are its principal asset and the main source of value added by it. In 1996, 54 per cent of the current expenditure consisted of payments to employees for their services (Statistics Canada, 1996). Expertise contributed by consultants engaged for short-term assignments and by the partners of firms whose remuneration is not designated as salaries is over and above it. By contrast, physical capital plays a lesser role in production. Only 7 per cent of the current expenditure was charged to the services of machines and buildings (Statistics Canada, 1996).

[3] The total revenue estimated at $6,928 million includes recovery of reimbursable expenses the engineering services firms incurred on behalf of their clients. As reimbursable expenses are not part of the industry's value added the fee income is a more accurate measure of the size.

Second, the industry stands out as knowledge-intensive among similar consulting industries and the economy as a whole. Measures of knowledge intensity at a fine industrial disaggregation level are not easily available. However, average salary is a reasonably proxy. Although it is determined by many factors it is realistic to expect the average salary will be higher in knowledge-intensive industries if the society accords knowledge more value. The data confirm it. Average salary in the engineering services industry (broadly defined to include architectural, engineering and scientific services) was $44,000 in 1996, 30 per cent higher than in the business services sector, which includes various professional consulting services industries. It was substantially, 44 per cent, above the average salary in the economy overall (Statistics Canada, 1998a).

Finally, as providers of inputs in the production of capital goods, firms in this industry play a key role in the diffusion of up-to-date technologies, whether they develop them themselves or borrow them from elsewhere for use in projects they undertake. Such technologies as computer-aided design and drafting and computer-assisted engineering design developed by consulting engineers are widely used in the manufacturing sector. Forty-four per cent of the manufacturing establishments use CAD/CAE technology and 36 per cent use CAD/CAM technology. Their use is twice as prevalent among the large establishments (Statistics Canada, 1998b).

3. Capacity to Innovate

A firm's ability to innovate depends, first and foremost, on its knowledge base and how much of it is devoted to the pursuit of creative activities. It accumulates knowledge through experience, experimentation and acquisition. Fundamental to all these mechanisms is a knowledgeable workforce conversant with the existing stock of knowledge, able to question its premises and establish new paradigms.

3.1 Tacit Knowledge Base

The industry has a large base of workers who possess conceptual skills. Professionals who are overwhelmingly engineers account for more than one-half of the workforce (56 per cent). Consultants engaged for specific tasks on a temporary basis and the principals and partners of firms who are not classified as employees and hence missed by the innovation surveys are a very significant component of the professional base. According to our estimate, they make up as much as 15 per cent of the professional labour force. However, their contribution to the knowledge base may be more than that. Hansen et al. (1999) suggest that consulting firms that specialize in finding solutions to highly complex problems attach more value to the tacit knowledge of their principals and partners as compared with employees with similar professional qualifications. Technicians and technologists, who are hired for their implementation skills, account for 30 per cent. Just over one-tenth of the industry's labour force is in the administrative and support group.

Formal educational attainment of the workforce is another indicator of the stock of tacit knowledge. Five per cent of the engineers hold doctorate degrees, 24 per cent have master's degrees with the rest holding bachelor's degrees.

Educational qualifications of the labour force provide useful information about the tacit knowledge base, but the acquisition of knowledge continues beyond the formal education at school to learning in the workplace. Investment in skill improvement in the knowledge-based society is akin to expenditure on the upkeep of physical capital in the industrial economy, with a very important difference, however; while the former serves to appreciate the capital the latter only slows the rate of depreciation. Skill upgrading can be accomplished through formal, structured training or learning at the employee's initiative. The choice depends upon the firm's innovation strategy, approach to learning and its size. Formal training such as that offered to groups is typical of firms that have large numbers of employees with implementation skills and want to improve their operational efficiency. Firms with a heavy concentration of conceptual skills are more likely to encourage transmission of knowledge in a less structured way because the subtle points and nuances, which are of essence in knowledge generation and discovery, are often difficult to transfer to groups (Hansen et al., 1999). Finally, a firm's view of human capital building also influences its decision as to whether to offer formal training or provide opportunities for learning by letting the employee decide what he wants to learn -- within the competencies identified by the firm as essential for its ongoing success -- and set his own schedule (Stewart 1997).

Structured training does not seem to be very common in the engineering services industry. Only 11.3 per cent of the firms noted that they had formal training and development programmes for their employees. This relatively small number is in sharp contrast to the large number of firms (50.6 per cent) which underlined the importance of training for the success of their business. To some extent, the gap reflects the skewed structure of the industry in favour of small firms, which may not afford to provide formal training and development programmes but nevertheless acknowledge its importance. It also suggests that much of the training and learning takes place as an informal process, which the question in the survey instrument was not designed to capture.[4]

While learning and training are one aspect of a firm's human resource policies, the process of creative destruction in the economy offers firms an opportunity to attract workers equipped with knowledge and skills accumulated at the competitors' expense. Firms have been gathering intelligence for years through networks and alliances to enable them to

[4] According to a survey conducted for the Association of Consulting Engineers of Canada (1998), 81 per cent of the firms provided formal and informal training to new graduates. The gap between the two surveys should not be taken as an indication of informal training because there are other factors at play. First, this survey is more recent and probably captures the impact of industry's special effort to emphasize training following the recommendations of HRDC (1994) and the appointment of a training coordinator. Second, members of the Association of Consulting Engineers of Canada are typically larger firms, whereas the survey of innovation covered all firms. Finally, the Association survey pertains to training of only new graduates.

predict changes in buyers' preferences and to reduce uncertainty caused by the unpredictable actions of their competitors. Inter-locking directorships, for example, are used to facilitate the exchange of ideas between companies at the policy level. Secondment of professionals creates opportunity for an interchange of ideas at the operating level. Beyond the formal arrangements, the marketplace provides an important mechanism for the flow of knowledge and information throughout the economy. Just as it allocates financial capital to industries where it commands the highest price and yield, so does it move people to firms and industries where their knowledge finds its optimum use. By rewarding good business decisions and punishing bad judgments, the market continuously reallocates jobs from stagnant companies to dynamic firms, forcing circulation of people who take their knowledge and experience with them to their new employers, saving them time and money it would take to develop expertise and learn about the best practices of the competitors. While the job turnover is lower in the engineering services industry than the economy as a whole, it is still sizeable. For every new job created, three jobs are estimated to change hands in the economy and about two in the engineering services industry (Hamdani, 1998). The innovation survey did not address the question of job turnover directly but the information gathered about the workforce strategies revealed the importance firms attach to knowledge and skills beyond formal education. An overwhelming majority noted the need to recruit skilled workers and 56 per cent called it crucial or very important for the ongoing success of their firm.

3.2 Research and Development

R&D is the source of original knowledge, and path-breaking innovations are less likely to happen without it. The engineering services industry is uniquely equipped to undertake this activity and create intellectual property. As already discussed, its large tacit knowledge base provides the necessary reservoir of expertise. Complementing the infrastructure is a keen awareness in the industry of the importance of R&D. Respondents to the survey of innovation overwhelmingly acknowledged its role in innovation and as many as one-half rated it as crucial for getting ahead of the competitors. Other sources of data affirm the importance the industry gives this activity. Among the 45 industrial aggregates for which Statistics Canada publishes data on industrial R&D, the engineering services industry (including scientific and technical services) ranks first in the service sector and third overall, after the telecommunication equipment manufacturers and the manufacturers of aircraft and parts (Statistics Canada, 2000).

R&D intensity is another indicator. The ratio of R&D expenditure to the gross domestic product for the engineering services industry at 8.4 per cent was more than eight times the figure for the whole industrial sector. The industry planned to spend $910 million on R&D in 1999, a sharp increase from $685 invested in 1996. Definitions underlying these data are consistent with the Frascati Manual (OECD, 1993) and therefore research that takes place on the job as part of the project development and implementation process is not included. The amount of expenditure on this type of R&D may not add up to much but the number of firms undertaking it does, as several studies of the comparisons of innovation and R&D surveys have found (Kleinknecht and Reijnen, 1992; Sirilli, 1998; Gault and Hamdani, 2000).[5] However, R&D is concentrated among large firms. Only 15.3 per cent of the firms reported performing R&D in the reference period. Large firms that pursue an innovation strategy to become technological leaders and have enough human and financial capacity to afford the risk devote resources to R&D on an ongoing basis. For the small firms, it is often an occasional activity, undertaken when a problem is encountered and takes place on the job as part of the project development and implementation.

Firms that do not perform R&D can nevertheless benefit from the research undertaken by other firms or institutions. The externalities or spillovers of R&D are well recognized in the literature[6] although they spread with a lag. The length of the lag in the diffusion of innovation is discussed in Section 4.1.5.

3.3 Alliances

Since all the necessary expertise may not reside in an individual firm and the risk involved in experimental research is very high, cooperative effort is a growing phenomenon. Strategic alliances and joint ventures for R&D create capabilities greater than the sum of the technological capabilities of individual firms or institutions by taking advantage of synergies and complementarities among them. Generic features of contemporary core technologies reinforce the case for cooperation. Further, the growing risk associated with the rapid technological change in recent years has increased the need to spread the risk. This is especially the case with research on breakthrough innovations. Nearly all R&D performers had cooperative arrangements with other firms or institutions.

3.4 Mergers and Acquisitions

Corporations use a variety of vehicles to accumulate knowledge. Each vehicle serves a specific purpose. The form or vehicle that a firm chooses is usually a response to changing competitive environment and adopted in order to generate more favourable conditions for technological change. Therefore, the acquisition of a firm represents a very different strategy from that underlying alliances and joint ventures. As discussed in the preceding section, an alliance allows access to learning available elsewhere which may eventually lead to new products or processes. By acquiring technology through acquisition, the acquirer is able to enter a new market immediately. Whereas in joint ventures and alliances participants share knowledge and technology, the acquisition entails proprietary rights and enables the firm to create a strategic barrier and preempt the entry of new competitors. It is therefore not

[5] The gap between innovation and R&D surveys with respect to the number of R&D performers is not fully explained by differences in the survey methods (Gault and Hamdani, 2000) and is, therefore, attributed to the restrictive definitions used in R&D surveys.

[6] While economic theoreticians argue against subsidies, the externalities of R&D are used by endogenous growth theories to make a case for R&D incentives. See, for example, Rivera-Batiz and Romer (1991a and 1991b).

unusual for firms to pay large premiums to acquire firms which are not profitable and in some cases have hardly any revenues.

Alliances are the preferred choice of the engineering services industry as an organizational form of increasing learning and acquiring knowledge. Just over 2 per cent of the firms responding to the survey of innovation noted that their ownership had changed hands during the reference period. This partly reflects the fact that acquisitions as a tool of acquiring knowledge are better suited for fast paced industries where the speed and frequency of bringing new products to the market and the need to be first are critical for the growth or even survival of firms. The long time lags involved in developing greenfield technologies can prove far more costly in dynamic industries in terms of opportunities lost than the premiums firms may pay to acquire well developed knowledge available in upstart firms. It should be noted that mergers and acquisitions do not simply mean transfer of technology between two firms. They enhance its value because acquirers acquire firms either because of the complementarities or because they can make more efficient use of the acquired firm's knowledge assets than the previous management did.

3.5 Networks

Interactive theories of innovation note the importance of various sources of ideas for innovation. This can partly be seen in the fact that while only less than 15 per cent of the firms in the engineering services industry performed research and development, more than 40 per cent innovated. Collaborative effort between firms, between firms and institutions and between the public and private sectors has drawn considerable attention in the literature to understand the role of joint effort in innovation. Collaboration takes varying degrees of formality. We have already discussed the role of more formal types of cooperation, i.e. R&D alliances in Section 3.3 and acquisition of firms in Section 3.4. In this section, we turn to the informal type of cooperation, namely networking. The survey of innovation addressed this question in considerable detail and dealt with more than a dozen networks extending from clients to institutions of higher learning and research. Here, we provide only a brief summary of the results.

Since firms simultaneously use several networks, it is necessary to know what degree of importance they attach to them in order to identify the real drivers of innovation. To this end, the respondents were asked to not only identify the sources of ideas, but also rank them on the Likter scale from 1 to 5, with a score of 1 indicating the least important and 5 signifying crucial. The data presented below pertains to firms identifying a source as very important or crucial.

Notwithstanding the fact that the engineering services industry is R&D-intensive, the customer interface emerges as the most important source of ideas. Unlike the firms in the construction industry which tend to get ideas from their suppliers, firms providing engineering services interact closely with their clients. Clients' specifications and unique problems provide ideas for research (von Hippel, 1986). Over 70 per cent of the innovators viewed their customers as a very important or crucial source of ideas. The client interface goes well beyond just finding solutions to the problems they bring. In many cases, they are involved in jointly pursuing innovative solutions.   Among the firms that developed new products or processes in a cooperative arrangement, most did so with their clients. While 20.5 per cent of the innovators entering cooperative ventures made such arrangements with universities, more than one-half (51.6 per cent) did so with the customers. Clients commissioning large projects are well aware of the latest technologies and can, therefore, make useful contributions. Firms dealing with sophisticated clients are more likely to introduce technologically sophisticated products and processes.

Innovators also noted the importance of the institutions of higher learning and research, both private and public, and professional conferences and literature. While educational and research institutes appear to play a lesser role, the cooperative efforts in which they are involved are of a higher technological sophistication and leads to innovations that have the potential of making a big economic impact.

However, ideas can spring from anywhere - clients, competitors, research, and even from small talk.[7] The role of informal type of networks is recognized in the literature and the cultural factors and even common leisurely interests are noted to play an important part (Freeman, 1991; Stewart and Conway, 1996). In the survey, social gatherings among professionals ranked similarly to searches of patent literature as an inspiration for innovation. About 12 per cent of the respondents gave each a ranking of crucial or very significant.

3.6 Knowledge Embedded in Machines and Intellectual Property

The discussion has so far focused on the sources of tacit knowledge because the engineering services industry mainly relies on human capital. However, machines are important as they facilitate the work and more importantly link firms to their clients via technologies notably CADD and CAM which are widely used in the manufacturing sector. Therefore, accumulation of embedded knowledge in both hardware and software receives attention as a business strategy, whether firms purchase it or develop it in-house. Forty-five per cent of the innovators reported that developing new or refining existing technology was very important. This is consistent with the high priority given to reducing production and delivery time.

There are other objects as well, which contain embedded knowledge. Patents are a classical example.   An easy alternative to undertaking R&D is to acquire the right to use other firms' intellectual assets. They may be in the form of patents, industrial design, trademarks or trade secrets. Less than 8 per cent of the firms acquired the use of intellectual property from other firms. Most of the dealings were between Canadian firms but there were international transactions as well. About 2 per cent of the firms received the rights from foreign firms. It is not clear, however, whether the cross-border transfers were between Canadian firms and their subsidiaries abroad or between Canadian and foreign firms.

[7] For the role of informal networks of friends in producing successful innovations, see Stewart and Conway (1996).

4. Outcomes of Innovation Activity

The outcomes of the use of knowledge assets are innovations and intellectual property. Innovation, defined as the first commercial use of an idea, may take the form of a product or a production process. It is a relative concept. Products that were new a few years ago are obsolete today. Similarly, what may be commonplace in one country may be a technological marvel in another. Any new offering made by a firm during the three-year period 1994-96 is taken to be an innovation.[8] All new offerings are included, whether new only to the firm that introduced them or new to the world representing breakthroughs. However, in a rapidly changing world, the proper measure of innovation is not whether a firm is doing a lot of it but whether it is doing so much so well that it can stay ahead of competitors. Starting with the innovation rates, in the following we discuss whether firms compete by introducing new products (growth-orientation) or processes (efficiency-orientation), frequency of innovation, novelty or innovation content of the new products and the innovation diffusion cycle.

Other concrete outcomes may not yet have resulted in the introduction of new or improved products and processes during the reference period, but they can be licensed to other firms for commercial use or kept by the firm for converting into saleable products and processes later. These include patents, copyrights, trademarks, etc.

Although not directly related to creative activity yet crucial in the service sector, particularly the professional service industries, is the organizational structure and leadership. Innovations in organizational structures are therefore also included.

4.1 New and Improved Products and Processes

4.1.1 Innovation Rates

The rate at which new or improved products and processes are brought to the market by the engineering services industry is lower than that in most other service industries covered by the survey. Overall, 40.7 per cent of the firms reported introducing an innovation during the period 1994-96 (Table B). By comparison, the rates were significantly higher in the financial services and computer services industries and more than twice as high in the telecommunications industry. Only the scientific and technical services industry lagged behind. The relatively lower rate in the engineering services industry can hardly be attributed to the innovation capacity. Nor can it be due to the relative lack of management's ability to translate knowledge assets into saleable products. Rather, we argue, low innovation rates inhere in the nature of this industry's products, pricing mechanism and structure.[9]

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[8] The Canadian survey of innovation used the Oslo Manual (OECD, 1997) guidelines and included the core CIS (European Community Innovation Survey) questionnaire to collect internationally comparable data.

[9] An important implication of this argument is that inter-industry comparisons of innovation rates can be misleading unless seen in the context of industry-specific characteristics. Therefore, international comparisons of individual industries are more meaningful provided that same methods and definitions were used.

Products that drive the demand for engineering services have long economic lives. Because of the large investment required, structures and machines once put in place are not replaced just to take advantage of a newly introduced design. Instead, the decision to replace an existing structure -- which still has useful economic life left -- with a new one must weigh the incremental benefits of new structure against the cost of an accelerated write-off of the existing one. The economic benefits of new structures are discounted because of the perceived risk associated with the purchase of an untried product. Therefore, unless the cost of writing-off the structure is very low, i.e. its economic life is almost over, or it does not meet the regulatory standards in which case there is no choice, it will not be replaced. The long lives of physical assets that drive the demand for engineering services suggest that the three-year time horizon to define innovation in this industry is too short just as it may be too long for other industries such as the software developers and semi-conductor manufacturers.[10]

Table B: Innovation Rates, Inter-industry Comparisons, Service Industries, 1994-96

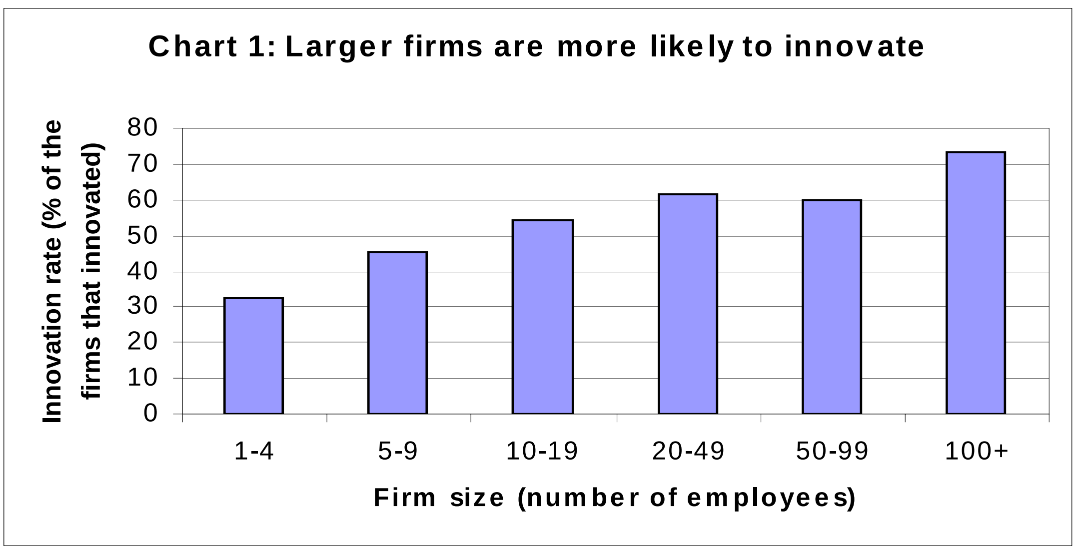
Industry	Innovation Rate (% of all firms)
Telecommunications	85.0
Television and radio broadcasting	41.0
Banks and trust companies	54.2
Life insurance companies	75.5
Property and casualty insurance companies	56.1
Computer services	55.8
Engineering services	40.7
Other scientific and technical services	35.3

Second, while new products drive competition in some industries, prices form the basis of competition in most industries. Price becomes a key variable in industries where competing products are intangible, not distinctive, and produced only when there is a commitment from the client to buy. Intangible product pricing lacks the flexibility which the marketers of tangible products have because the intangibles cannot be stored. Added to the effect of price inflexibility is the difficulty of demonstrating the claimed benefits of a new or improved intangible product. As this leaves some uncertainty in the mind of the first buyer about whether the new or improved product will deliver its claimed benefits, the untried product must carry a lower price or offer other benefits to compensate for the perceived risk. In the absence of additional benefit, the price becomes the key feature of competition in the industry. To complicate matters further, whether the quoted price is right becomes known only after the contract is lost to a lower bidder. Under these circumstances, consistency of quality rather than improvements whose claimed benefits are difficult to demonstrate is the key to more business. This is corroborated by the survey results. Among the two dozen

[10] The U.S. survey of innovation of the producers and users of information and communication technologies proposes to use a one-year time horizon to define innovation.

factors affecting a firm's success identified in the questionnaire, an approach focused on customer satisfaction emerged as the most important strategy, and indeed as important as in the financial services industry which goes to considerable lengths to win and retain customer loyalty. Meanwhile, frequency of innovations as the basis of competition ranked the lowest, with only 21.6 per cent of the innovators rating it as very important or crucial compared with 36.0 per cent in business services and 69.8 per cent in the financial services industries.

The impact of industry-specific characteristics is felt much more in the small firms as they would rather continue to provide the products that clients have tried before and meet their needs rather than make changes whose benefits they are not in a position to demonstrate to them. The large firms, on the other hand, armed with the advantage of reputation, brand name recognition and trademarks, do not have to demonstrate the benefits of their innovations in order to convince the client that the improved product contains a richer bundle of services. The large number of small firms combined with their low propensity to innovate (Chart 1) depresses the overall innovation rate for the industry.



Source: Statistics Canada, Survey of Innovation

In order to put the overall innovation rate in perspective, two observations are warranted. As we have already noted, a definition recognizing the longer product life cycle in the engineering services industry would probably yield a higher innovation rate. Second, the propensity to innovate would be higher if calculated by using the economic weights.

4.1.1.1 Defining Characteristics of Innovators

In an industry where nature of the product and pricing mechanism act to keep the innovation rates low, how can some firms can overcome these difficulties and innovate. Did they just happen to have new or improved products and processes when the survey was conducted or do they have special characteristics which non-innovators do not? We address this question in the general context of the culture of innovation in Section 4.1.6 where we argue that some firms have an innovation culture and some do not. Here we pursue specific characteristics of innovators in an effort to identify their technological and organizational competencies.

As discussed in Section 3 above, knowledge plays a key role in the ability to innovate. Highly educated and trained workforce is a prerequisite for knowledge creating activities as well as assimilating knowledge from other sources. Beyond a minimum efficient combination of conceptual and implementation skills, we found a correlation between knowledge intensity and innovation. Firms with a higher engineer/technologist ratio were more likely to be innovative than were firms with fewer engineers in proportion to technologists. Where firms had a lower ratio but nevertheless innovated, it was partly because of their knowledge management strategy. They contracted expertise only when their staff could not handle a problem instead of keeping it on their payroll all year round.[11]

Investment in R&D is another source of technological competency. Most of the R&D performers innovate. Fully 82 per cent of the firms that reported performing R&D during the reference period also reported introducing an innovation. It should be noted, however, that investment in R&D is not necessarily a prerequisite for generating ideas for innovation. Because of the spillover effects of R&D and the availability of other sources of information and knowledge many firms that did not perform R&D were also able to innovate.

The survey also affirms the role of information technologies in the innovation process. While information technologies are important to every industry they play a crucial role in the service sector and in particular the consultancies.[12] Recognizing this, the survey of innovation included a bloc of questions on the penetration of Internet technology and its usage. Firms that employed information technology had a better chance of introducing an innovation. While the use of the Internet itself is related to innovation, the specific purpose for which it is used is more important. Innovation rates were higher among firms that reported using the Internet to do Web searches. Seventy-seven per cent of the firms that had the Internet technology and used it to do searches on the Web reported introducing an innovation.

Firms that had undergone a change in ownership in recent years had a higher innovation rate. Firms are acquired because the potential of their technology far exceeds the use the present management is making of it. The organization theory provides additional insights into the seemingly superfluous relationship between change in ownership and the propensity to innovate. Mintzberg (1979) argues that as an innovative organization ages, many forces act

[11] This raises the question of how best to measure labour input or knowledge used in the process of innovation. Labour input as presently measured in innovation surveys or production surveys distorts the relationship between knowledge and innovation because employees are assigned to firms that employ them rather than the firms that actually use their services. The growing use of outsourced and just-in-time labour underscores this problem. See Hamdani (1998 and 2000).

[12] Information and cultural industries, professional, scientific and technical services industries, and educational services industry (private) rank the highest in terms of the Internet proliferation rate in the private sector (Bakker, 2000).

to push it towards bureaucratization and standardization, which may suit the employees who themselves growing old may welcome stability. The change in ownership and management rejuvenates these firms and they begin to act more like they were before the standardization and complacency set in. Fully 61 per cent of these firms reported introducing an innovation during the reference period as compared with 41 per cent of all firms in the industry.

The ability to innovate is also strongly correlated with exposure to foreign markets. Competing in international markets with the best of the firms provides a strong incentive or rather makes it imperative to continually improve products or introduce new ones. Survey findings show that export-oriented firms were more than twice as likely to innovate than the non-exporters. While three-quarters of all exporters (74.3 per cent) innovated, the figure for non-exporters was only 32.2 per cent. It is noteworthy that the non-exporters that were eager to break into foreign markets were also more likely to innovate than the non-exporters whose strategy was simply to focus on the domestic market. For example, all the non-exporters who rated the US, European and the Pacific Rim markets as crucial or very important to business growth had introduced an innovation. Conversely, the innovation rates were very low among firms that did not export and did not see export markets fitting into their strategy.

4.1.2 Types of Innovation

The type of innovation that a firm introduces reflects its competitive environment, its willingness to take risk, and its competitive strategy. Firms focusing on improvements in processes generally compete in markets that are not expanding and grow by increasing their market share through increased operational efficiency. Firms investing in product development, on the other hand, tend to be growth-oriented businesses that seek or create new markets. The distinction between types of innovation is particularly relevant to services industries which provide intermediate inputs and thus have an effect on client industries. For example, although the direct impact of a service provider's process innovation is primarily on the service firm itself, the introduction of a new product such as a better factory design improves the efficiency of the client that commissioned the design. Of the engineering services firms responding to the survey, 26 per cent reported that they had introduced a process innovation in the 1994-96 period. Product innovations are more common. Some 30 per cent of the engineering services firms replaced an existing product, added a new product to their existing line, or diversified into new product lines (Table C).

While classifying firms according to the type of innovation sheds light on their innovation and competitive strategies, fewer firms undertake only one type of innovation. To some extent, product and process innovations go hand in hand, as a new product may necessitate a change in the production process. Alternatively, adoption of more flexible production processes enables firms to offer more products. Survey findings confirm this. Only 9 per cent of firms reported they introduced a new product without altering production process or making an organizational change. Firms changing production processes but not introducing a new or substantially improved product account for 7 per cent of all firms in the industry.[13]

Table C: Innovation rates, by type of Innovation	
Type of Innovation	Innovation rate (% of firms)
Firms introducing:	
Any innovation (product, process or organizational change)	40.7
Product innovation	30.2
Process innovation	26.2
Organizational change	15.6
All three types of innovation	7.7
Product and process innovation	15.6
Product innovation and organizational change	12.0
Product innovation only (no other type of innovation)	8.7
Process innovation only (no other type of innovation)	7.2
Organizational change only (no other type of innovation)	2.5

4.1.3 Frequency of Innovation

A firm's ability to compete in the marketplace depends not only on whether or not it innovates but also on how often it does so. While an innovative firm continually evaluates its product portfolio in the light of its financial and strategic objectives and changing business and competitive environment, we have seen that for the industry as a whole the nature of the product, industry structure and pricing mechanism limit the frequency of innovations. As noted earlier, a distinguishing feature of the engineering services industry is that the demand for its services is derived from capital expenditures. Since the life cycles of capital goods are typically long the frequency with which new products are brought to the market is much less than in other industries such as computer services where the technology changes rapidly and product life cycles are short. The relatively long innovation diffusion cycle observed in this industry (see Section 4.1.5) reinforces the evidence of the low frequency of innovation rates.

[13] The distinction between product and process innovation, which is easily applied in the manufacturing sector, is not as clear-cut in the service sector and in particular the engineering services industry. Compared to firms in other industries, more engineering service firms experienced difficulty classifying their innovations into these categories. Some 18 per cent of the respondents noted that they had difficulty deciding, based on definitions provided in the questionnaire, whether to classify their innovation as a product or a process innovation. The fact that most innovators reported introducing both product and process innovation and few reported only product or only process innovation might be a reflection of the difficulty they faced.

4.1.4 Novelty of Innovation

Innovation, as discussed above, is defined very broadly. It encompasses innovations that represent major breakthroughs as well as products and processes that are new only to the firm reporting them even though they already existed on the market. It is important to distinguish between the two because the unique advantage firms or countries seek in international markets derives from the breakthrough innovations. But the measurement of novelty presents challenges (Gault and Hamdani, 2000). It can be defined by reference to the geographic boundaries of the market (OECD, 1997), a variant thereof such as whether the firm developed the innovation itself or not (CIS3 draft[14]) or by reference to its technological content (Booz, Allen and Hamilton, 1982). It is somewhat easier though still difficult for respondents in the goods-producing sectors to know whether their innovations are genuinely new by checking them against the patents issued. However, the legal instruments to protect intellectual property in the service sector are different and information about properties so protected is not available in any central repository for reference. In addition, many service-providing firms deploy business strategies to appropriate the benefits of their investment in intellectual property. The small size of firms in some service industries further compounds the difficulty. The survey of innovation used the Oslo Manual taxonomy – new to the world, new to the country and new to the local market.[15] However, flexibility in the survey instrument also allows us to classify according to the technological content the vast majority of firms introducing innovations that are not original .[16]

Very few firms seem willing to undertake the risk associated with developing radical innovations. A vast majority of innovators introduced low-risk innovations, i.e. improvements in product quality and cost reduction. Such innovations are relatively easy. Investment and additional know-how needed to implement them is usually small because firms are already familiar with the underlying technology. Close to two-thirds or 63 per cent of the innovators were in this category. The competitive advantage of this type of innovation is not sustainable for any significant length of time because they can be easily and quickly replicated by competitors. New products within the firm’s existing line of products or specialization were next, with just over one-quarter of the innovators reporting it. Products outside the existing range of product lines that would allow the firm to enter a new market accounted for 15 per cent. These innovations not only require new technology that the firm does not already have but also carry the risk of uncertainty associated with entering a new market.

[14] Third European Community Innovation Survey.
[15] The last category was a variation from the Oslo Manual’s new-to-the-firm classification.
[16] For a discussion of the issues in the measurement of novelty, see Gault and Hamdani (2000).

The number of firms claiming innovations that were new to the world is very small. Less than 4 per cent of the innovators were in this category.[17] Development of such products and processes requires large investment of money and long periods of time and carry high risk because R&D may reach dead end or a competitor may get to the market first. However, the benefits are enormous. They establish the innovator's reputation as problem solver, and bestow temporary monopoly in the world market until competitors emerge with a similar or better product.

4.1.5 Innovation Diffusion Cycle

The innovation diffusion cycle provides insights into the barriers to technology flows between firms within a country and between countries. These barriers can be administrative which are designed to ensure that inventors receive sufficient reward for their efforts. They may be technological in the sense that other firms that want to adapt it may not have the knowledge or financial resources to analyze and implement it. They could also be a part of the innovators' strategy to discourage imitation such as complexity and a deliberate rapid rate of obsolescence. International borders may pose yet another barrier although they are becoming less relevant because of the trend towards globalization and the growing influence of global corporations. The impact of all the obstacles, national or international, on technology diffusion is summed up in the innovation diffusion cycle, that is, the length of time it takes to adopt or adapt a new product or process after it was first introduced elsewhere. In the absence of barriers, the information flows rapidly so the duration of the cycle will be short, assuming that the new products or processes are of sufficient merit to attract other firms to adopt them. A long duration, on the other hand, implies strong barriers. The innovation diffusion cycle in the engineering services industry is, on average, 21-months long. For innovations that already existed in the country the lag was estimated to be 18 months. This is consistent with the finding from the data on the frequency of innovation that about two-thirds of the innovators take one year or more to introduce an innovation.

The length of the cycle varies with the complexity of technology underlying the new product or process. More complex innovations are difficult to imitate.[19] Further, the cycles are likely to be shorter for trademarks and brand names, which protect the name or symbol rather the contents, than for patents.

However, technological complexity is a relative concept and perceived differently by organizations according to their stock of knowledge. Firms with a small stock of knowledge might find it daunting to adapt even a simple technology while complex technologies may

[17] In a comprehensive study of innovations introduced by manufacturing firms, Booz, Allen and Hamilton (1982) found that only 11 per cent of the innovations were of the world-first type. For a comparison between this study and innovation in the Canadian software development and computer services industry, see Gault and Hamdani (2000).

[19] The use of technological superiority to produce complex products is one of the methods firms deploy to protect their innovations from imitation.

not intimidate firms with sufficient knowledge. For example, the diffusion lag was longer for firms for whom the innovation represented a new line of products than for firms for which it simply meant adding another product to their existing line of specialization.

Table D: Length of the Innovation Diffusion Cycle	
Origin of Innovation	Length of the Cycle (months)
All innovations	21
- Domestic innovations	18
- adopted from other countries	33

In spite of the trend towards globalization, the national borders, although not a bar to technology flows, still matter in this industry as the diffusion cycle for imported technologies is almost twice as long as in the case of domestic technologies. It took, on average 33 months to adopt an innovation that was first introduced in a foreign country, compared with 18 months for innovations adapted from the Canadian firms.

4.1.6 Innovation Culture

The analysis has so far focused on innovators, i.e. firms that commercialized a new product or process. However, innovators only represent a part of the innovation effort, as there are more non-innovators than innovators in the engineering services industry. While it is useful to know how many did not innovate and why, we must first determine the status of their innovation effort, i.e. did they try but failed or did they not take the risk at all? Firms learn from both their successes and failures. Therefore, the behaviour of non-innovators as well as an assessment of the unsuccessful attempts by firms that eventually succeeded is also essential to the understanding of the innovation culture.

The analysis can be approached in two ways. The first approach is to include questions in the survey instrument about practices generally associated with innovation strategy such as whether the respondents have a mission statement, written strategy or objectives. Observance of such practices is taken to be an indication of a firm's commitment to innovation. However, such an approach is less than optimal for industries that have a large number of small firms because small firms are less likely to observe such practices, but may nevertheless be taking risks in an effort to innovate.

The survey of innovation adopted a different approach. It gathered information on innovation effort, defined as ongoing (in-progress but not yet completed) activities and suspended activities. In addition to asking whether respondents introduced a new or improved product or more efficient process, firms were asked whether they undertook any innovation activity that did not result in commercializing a new product or process. Firms responding in the affirmative were further asked about the status of the activity – whether it was ongoing or it had been suspended. Note that the innovators were not excluded because they too could have suspended some innovation activities or had ongoing projects.

The analysis of responses to these questions, combined with the information on innovations actually introduced to the market provides useful insights into the innovation behaviour of the industry. The results indicate that non-innovating firms were only one-fifth as likely as innovating firms to have had ongoing innovation activities or innovation activities that were suspended. The non-innovating firms therefore appear to be risk averse.

There are several possible explanations of why some firms are averse to the search for, and development of, new products and processes. First, the structure of the industry has much to do with it. Nearly three-quarters of the firms that neither innovated nor made an effort to innovate were small. As discussed in Section 4.1.1, offers of new, untested products are less likely to appeal to potential new clients unless the benefits are demonstrable. Innovations tend to be of more interest to small firms only if they can enhance their competitiveness on the basis of cost. Otherwise, they would rather wait for someone else to innovate, before adopting it.

Corporate culture may also be a factor. The management style, organizational structure and operating philosophy of a firm greatly influence its tolerance for risk and its ability to innovate. Organizational problems were identified as a key obstacle to innovation in the United States in the 1960s, and management practices and planning attitudes emerged as major deterrents in the 1980s (Booz, Allen and Hamilton, 1982). More recently, a report (HRDC, 1994) on human resources in the engineering services industry noted the need for a corporate culture that values increased teamwork and employee empowerment and supports continuous learning. It recommended that firms need more participative, non-traditional organizational forms.

Innovative firms share certain characteristics which transcend national and cultural boundaries, size, type of industry, etc. Many have a certain leadership and management style. This is particularly true of research and professional service organizations such as the engineering services firms which are in the business of providing solutions. Such firms need a unique organizational structure, described as an ‘ad hocracy’, as opposed to ‘machine’ organizations which are primarily concerned with efficiency and standardize procedures to produce standardized outputs (Mintzberg, 1979). The decision-making authority in ‘ad hocracies’ typically rests with experts and professionals, regardless of their position. The traditional command-and-control type managers, who play a significant role in ‘machine’ organizations, are limited to liaison-type functions in innovative organizational structures.

4.2 Organizational Change

The role of organization is particularly important in consultancies and is drawing more attention with the shift from natural to human resources as the strategic asset. While this shift is relatively new to the goods-producing sector, people have always been the principle asset of service-providing firms. What is new is the realization among firms that their success depends upon a resource that they do not and cannot own but can only share with their employees (the owners) and that is highly mobile within the country and, with globalization, between countries. It has caused rethinking of management practices and operating philosophies and call by management strategists for leaders who provide vision and context instead of managers who command and control. In more concrete terms, it means changes in the management's function and new organizational forms. The survey of innovation made a pioneering attempt to capture the extent of these crucial changes and their impact on companies' performance. The survey instrument included a question on whether the respondents had made an organizational change. A supplementary question was added about improvement in employee morale as a proxy for higher productivity to test whether the organizational change qualified as innovation in the sense that its effect on productivity or sales was measurable and positive (OECD, 1997). In addition, questions were added about the importance firms attach to specific management practices, which are associated with innovative and new organizational structures.

Organizational change[20] is far less common than product and process innovations in the engineering services industry. Only 16% of the firms implemented it. Since firms do not reconceptualize their work often, the need for a major strategic reorientation occurs infrequently, and organizational changes usually coincide with the appearance of a new chief executive officer. It is also relatively more difficult to implement because it involves dealing with attitudes, values and human behaviour. The success of significant organizational changes designed to change the strategic orientation of firms often depends on the cultivation of new values and behaviours.

Measurement of the impact of an organizational change on economic performance is fraught with difficulties. However, it can be argued that a significant organizational change would be usually accompanied by or lead to other types of innovation. It may even be said that radical product or process innovations are less likely to happen without it. Therefore, the introduction of a product or process innovation along with an organizational change can be used as a proxy for its impact on revenue. While reported by only 16 per cent of the firms, organizational change was closely linked with other types of innovation. Eighty-seven per cent of the firms implementing an organizational change also reported adoption of a more efficient production process or the introduction of a new or improved product to the market. The remaining 13 per cent of the firms may well have made significant organizational changes, even important enough to change their strategic orientation, but they did not result in a product or process innovation. This can happen when an organization evaluates its product portfolio and decides to drop a product or a whole line of products that do not fit in its new strategy causing a decline in its sales but positioning it for greater profitability or strategic advantage in the future.

To test the impact of organizational changes on productivity, we used the employee motivation as a proxy, as noted above. The choice of this particular attribute was based on the premise that an inspiring leadership and employee empowerment motivate workers which leads to higher productivity. The findings suggest that firms introducing

[20] Organizational change was defined as "significant changes to organizational structures, the implementation of advanced management techniques or changed corporate strategic orientations." These are the main elements proposed in OECD (1997) for developing a definition of organizational change.

organizational changes are more likely to report an improvement in employee motivation than others, albeit by a small margin -- 27.4 per cent versus 21.1 per cent. As to the possibility of the built-in bias in this type of question, the relatively small number of firms, 24 per cent overall, reporting a significant impact on employee morale suggests that the bias may not be an important factor.

Management style also emerged as an important determinant of a firm's ability to innovate. Firms, that sought to build consensus or delegated decision-making, were more likely to introduce new products or process than those that accorded no or only low importance to these management styles.

4.3 Intellectual Property (IP)

Intellectual property is another significant outcome of the creative activity. Measured by the use of the legal instruments to protect intellectual property in the industry, 21 per cent of the firms created IP during the reference period. Much of it was in the form of patents or copyrights. Trademarks and trade secrets accounted for the rest. It should be noted that the data pertain to the number of firms and not the number of intellectual properties. While firms creating many properties but using the same instrument were counted only once, firms using different types of instruments were counted as many times as the number of instruments they used. Further, firms deploying business strategies such as planned rapid obsolescence to appropriate the benefits of their R&D are not counted at all.

While some intellectual properties may have already been converted into new products and processes and some would be put to commercial use later, other properties were transferred between firms through licensing or similar arrangements. However, the number of firms involved is small. Less than 8 per cent of the firms transferred IP to others under various arrangements. The transfer of patents and copyrights was more common than other types of property such as industrial design, trade secrets and trademarks.

The data also provide an indication of the globalization of technology. Of the firms reporting these transfers, just over one-quarter (28 per cent) engaged in dealings with foreign firms. However, it cannot be determined from the data whether the international transfers were between Canadian firms and their foreign subsidiaries or between Canadian firms and foreign firms. We should note that the international technology flows are not uni-directional. Just as the Canadian firms transfer their IP to foreign firms so do they receive technology from foreign countries. On balance, the number of Canadian firms transferring technology to foreign countries exceeded the number of firms receiving it.

5. Performance Indicators or Economic Impact

As knowledge is the strategic asset, efficiency in its use is crucial for the competitive advantage. How much of the knowledge base is devoted to the pursuit of creative activities and how effective it is in that pursuit are the two main components of efficiency. Indicators of the stock of knowledge were discussed in Section 3 but we only alluded to the efficiency in Section 4.1.6 in the discussion of innovation culture by noting that unsuccessful innovation efforts provided just as useful information as did the efforts successfully completed. We now turn to the impacts of new or improved products and more efficient processes introduced during the reference period.

Two types of indicators will be discussed. The first type pertains to the process-related indicators which measure the competencies driving performance. Summary or macro indicators showing the impact of innovation on sales, jobs and skills are addressed next.

5.1 Process-based Indicators

The impact of innovation on the performance of a firm can be gauged by looking at a number of indicators. Traditional performance measurement systems, primarily concerned with creating value for the shareholders, stress financial ratios such as breakeven points, profitability ratios, rate of return on investment and share prices. While these are consistent with a firm's operating goals and objectives, the analysis of the critical factors also requires yardsticks that explicitly focus on clients. As the real battles are fought over customers, one needs to look beyond the financial performance measures and develop indicators to measure how well the firms are meeting their customers' needs and expectations.

A large majority of innovators noted improvement in product quality as a result of the innovation activity with more than one-half rating the impact as crucial or very important for the firm. Among the one dozen items related to different aspects of the business on which the respondents were asked to evaluate the impact of their innovation, three of the four items receiving the highest score were process-related and concerned with customer satisfaction. These were flexibility in meeting customer demand, reliability of the product and the timeliness and speed of delivery.

5.2 Operating performance

5.2.1 Revenue and Exports

A firm's success in achieving its objectives should ideally be analyzed by matching the impact with the stated objective of its innovation. For example, the proper performance measure of an innovation intended to reduce cost is the change in profitability ratios, whereas an innovation that represented an addition to a firm's existing lines of products would be properly evaluated in terms of market shares and growth in revenues. Such in-depth analysis is out of scope for this paper. However, the impact of innovation on sales is a good summary measure which provides insights, albeit indirectly, into a firm's ability to anticipate changes in customer demand and bring new products to the market in time. In other words, it reinforces the analysis based on performance related indicators.

New and improved products and processes introduced over the three-year period, 1994-96, accounted for 16.8 per cent of industry's total sales over this period. New products contributed more than did the improved products in spite of the fact that innovations representing quality improvements were far more numerous. New products represent more novelty and are likely to attract more clients than the improved products. However, all new products are not alike. They vary significantly with respect to the novelty and affect sales in different magnitudes. Therefore, it is pertinent to ask whether the impact on sales was the result of breakthrough innovations which can establish the country as a world leader, or arose from products that embodied only small additional technological content. It is not our intention to analyze the impact on sales according to the novelty of new products, but the following statistical considerations would be useful in interpreting the data. Since innovation is defined as products and processes new to the firm, the entire revenue of the new firms entering the industry during the reference period becomes classified to new products. Second, in instances where the new product cannibalizes an existing one, the total revenue remains more or less unchanged – at least in the short run – although the contribution of the new products increases significantly. Fifteen per cent of the innovators reported innovations that replaced products being phased out.

However, the most important impact of the innovations was on the ability to compete in international markets. This is an encouraging sign for the industry because Canadian firms have a large exposure to the foreign markets and also see them as representing best opportunities for growth. In a survey, more than one-half of the firms identified the United States as the place offering the best opportunities for new business (ACEC, 1999). The industry appears to be making some headway, according to the estimates. Products three years old or less contributed 20 per cent of the exports, as compared with 17 per cent contributed by innovations to total sales.

5.2.2 Demand for labour

The impact of innovation on employment works in two ways. Increase in the demand for new services results in new hires. On the other hand, improvements in the processes of production and delivery reduce the demand for workers. However, the scope for substituting machines for human capital is limited because of the labour intensive nature of the work and of the need to interact with clients. Where substitution does take place it is often to replace workers who were hired for their implementation skills. On balance, the labour-augmenting effect of product innovations more than offsets the labour-saving effect of the process innovations.

One-third of the innovators reported that the technological advance actually resulted in an increase in their labour requirements. Gains in productivity were not enough to meet the demand generated by the new and improved products.[22] Only 4 per cent of the innovators

[22] The Canadian survey specifically asked firms to evaluate the impact of innovation on employment and skills in order to separate it from the effect of other factors such as cyclical swings and government procurement programmes.

increased their productivity to the point where they reduced their staff. In many cases where labour requirements declined, the impact was largely on the less educated workforce. These firms tend to be less knowledge intensive to start with, are more interested in the economies of scale and aim to grow by increasing efficiency rather than offering innovations. For the majority of firms, however, the impact was neutral.

Table E: Impact of Innovation on Jobs

% of innovators reporting:	Jobs
Increase	32.5
Decrease	4.0
Neutral	63.5

The actual job creating effect of the innovation may be more than the estimates suggest. Innovation surveys measure the immediate impact while the full impact may not be felt for some time after the innovation is introduced. Moreover, in the early stages of the introduction of a new product, increase in demand may be met by extending the working hours of the present staff as firms evaluate the demand over a longer period of time before committing to hire additional resources full time.

It needs mentioning that, as a provider of intermediary inputs into the production of capital goods, innovation affects the demand for resources not only in the engineering services firms but also in the client firms. Indeed, the clients may be affected more. The survey of innovation was not designed to measure this impact, but some relevant information is available. More respondents reported an increase in their clients' productivity than in their own as a result of their innovation, 34 per cent and 31 per cent respectively.

5.2.3 Skills

Innovation and knowledge move in a spiral. Knowledge leads to innovation and innovation, in turn, sets in motion a new cycle of learning through insights obtained from experimentation in search of solutions to complex problems. In order to determine the effect of innovation on skills, we asked respondents whether their experience in the adoption of new technology was skill-enhancing, de-skilling or neutral. Nearly two in five firms reported that the introduction of new products and processes improved their skill requirements. Only 2 per cent reported a decline in skill requirements, while the impact for the remainder was neutral.

However, learning and skill improvement is a function of the novelty contents of innovation. An innovation representing a breakthrough will obviously have a much larger effect on skill levels than minor product improvements which do not require much experimentation. This is clearly borne out by the data. While 44 per cent of the innovators reporting an innovation representing quality improvements experienced an increase in skill requirements for their workforce, the figure for innovations representing a new product was more than 50 per cent and gradually increased to 55 per cent for radical innovations.

Table F: Impact of Innovation on Skill Requirements (% of innovation firms)				
	Upskilling	De-skilling	Neutral	Sum
Overall workforce	39	2	59	100
Non-graduates	22	3	75	100
College graduates	35	2	63	100
University graduates	43	2	55	100

As the nature of knowledge in this industry is highly technical, the impact varies with the educational levels of the workforce. For example, the skill improvements in the case of university graduates was double that for those who did not have post-secondary education (Table F, column captioned Upskilling). Further, the impact varied with the novelty of innovation. While non-graduates benefited considerably when the innovations were of low grade, they did not do so well with radical innovations (Hamdani, 2000).

6. Conclusion

This paper presented the first attempt towards estimating a complete innovation system. The data used are consistent and derived from the Survey of Innovation which was a comprehensive self-contained statement of a system of innovation. In this system, innovation depends on the stock and flow of knowledge. Firms learn from experience and through experimentation, and, in order to get access to knowledge available elsewhere, they form networks, forge alliances and buy other firms.

However, the unique industry characteristics also influence the rates at which new products and processes are brought to the market. Long life cycles of the physical assets that drive the demand for engineering services depress the innovation rates in spite of the large knowledge base and knowledge intensity of the industry. But export orientation, the application of advanced embodied technologies, and R&D create opportunities for innovation.

In spite of the significant number of firms claiming innovations, few firms introduce breakthrough innovations. A vast majority of new and improved products represents small quality upgrades of the existing products. Firms tend to introduce innovations that embody the technology with which they are already familiar in order to keep risk down.

The speed of the diffusion of innovation through the industry depends on the complexity of technology and, more importantly, on the stock of knowledge of the firm trying to adapt it. International borders are not a barrier to the flow of technology but innovations first introduced in foreign countries take almost twice as long to adapt and implement than those adapted from other firms in Canada.

Management practices play an important role in enabling creative activity and innovation. Although the least common of all types of innovation, organizational change almost always leads to or is accompanied by the introduction of new products, improved quality, or the adoption of a more efficient process of production or delivery.

In spite of the gains in operational efficiency by many firms, the net effect of innovation is to increase jobs. Innovation helps Canadian firms to expand in foreign markets and increase business in the domestic market. Products three years old or less contributed more to exports than to sales in the domestic market.

Finally, learning and innovation move in a spiral. While a large knowledge base and high knowledge intensity are closely linked to innovation, the process of innovation, in turn, sets in motion a new cycle of learning through insights obtained from experimentation in search of solutions to complex problems.

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Appendix A. Statistical Tables

Table 1. Innovation Rates, by Type of Innovation

	Engineering Services Industry*	Business Services Industries**
Type of innovation introduced:	% of firms reporting an innovation	
Product	30.6	36.0
Process	23.2	23.9
Organizational	15.6	16.4
All three types	7.7	8.2
Any of the three types	40.7	46.0

Table 2. Frequency of Introducing Innovation

	Engineering Services Industry*	Business Services Industries**
	% of innovators	
More than 3 times a year	8.0	19.3
Three times a year	4.9	8.8
Twice a year	22.0	17.8
Once a year	24.1	25.8
Every second year	11.8	9.6
Every third year	9.3	5.1
Less frequently	19.9	13.6

***** 1980 Standard Industrial Classification code 7752.

****** Covers Consulting engineering industry (SIC 7752); Scientific and Technical services industry (SIC 7759) and Computer services industry (SIC 772).

Table 3. Competitive Environment

	Engineering Services Industry*	Business Services Industries**
	% of innovators agreeing with statements about their industry	
High threat of arrivals from new competitors	54.1	60.7
Consumers can easily substitute	42.9	47.6
Production technology changes rapidly	39.8	54.7
Products quickly become obsolete	25.9	48.3
Competitors' actions are difficult to predict	34.0	35.6
Consumer demand is difficult to predict	37.2	38.4

Table 4. Intensity of Competition

	Engineering Services Industry*	Business Services Industries**
	% of innovators reporting highly intense competition in their industry	
Price	61.5	58.3
Flexibility in responding to customer needs	58.9	57.8
Quality	61.0	64.5
Customer service	64.5	66.2
Customization of products	42.3	52.8
Offering a wide range of related products	34.1	40.2
Frequently introducing new products	21.6	36.0

Table 5. Importance of Business Strategies

	Engineering Services Industry*	Business Services Industries**
	% of innovators rating very important or crucial	
Financing		
Flexibility in meeting unforeseen circumstances	53.4	58.1
Financial management	61.8	68.4
Finding/maintaining capital	45.4	52.9
Human resources		
Providing incentive compensation plans	35.1	35.6
Recruiting skilled employees	56.0	63.9
Training	50.6	54.9
Marketing		
Using third party distributors	15.1	24.7
Promoting company or product reputation	65.1	66.2
Satisfying existing customers	82.8	87.1
Improving position in existing markets	68.6	72.7
Targeting new foreign markets	33.5	35.2
Targeting new domestic markets	55.0	58.4
Management		
Consensus decision-making	41.3	42.0
Delegating decision-making	32.2	30.9
Using information technology	57.6	68.3
Continuous quality improvement	68.0	70.7
Production		
Using high quality suppliers	46.2	49.7
Using computer controlled processes	49.5	49.1
Reducing production times	45.8	45.2
Technology and R&D		
Protecting products/processes with IPRs	21.8	23.6
R&D capabilities	27.4	39.1
Purchasing other technology	19.4	27.0
Developing new/refining existing technology	45.5	57.7

Table 6. Objectives of Innovation

	Engineering Services Industry*	Business Services Industries**
	% of innovators rating very significant or crucial	
Reducing unit labour costs	26.4	26.0
Cutting consumption of materials	9.2	9.2
Cutting energy consumption	6.5	5.1
Reducing product design costs	22.0	22.0
Reducing production lead times	24.4	28.0
Other means of lowering costs	6.4	8.9
Replace products being phased out	15.1	22.7
Extend product range within main product field	39.6	43.2
Extend product range outside main product field	21.3	21.9
Maintain market share	63.9	61.6
Increase market share	61.5	64.1
Open new domestic markets	46.8	50.0
Open new American markets	29.9	26.8
Open new European markets	9.7	11.4
Open new Japanese markets	6.4	5.8
Open new other Pacific Rim markets	12.7	10.0
Open other new markets	12.4	8.9
Improve production flexibility	40.7	35.6
Improve product quality	51.9	57.1
Improve working conditions	24.4	25.4

Table 7. Impacts of Innovation

	Engineering Services Industry*	Business Services Industries**
	% of innovators rating very significant or crucial	
Productivity of employees	30.6	31.7
Motivation of employees	23.5	27.5
Productivity of customers	33.9	40.9
Range of goods & services	39.8	44.6
Geographic accessibility of product/service	23.1	27.3
Customers' quality of life	21.3	23.0
Ability to adapt to customer requirements	53.1	53.9
Speed of supply or delivery	43.4	48.1
Access by hours	24.2	32.4
User-friendliness of product/service	35.0	43.4
Product/service reliability	44.9	49.3
Ability to comply with safety requirements	27.9	20.4

Table 8. Sources of Ideas for Innovation

	Engineering Services Industry*	Business Services Industries**
	% of innovators rating as very important or crucial	
Internal:		
Management	48.1	48.1
Marketing	38.2	46.2
In-house R&D	50.0	57.7
Production	32.8	35.5
Other internal sources	8.1	9.8
External:		
Customers	70.3	76.0
Competitors	41.7	43.2
Suppliers	36.5	34.4
Technology acquisition	27.4	25.4
Consultants	21.8	18.2
Generally available information:		
Conferences, meetings, publications	40.2	37.1
Fairs and exhibitions	15.6	19.6
Government information programs	20.2	15.4
Social gatherings	11.8	11.6
Patent literature	12.1	8.7
Education and research:		
Higher educational institutions	29.9	25.1
Private research institutions	13.4	13.1
Government research institutions	19.4	10.5

Table 9. Technologies Important to Innovation

	Engineering Services Industry*	Business Services Industries**
	% of innovators reporting that a technology was important to innovation activity	
Software	86.3	90.7
Computers and related hardware	91.6	91.2
High performance communication networks	30.8	49.8
Media-related technology	52.4	57.9
Transportation and traffic technology	14.8	12.2
Measuring, automation, control & steering technology	28.7	19.2

Table 10. Impediments to Innovation

	Engineering Services Industry*	Business Services Industries**
	% of innovators rating as very significant or crucial	
High risk related to feasibility	34.6	33.6
High risk related to market success	34.3	38.6
Innovation easily imitated	30.1	31.3
Costs difficult to predict	38.7	36.2
High costs	43.7	44.2
Long amortization period	32.8	31.4
Lack of equity capital	37.2	40.8
Lack of outside capital	35.5	37.5
Lack of qualified personnel	26.7	29.2
Lack of technical equipment	13.7	15.6
Internal resistance	5.8	6.9
Long administrative approval	7.1	6.3
Legislative or legal restrictions	9.8	10.3

Table 11. Use of Intellectual Property Instruments

	Engineering Services Industry*	Business Services Industries**
	% of innovators using one or more of:	
Copyrights	17.4	24.5
Patents	11.6	8.9
Trade secrets	17.5	16.2
Trademarks	14.2	19.8
Other	3.9	9.1

Appendix B. List of Products of the Survey of Innovation 1996

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