Technology Adoption in Canadian Manufacturing

Survey of Advanced Technology in Canadian Manufacturing

1998

By

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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.

Our working papers and research papers are available at no cost on the Statistics Canada Internet site at http://www.statcan.ca/english/research/scilist.htm.

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Preface

The study of the adoption and dissemination of technologies is one of the key components of innovation and technological development. Indeed, it is through the adoption of newer, more advanced, technologies that industries can increase their production capabilities, improve their productivity, and expand their lines of new products and services.

Surveys on the adoption of new technologies complement other information we collect about R&D and innovation, by allowing us to measure in what way and how quickly industries adapt to technological change.

This is the fifth Survey of Advanced Technology in the Canadian Manufacturing Sector. Three surveys of advanced manufacturing technologies were conducted in 1987, 1989 and 1993 (which was part of the Survey of Advanced Technology in Canadian Manufacturing), followed by a survey of the use of biotechnology by Canadian industries, conducted in 1997.

The first three surveys were similar and used a list of advanced technologies developed in 1986. Since technologies are constantly changing, what was an advanced technology in the past may be the norm today. Consequently, this survey is based on a new list of advanced technologies developed with the help of experts in manufacturing. New technologies include modeling and simulation technologies, flexible manufacturing systems and artificial vision systems for inspecting or testing parts.

Increasingly, manufacturing industries rely on information technology and telecommunications, computerizing and linking all functions of their production process. This survey puts the emphasis on issues such as the use of communication networks, whether internal (e. g. Local Area Networks) or external (e.g. the Internet).

This survey was directed by David Sabourin, from the Microeconomic Analysis Division, on behalf of the Science, Innovation and Electronic Information Division.

Highlights

1. Advanced manufacturing technologies are widely adopted in the Canadian manufacturing sector—75% of establishments in this sector use at least one of the 26 advanced technologies listed on the survey.

2. Adoption of advanced technologies is spread throughout the whole production process. Use is not restricted to one or two areas of technology. One out of every two plants has adopted at least one technology from each of the four leading areas of technologies—design and engineering; processing and fabrication; network communications; and integration and control.

3. The leading technologies are computer-aided design and engineering, programmable logic controllers, local area networks, company-wide networks, computer aided design and manufacturing, and electronic exchange of computer aided design files.

4. Advanced technology use increases with establishment size. Nine out of every ten large plants have adopted at least one technology from each of four technology groups—network communications, processing and fabrication, integration and control, and design and engineering.

5. Technology use also varies across industries. Establishments in beverages, primary textiles, paper and allied products, primary metals, and electrical and electronic products tend to have the highest adoption rates.

6. In order to obtain a measure of the competitiveness of Canadian manufacturing establishments relative to their foreign competitors, the survey asked Canadian manufacturing establishments to rank themselves relative to their foreign competitors with regards to their production technologies. Thirty-three percent of plant managers rated themselves equal to their U. S. competitors, while the rest were about equally split (24%) between those that felt they were more advanced and those that felt they were less advanced than their U. S. competitors.

7. Communications networks—such as Intranet, Extranet, and Internet—are fast becoming an integral part of the day-to-day operations of firms. Most establishments presently use their networks as a general reference tool, for marketing and customer information purposes, and for accounting and financing purposes.

8. Business practices—such as continuous improvement and just-in-time inventory—are important complements to advanced technologies. Continuous improvement, which involves an incremental approach to quality improvement, has the highest usage rate at 49%. This is followed by just-in-time inventory at 40%. Certification of suppliers and benchmarking are next at about 35% apiece.

9. Establishments introduce technologies using a variety of methods. Sometimes the

same establishment uses more than one method if they have introduced more than one technology. The most popular method is to purchase it right off-the-shelf with 84% of plants using this method. A substantial number prefer to modify an existing technology (50%), while 29% choose to develop brand new technologies themselves.

10. Ideas for the adoption of technology come from both inside and outside the firm. Both internal and external sources are important. Among internal sources, the production unit is the most important with 69% of technology users relying on their production staff and 55% on their production engineering department for ideas. Among external sources, the category of trade fairs, conferences and publications are the most important at 76%. At close to 70%, suppliers and customers are used as frequently as are production staff.

11. With technological change comes changing skill requirements. Three-quarters of technology-using plants reported that their employees had received some training related to technology use over the last three years. The types of training received covered a number of different areas—computer skills, technical skills, safety skills and quality control skills were all reported by at least 80% of these plants.

12. Two-thirds of technology users experienced skill shortages during the past year. In particular, these plants experienced the greatest shortages in the professional (41%) and skilled trade (40%) categories. Technicians and technologists were not far behind with 37% of plants indicating shortages in this area.

13. Slightly more than three-quarters of the plant managers facing shortages indicated that they had taken some action to deal with the shortages. A large percentage of plants (84%) provided training. Half of the plants indicated that they had established stronger links with educational institutions.

14. Establishments adopt advanced technology with the expectation of realizing certain benefits. *Improvements in product quality, increased profitability,* and *improvements in productivity due to a reduction in the rejection rates* are the most often-cited benefits from technology adoption.

15. Of the various obstacles to technology adoption that plants face, *high equipment costs* is the most important—60% of plants rate it highly. *Cost of capital* (50%) is next, followed by *integration costs* (43%). *Lack of skilled workers* is an important obstacle for 35% of establishments. This rivals *software development costs* in importance.

16. R&D is an important input into the innovation process. Firms engage in R&D both to create new products and processes and also to be more receptive to the technological advances of others. Fifty-five percent of plants indicated their firm performed some type of R&D over the past three years. Most (49%) preferred to perform R&D in-house. Twenty percent performed R&D jointly with another firm.

17. Two-thirds of firms perform R&D on an ongoing basis. Most firms (74%) engage in R&D to create original products, although a substantial percentage (56%) also do it to create new process technology.

18. Seventy percent of establishments report their firm uses the Internet. Most of these firms (89%) use it as a browsing facility, although a substantial percentage (57%) also use it as an advertising and marketing tool. Close to 40% use it to sell their products.

Acknowledgements

We are grateful to many individuals for participating in various stages of the project—particularly to Fred Gault from Science, Innovation and Electronic Information Division at Statistics Canada for funding and directing the whole project and to John Baldwin from Micro-Economic Analysis Division at Statistics Canada for valuable input into the design of the questionnaire and overseeing various stages of the exercise. We would also like to thank all of the other participants in the questionnaire design phase of the survey; in particular, Frances Anderson and Antoine Rose from the Science, Innovation and Electronic Information Division at Statistics Canada; Kevin Fitzgibbons from NRC; Margaret Dalziel from PRECARN Associates Inc.; and Can Le, William Cowley, Bev Mahoney, and Misa Palacek from Industry Canada.

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Introduction

Adoption of new technologies is a key element to a firm's success (Baldwin, Diverty, and Sabourin, 1995). Therefore, this report outlines the extent to which establishments in the Canadian manufacturing sector use advanced technologies. It investigates the extent to which advanced technology is being used—both at the individual technology level and at the functional technology group level, where functional group refers to collections of technologies that serve a common purpose. For example, local area networks and wide area networks are both network communication technologies. Differences in patterns of use by size and industry are also examined.

Not all firms adopt advanced technologies because of the costs associated with their adoption. Adoption occurs when the benefits from adopting the new technology outweigh the costs. Adoption rates, alone, are insufficient for attempting to understand the complex nature of technological change. Thus, the survey investigates the benefits and effects that manufacturing establishments receive as the result of adopting advanced technology. The problems associated with adoption are also examined, as are the sources of ideas about technology adoption.

This study extends previous work (Baldwin and Sabourin, 1995) in a number of interesting areas. First, it explores the use of various business practices by the establishment. In a recent study of Canadian food processing establishments, Baldwin and Sabourin (1999) have found that business practices are an important part of the technological regime of a firm. They serve as complements to advanced technologies. Inclusion of a business practice question on this survey allows us to investigate whether this holds true for all manufacturing.

Second, there is widespread interest in the rapidly growing area of communications networks. In order to address this, the survey has a section dealing with electronic communication which explores the extent to which manufacturing firms are using the Internet and for which purposes. In addition, there is a question which takes a broader approach. Establishments are asked to indicate the purposes for which they use communications networks of any kind—Internet, Extranet, and Intranet. The findings from these questions provide a basis for a better understanding of this emerging technology.

Third, much has been written of late about the shortage of skilled workers. Recent studies (Baldwin and Sabourin, 1995; and Baldwin, 1997) have shown that the lack of skilled workers is one of the main obstacles to both technology adoption and innovation. The survey investigates the issue of changing skill requirements as the result of technological change. It not only examines the extent to which skill shortages exist, and in which areas, but it also investigates the solutions being used to address these shortages.

1. The Survey

1.1 Characteristics and Coverage

The Survey of Advanced Technology in Canadian Manufacturing was conducted by Statistics Canada over a three month period—from November 1998 to January 1999. It was based on a frame of Canadian manufacturing establishments taken from Statistics Canada's Business Register. Food processing establishments were excluded from the survey because they had been surveyed separately earlier in the year.

The survey consists of nine main sections. Covered are questions on general firm and establishment characteristics; adoption of advanced technologies; use of business practices; the development and implementation of advanced technologies; skill requirements; results of adoption; obstacles to adoption; research and development; and electronic communication.

1.2 Sampling Methodology

The sample was randomly drawn from a manufacturing establishment population that was stratified by size and industry. Four employment size categories were used: 10 to 49, 50 to 99, 100 to 249, and 250 or more employees. Plants with fewer than 10 employees were not surveyed because of cost constraints. Forty-three industry categories were used. They are based on three digit S.I.C. categories with some aggregation being done both for cost and confidentiality issues. Details on the industry codes that were used are found in Appendix A.

1.3 Data Collection

The survey was conducted in stages. First, the sampled units were contacted to ascertain if they were still in-scope, i.e., was their dominant activity still in manufacturing. If so, they were asked to provide the name and mailing address of the individual who should receive the questionnaire. As this is an establishment-based survey, the plant manager was the obvious choice. The questionnaire was then mailed out to the respondent. Follow-ups were done through telephone interviews.

1.4 Response and Non-response

The overall response rate[1] for the survey was 98.5% (Table 1.1). Response rates are virtually identical across size categories—ranging from 98.3% for medium-sized establishments to 98.7% for both small and large establishments. For the purposes of this study, small establishments are those with between 10 and 49 employees, medium-sized

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[1] Response rate is calculated as the total completed cases divided by the total, active, in-scope cases. Total active, in-scope cases equal total sampled cases less out-of-business cases less out-of-scope cases.

establishments have between 50 and 249 employees, while large establishments are those with 250 or more employees.

Table 1.1
Response Rates for the Survey

	Small	**Medium**	**Large**	**All**
Total Sample	1592	1556	1052	4200
Inactive, Out-of-Scope				
• Out-of-Business	72	43	25	140
• Out-of-Scope	143	83	77	303
Active, In-Scope				
• Completed	1359	1405	938	3702
• Non-Response	18	25	12	55
Response Rate	98.7	98.3	98.7	98.5

All surveys have to be concerned with non-response which can take two forms. Sampled units may choose not to complete any of the questionnaire (referred to as complete non-response), or they may choose to complete only parts of the questionnaire (referred to as partial or item non-response). For this survey, both the complete non-response and the item non-response were extremely low. Only 1.5% of the active, in-scope units did not respond at all. In addition, virtually all of the units that completed the questionnaire did so in its entirety.

Even though the non-response rates are very low, they were dealt with. The sampling weights of respondents were adjusted to account for complete non-response. Item non-response was dealt with through imputation.

1.5 Sampling Error

Answers to the survey questions presented in this report are population estimates, that is, they represent the percentage of establishments in the population that exhibit a particular characteristic. The population estimates are generated through the application of probability or establishment weights when tabulations are generated. Establishment weights for the survey are equal to the inverse of the sampling rate.

As the sample drawn for this survey is but one of many possible samples that could have been drawn, there is a sampling error attributed to it. Standard errors are used to provide a guide as to the precision of the results. The standard errors for each data cell in the questionnaire are provided in Appendix B.

1.6 Advanced Technology Section

There are 26 advanced technologies listed in the survey. The list is an updated version of the one used on the previous three technology surveys conducted by Statistics Canada—the 1987 survey (Statistics Canada, 1988), the 1989 survey (Statistics Canada, 1991), and the 1993 survey (Baldwin and Sabourin, 1995). Roughly two-thirds of the technologies listed on this survey are the same as those found on the previous surveys. One third are new additions. The technologies new to this survey span all functional groups. In particular, simulation technologies are new to the design and engineering group; rapid prototyping, high speed machining, and near net shape technologies have been added to the processing, fabrication and assembly group; part identification is new to automated material handling; automated vision-based systems to the inspection group; company-wide computer networks to communications; digital remote controlled process plant control, and use of inspection data for manufacturing control to the integration and control technologies group.

The 26 technologies belong to six functional technology groups—design and engineering; processing, fabrication, and assembly; automated material handling; inspection; network communications; and integration and control. These are much the same functional groups that were used on the previous surveys. The functional groups and their constituent technologies, along with a brief description of each, are provided in Table 1.2.

Table 1.2
Advanced Technologies by Functional Group

TECHNOLOGIES	DESCRIPTION
Design and Engineering	
a) Computer-aided design and engineering (CAD/CAE)	Use of computer-based software for designing and testing new products
b) CAD output to control manufacturing machines (CAD/CAM)	Computer-aided manufacturing uses the output produced by CAD systems to control the machines that manufacture the part or the product
c) Modeling or simulation technologies	Used to provide a computer-based visualization of the performance of a computer-aided design, e.g., the simulation of the flow of molten plastic into an injection mould
d) Electronic exchange of CAD files	Electronic transfer of computer-aided design files
Processing, Fabrication, Assembly	
a) Flexible manufacturing systems	Collections of computer-controlled machine tools, serviced by robots and/or automated material handling systems and overseen by computers
b) Programmable logic controllers	Programmable solid state units that are used as switching devices
c) Lasers for materials processing	These are used for such processes as welding, cutting, treating, scribing and marking
d) Robots with sensing	Robots programmed to alter their function based on input from sensors—more sophisticated robots
e) Robots without sensing	Robots programmed to undertake simple tasks such as pick and place—less sophisticated robots
f) Rapid prototyping systems	Systems capable of producing a prototype part from the output of a computer-aided design
g) High speed machining	Metal cutting machines operating at speeds of 10,000 rpm or higher
h) Near net shape technologies	Technologies that produce finished plastic, metal or composite parts in a single production stage with a minimum of final machining
Automated Material Handling	
a) Part identification for manufacturing automation	Use of machine readable labels for monitoring parts during the manufacturing process and afterwards when they are being stored
b) Automated storage/retrieval system	Use computer-controlled equipment to handle and store goods and materials

Table 1.2
Advanced Technologies by Functional Group - *concluded*

TECHNOLOGIES	**DESCRIPTION**
Inspection	
a) Automated vision-based systems used for inspection/testing	Systems typically using a computer-controlled video camera for inspecting products for defects, blemishes, colour, orientation, etc.
b) Other automated sensor-based systems used for inspection/testing	Automated sensor-based equipment used for inspecting/testing incoming materials or final products
Network Communications	
a) Local area network (LAN) for engineering or production	Communications networks within a plant used for exchanging information on the ‘shop floor’, and within design and engineering departments
b) Company-wide computer networks	Communications networks within an enterprise extending beyond a single site; includes Intranets and Wide Area Networks (WAN)
c) Inter-company computer networks	Wide area communications networks that connect establishments with their subcontractors, suppliers, and customers
Integration and Control	
a) Manufacturing Resource Planning	Information system used to keep track of machine loading, production scheduling, inventory control, and material handling
b) Computers used for control on the factory floor	These are ‘stand-alone’ machines dedicated to controlling the manufacturing process but are also capable of other functions
c) Computer integrated manufacturing	Totally automated factory, where all activities, from start to finish, are co-ordinated by computers
d) Supervisory control and data acquisition (SCADA)	Technology which involves ‘real-time’ monitoring and controlling of production processes
e) Use of inspection data for manufacturing control	Inspection data is used to discriminate between good and defective parts, and monitoring production throughput
f) Digital, remote controlled process plant control	Local area network used to connect measurement and control equipment (such as sensors and controllers)
g) Knowledge-based software	Software systems that use artificial intelligence or rules based on process knowledge to control manufacturing processes

2. General Characteristics

General plant characteristics are provided in this section. Included is information on nationality of ownership, average plant size, market structure, the extent of competition, and the importance of various factors in the overall business strategy of a firm.

Ninety percent of Canadian manufacturing plants are Canadian controlled (Table 2.1). Of those that are not, most are U.S. controlled (7%). Only 2% are European controlled. Although the majority of establishments are domestic controlled, foreign controlled plants are important as they control a substantial portion of the manufacturing sector.

Table 2.1
Geographic region of head office of controlling firm (Establishment Weighted)

REGION	
	(percentage of establishments)
Canada	90
U.S.A.	7
Europe	2
Pacific Rim	1
Other foreign	0[2]

The majority of manufacturing establishments are small (Table 2.2). Sixty-eight percent of them employ between 10 and 49 employees. One quarter are in the mid-size range, with between 50 and 249 employees, while large plants account for only 6% of the population. In fact, small plants actually account for a larger percentage of the population than that reported here because the smallest plants—those with less than 10 employees—were outside the scope of the survey.

Table 2.2
Average number of employees working in the plant (Establishment Weighted)

NUMBER OF EMPLOYEES	
	(percentage of establishments)
Less than 50	68
50 to 99	15
100 to 249	11
250 or more	6

Most plants (90%) produce goods for the domestic market. A substantial percentage, however, are also active in foreign markets, primarily in the United States. Forty percent of establishments produce products that are sold in the U.S., eight percent in Europe and six percent in the Pacific Rim[3] countries.
Table 2.3

[2] This value was rounded to zero since the raw estimate was less than 0.5 .
[3] Pacific Rim includes Hong Kong, Indonesia, Japan, Malaysia, Singapore, South Korea, Taiwan, and Thailand.

Markets for Plant's Primary Product (Establishment Weighted)

MARKETS	
	(percentage of establishments)
Canadian markets	90
U.S. markets	40
European markets	8
Pacific Rim markets	6
Other foreign markets	7

Competition is intense in the manufacturing sector. Close to half of the establishments face more than 20 competitors apiece. Another quarter of the establishments face between six and 20 competitors. Few plants face no competition at all. Only six percent of establishments are in this category.

Table 2.4
Domestic and Foreign Competitors (Establishment Weighted)

NUMBER OF COMPETITORS	
	(percentage of establishments)
None	6
1 to 5	19
6 to 20	28
Over 20	48

Firms develop certain competencies in order to achieve their basic goals. They do so by setting and following a set of key business strategies. For example, firms intent on upgrading their workforce skills may do so by following a strategy of hiring new workers or introducing training programs. Because the focus of the survey is on advanced technology, the strategies examined in the survey relate to technology, as well as marketing and human resources since they affect technology adoption. Seven strategies belonging to the three broad areas—marketing, technology, and human resources—are included on the survey. Managers were asked to rate the importance of each of the strategies using a scale of 1 (low importance) to 5 (high importance). The distribution of scores are reported in Table 2.5.

Reducing manufacturing costs is clearly the most important strategy (of those listed) with 53% of plant managers reporting it to be of high importance (a score of five). This is almost double that of the next most important strategy. Entering new markets and developing new products are next in importance, with close to 30% of plants scoring both highly. Strategies geared towards developing new technologies are deemed crucial by one-quarter of establishments. Human resource strategies, such as using teams and providing ongoing training programs, are ranked lower than either technology or marketing strategies.

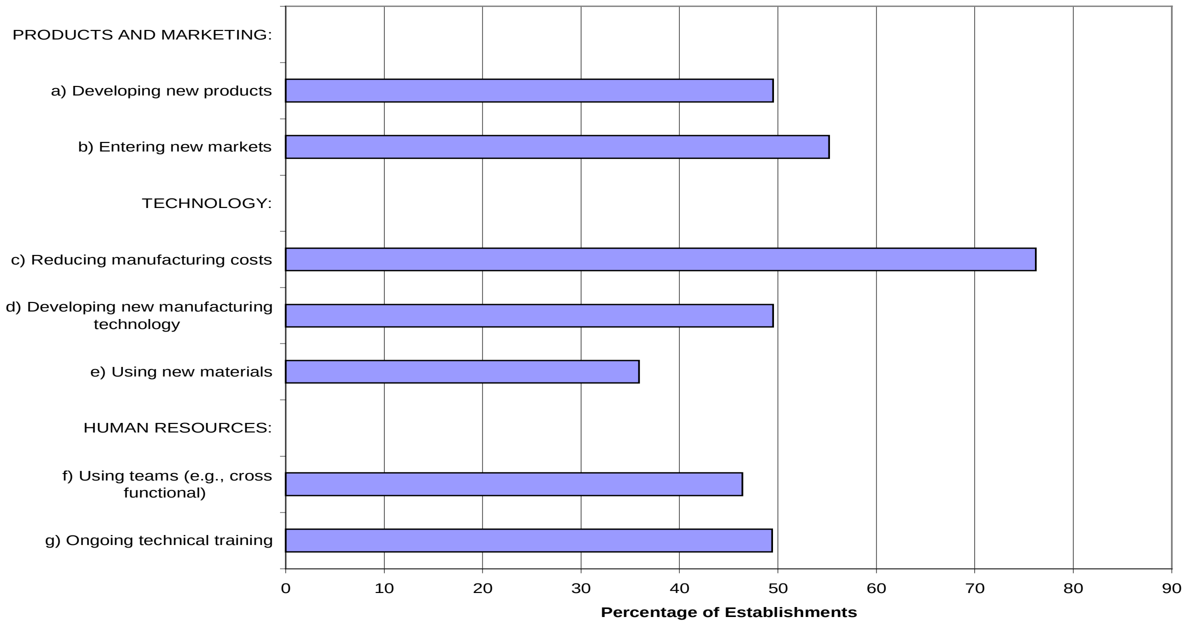
Table 2.5
Importance of Various Factors in Firm's Business Strategy

(Establishment Weighted)

FACTORS	IMPORTANCE				
	low				high
	1	2	3	4	5
	(percentage of establishments)				
Products and Marketing					
a) Developing new products	18	12	21	22	28
b) Entering new markets	12	9	24	26	29
Technology					
c) Reducing manufacturing costs	6	4	14	24	53
d) Developing new manufacturing technology	12	12	26	24	26
e) Using new materials	17	18	30	19	17
Human Resources					
f) Using teams (e.g., cross functional)	18	11	25	24	23
g) Ongoing technical training	13	11	27	29	21

Broadening our analysis to include responses of moderate importance, as well as high importance—extreme scores of 4 and 5—we find much the same patterns. Reducing manufacturing costs is still the most important with three-quarters of establishments considering it important. Once again entering new markets is next in importance, followed by developing new products. Only this time, training is found to be equally as important as developing new products. Using this measure, the emphasis on training, new products and new technology are now equally important. As before, using new materials is least important.

Figure 2.1
Extreme Scores for Importance of Business Strategies
(Establishment Weighted)



3. Advanced Technology Use

3.1 Introduction

Advanced technology use, at both the individual and functional group level, will be the subject of this section. First, overall patterns of use will be explored, followed by differences in use by size of establishment. Finally, adoption patterns by industry will be examined.

3.2 Overall

Functional Technology Use

Overall, three quarters of Canadian manufacturing establishments use at least one of the 26 advanced technologies listed on the survey (Table 3.1). Adoption rates range from a low of 16% for inspection technologies to 53% for design and engineering technologies. What this means is roughly half of the establishments in the manufacturing population have adopted at least one of the four design and engineering technologies listed on the survey—CAD/CAE, CAD/CAM, simulation technologies, and electronic exchange of CAD files. Similarly, 16% have adopted at least one of the two inspection technologies listed on the survey—automated vision-based systems, and other automated sensor-based systems.

Four of the functional groups have medium adoption rates of about 50%—design and engineering; processing, fabrication, and assembly; network communications; and integration and control—while two have low adoption rates of less than 20%—automated material handling and inspection technologies.

Table 3.1
Functional Technology Use (Establishment Weighted)

TECHNOLOGIES	**In Use**
	(percentage of establishments)
Design and Engineering	53
Processing, Fabrication and Assembly	49
Automated Material Handling	19
Inspection	16
Network Communications	51
Integration and Control	52
Overall	76

Individual Technology Use

As with the 1993 survey (Baldwin and Sabourin, 1995), computer-aided design and engineering leads with the highest adoption rate of any technology listed on the survey. Forty-four percent of establishments have adopted this technology. This is followed by programmable logic controllers (a fabrication technology), local area networks and company-wide networks (both communications technologies), and CAD/CAM and electronic exchange of CAD files (both design and engineering technologies).

Few establishments are using some of the newer, emerging technologies such as rapid prototyping systems (5%), near net shaping technologies (7%), and digital, remote controlled process plant control technologies (5%).

Table 3.2
Advanced Technology Use (Establishment Weighted)

TECHNOLOGIES	In Use	Plan to Use	No Plans
	(percentage of establishments)		
Design and Engineering			
a) Computer-Aided Design/Engineering (CAD/CAE)	44	10	46
b) Computer-Aided Design/Manufacturing (CAD/CAM)	36	14	51
c) Modelling or simulation technologies	17	13	70
d) Electronic exchange of CAD files	34	13	53
Processing, Fabrication and Assembly			
a) Flexible Manufacturing Cells or Systems (FMC/FMS)	15	11	74
b) Programmable Logic Control (PLC) machines or processes	37	9	54
c) Lasers used in materials processing (including surface modification)	9	8	84
d) Robots with sensing capabilities	8	7	85
e) Robots without sensing capabilities	7	5	88
f) Rapid Prototyping Systems (RPS)	5	7	87
g) High speed machining	17	12	71
h) Near net shape technologies	7	6	87
Automated Material Handling			
a) Part identification for manufacturing automation (e.g. bar coding)	18	21	62
b) Automated Storage and Retrieval System (AS/RS)	5	9	85

Inspection			
a) Automated vision-based systems used for inspection/testing of inputs and/or final products	11	8	81
b) Other automated sensor-based systems used for inspection/testing of inputs and/or final products	13	8	79
Network Communications			
a) Local area network (LAN) for engineering and/or production	36	13	51
b) Company-wide computer networks (including Intranet and WAN)	35	19	46
c) Inter-company computer networks (including Extranet and EDI)	29	21	50
Integration and Control			
a) Manufacturing Resource Planning (MRP II)/Enterprise Resource Planning (ERP)	21	19	61
b) Computers used for control on the factory floor	31	21	49
c) Computer-Integrated Manufacturing (CIM)	18	15	67
d) Supervisory Control and Data Acquisition (SCADA)	16	16	68
e) Use of inspection data in manufacturing control	26	16	58
f) Digital, remote controlled process plant control (e.g. Fieldbus)	5	8	87
g) Knowledge-based software	18	15.1	67

3.3 … By Employment Size

Functional Technology Use

It is generally accepted that technology use increases with size (Baldwin and Sabourin, 1995; Vickery and Campbell, 1989; Northcott, 1993). Possible reasons for this range from having better developed information networks, to superior financial and technical resources (Northcott, 1993), and even to economies of scale.

Large establishments have a very high incidence rate for four of the six functional technology groups, where incidence refers to the use of at least technology from the group of technologies being considered. Roughly nine out of ten large plants adopt at least one technology from each of the four groups—network communications; processing and fabrication; integration and control; and design and engineering. Although the incidence rate for the other two groups—automated material handling and inspection—is lower, still more than half the large plants have adopted these technologies.

As for medium-sized plants, close to three-quarters have adopted network communication and integration and control technologies. Two-thirds have adopted design and engineering, and processing and fabrication technologies. Few have adopted automated material handling and inspection technologies.

Design and engineering technologies are used the most by small establishments with 46% of small plants using at least one of these technologies. Close behind are integration and control, processing and fabrication, and network communications, all with about a 40% incidence rate. Very few—about one in ten small plants—have adopted automated material handling and inspection technologies.

Table 3.3
Functional Technology Use by Employment Size (Establishment Weighted)

TECHNOLOGIES	Small	Medium	Large	All
	(percentage of establishments)			
Design and Engineering	46	65	88	53
Processing, Fabrication and Assembly	40	66	92	49
Automated Material Handling	12	29	61	19
Inspection	10	24	51	16
Network Communications	39	73	94	51
Integration and Control	41	72	92	52

Individual Technology Use

At the individual technology level, technology adoption increases with size. Large establishments have higher adoption rates than medium-sized establishments, which in turn, have higher adoption rates than small establishments.

The technologies with the highest adoption rates, regardless of size, are computer aided design and engineering, programmable logic controllers, local area networks, company-wide computer networks, electronic exchange of CAD files, and computer aided design and manufacturing.

Large establishments have the highest adoption rates for local area networks (86%), company-wide computer networks (83%), programmable logic controllers (82%), computer aided design and engineering (81%) and computers used for control on the factory floor (79%). These technologies represent four functional groups—network communications, design and engineering, processing and fabrication, and integration and control.

For medium-sized establishments, the same five technologies are the most-used, albeit at a reduced level—local area networks (57%), computer aided design and engineering (57%), programmable logic controllers (54%), company-wide computer networks (54%), and computers used for control on the factory floor (47%).

A slightly different pattern exists for small establishments. The top three technologies are all design and engineering technologies—computer aided design and engineering (37%), computer aided design and manufacturing (31%) and electronic exchange of CAD files (28%). One processing and fabrication technology—programmable logic controllers (27%)—and two communications technologies—local area networks (24%) and company-wide computer networks (24%)—are the technologies with the next highest adoption rates.

Table 3.4
Advanced Technology Use by Employment Size (Establishment Weighted)

TECHNOLOGIES	Small	Medium	Large	All
	(percentage of establishments)			
Design and Engineering				
a) Computer-Aided Design/Engineering (CAD/CAE)	37	57	81	44
b) Computer-Aided Design/Manufacturing (CAD/CAM)	31	43	67	36
c) Modelling or simulation technologies	14	20	49	17
d) Electronic exchange of CAD files	28	42	74	34
Processing, Fabrication and Assembly				
a) Flexible Manufacturing Cells or Systems (FMC/FMS)	12	20	40	15
b) Programmable Logic Control (PLC) machines or processes	27	54	82	37
c) Lasers used in materials processing (including surface modification)	5	13	26	9
d) Robots with sensing capabilities	4	11	34	8
e) Robots without sensing capabilities	4	10	32	7
f) Rapid Prototyping Systems (RPS)	4	6	14	5
g) High speed machining	14	21	35	17
h) Near net shape technologies	6	8	13	7
Automated Material Handling				
a) Part identification for manufacturing automation (e.g. bar coding)	11	27	57	18
b) Automated Storage and Retrieval System (AS/RS)	4	6	17	5

Inspection				
a) Automated vision-based systems used for inspection/testing of inputs and/or final products	7	15	35	11
b) Other automated sensor-based systems used for inspection/testing of inputs and/or final products	8	18	45	13
Network Communications				
a) Local area network (LAN) for engineering and/or production	24	57	86	36
b) Company-wide computer networks (including Intranet and WAN)	24	54	83	35
c) Inter-company computer networks (including Extranet and EDI)	20	42	74	29
Integration and Control				
a) Manufacturing Resource Planning (MRP II)/Enterprise Resource Planning (ERP)	13	34	52	21
b) Computers used for control on the factory floor	21	47	79	31
c) Computer-Integrated Manufacturing (CIM)	15	23	42	18
d) Supervisory Control and Data Acquisition (SCADA)	11	23	43	16
e) Use of inspection data in manufacturing control	18	39	70	26
f) Digital, remote controlled process plant control (e.g. Fieldbus)	3	8	20	5
g) Knowledge-based software	16	20	32	18

3.4 … By Industry

Functional Technology Use

The adoption of advanced technologies varies considerably across industries. Reasons for this have to do with different applicabilities of technology from industry to industry, and differences in the size distribution of plants across industries (Baldwin and Sabourin, 1995). For example, design and engineering applications, which are vital for the electronics industry, tend to be less important for the beverage and textile products industries. As for differences in size distribution across industries, industries dominated by large firms would be expected to have higher adoption rates since technology use increases with size.

Incidence of functional technology use by 2-digit S.I.C. industry is provided in Table 3.5. There are twenty-two manufacturing industries at this level but only twenty are reported here. Food processing is excluded as it was surveyed early in 1998 and tobacco is excluded due to the small number of establishments in this industry.

Table 3.5
Functional Technology Use by Industry (Establishment Weighted)

INDUSTRY	Design and Engineer-ing	Processing, Fabrication, Assembly	Automated Material Handling	Inspection	Network Communi-cations	Integration and Control
	(percentage of establishments)					
Beverage	34	65	40	34	77	77
Rubber Products	50	64	23	18	49	51
Plastic Products	51	68	23	21	54	59
Leather and Allied Products	38	33	19	3	37	42
Primary Textile	49	54	45	38	69	70
Textile Products	29	39	18	13	48	51
Clothing	33	22	17	6	34	36
Wood	37	53	18	13	34	43
Furniture and Fixture	43	37	16	6	36	37
Paper and Allied Products	55	63	41	33	66	66
Printing, Publishing and Allied	36	30	16	12	58	45
Primary Metal	80	67	30	29	62	61
Fabricated Metal Products	71	56	10	14	52	54
Machinery	70	60	19	20	61	60
Transportation Equipment	66	55	40	33	57	58
Electrical and Electronic Products	79	59	27	23	71	72
Non-Metallic Mineral Products	38	49	15	11	39	53
Refined Petroleum and Coal Products	42	33	16	21	33	51
Chemical and Chemical Products	36	48	22	24	65	58
Other Manufacturing	52	42	15	10	49	43

Establishments in five industries (beverages, primary textiles, paper and allied products, primary metals, and electrical and electronic products) tend to have the highest adoption rates across the majority of the functional technology groups. This pattern is easier to see by ranking the adoption rates, from highest to lowest, within industries. This rank ordering is provided in Table 3.6.

Results show that establishments in the beverage industry have the highest adoption rates of all industries for both network communications and integration and control technologies. They rank second for inspection technologies; and third for processing and fabrication, and automated material handling technologies. Only for design and engineering technology do they lag. Primary textiles are also among the leaders when it comes to automated material handling, inspection, network communications, and integration and control technologies. Although they lag somewhat for design and engineering, and processing and fabrication technologies, they are still ranked in the top half of all industries for these technologies.

Establishments in the paper and allied products, primary metals, and electrical and electronics products industries also have high adoption rates across all functional groups. They rank among the top five industries across all functional groups. The only real differences are that the primary metals and electronics products industries have higher adoption rates for design and engineering than does the paper products industry; primary metals has a higher adoption rate for processing and fabrication than do the other two industries; and electronic products has a higher adoption rate than the other two for network communications and integration and control technologies.

Table 3.6
Rank Order of Functional Technology Use by Industry

INDUSTRY	Design and Engineer-ing	Processing, Fabrication, Assembly	Automated Material Handling	Inspection	Network Communi-cations	Integration and Control
			(rank)			
Beverage	13	3	3	2	1	1
Rubber Products	8	4	6	8	10	12
Plastic Products	7	1	6	6	8	7
Leather and Allied Products	11	16	8	14	13	15
Primary Textile	8	9	1	1	3	3
Textile Products	15	14	9	9	11	11
Clothing	14	18	10	13	15	17
Wood	11	10	9	9	15	14
Furniture and Fixture	9	15	12	13	14	16
Paper and Allied Products	6	5	2	3	4	4
Printing, Publishing and Allied	12	17	11	10	7	13
Primary Metal	1	2	4	4	6	5
Fabricated Metal Products	3	7	14	9	9	9
Machinery	4	6	8	7	6	6
Transportation Equipment	5	8	3	3	7	8
Electrical and Electronic Products	2	6	5	5	2	2
Non-Metallic Mineral Products	11	11	13	11	12	10
Refined Petroleum and Coal Products	10	16	11	6	15	12
Chemical and Chemical Products	12	12	7	5	5	8
Other Manufacturing	7	13	13	12	10	14

Individual Technology Use by Industry

There is a core of technologies that establishments from all industries tend to adopt, albeit at different rates. According to Table 3.7, the top-ranked technologies, across all industries, are:
- CAD/CAE
- CAD/CAM
- programmable logic controllers
- local area networks (LANs)
- company-wide computer networks

These are the same technologies that had the highest adoption rates overall (Table 3.2). Although the actual ranking may differ somewhat from industry to industry, all five of these technologies are among the leaders in each industry. These five represent three functional technology groups. Two are network communications technologies—LANs, and company-wide computer networks—two are design and engineering technologies—CAD/CAE and CAD/CAM—and one is a fabrication and assembly technology—programmable logic controllers.

There are three other technologies that have moderately high adoption rates across a majority of industries. They are inter-company computer networks, factory floor computers, and the use of inspection data in manufacturing control. Inter-company computer networks are among the leaders for all but fabricated metal, machinery, electrical, non-metallic minerals, petroleum, wood and furniture. Factory floor computers are particularly important for leather, primary textiles, textile products, clothing, wood, and non-metallic mineral products. They either lead or rival the leaders for these industries. Adoption rates for inspection data control are among the leaders for two-thirds of the industries. They tend to rank fourth or fifth in adoption rates for all but primary textiles where they have the highest adoption rate of 50%.

Table 3.7 - Advanced Technology Use by Industry (Establishment Weighted)

TECHNOLOGIES	Beverages	Rubber Products	Plastic Products	Leather and Allied Products	Primary Textile	Textile Products	Clothing	Wood	Furniture and Fixtures	Paper and Allied Products
	(percentage of establishments)									
Design and Engineering	**34**	**50**	**51**	**38**	**49**	**29**	**33**	**37**	**43**	**55**
a) CAD/CAE	32	45	45	27	37	25	23	28	33	46
b) CAD/CAM	18	38	36	22	38	16	24	23	33	36
c) Modelling/simulation technologies	5	27	19	16	17	5	6	10	11	19
d) Electronic exchange of CAD files	23	20	31	18	22	10	12	15	20	35
Processing, Fabrication and Assembly	**65**	**64**	**68**	**33**	**54**	**39**	**22**	**53**	**37**	**63**
a) Flexible manufacturing systems	13	31	17	18	15	10	7	12	10	13
b) Programmable logic controllers	62	46	58	18	49	28	14	40	25	56
c) Lasers for materials processing	14	6	6	1	5	5	1	15	5	7
d) Robots with sensing	9	10	16	7	12	2	6	6	4	8
e) Robots without sensing	11	11	12	5	9	2	4	4	6	7
f) Rapid prototyping systems	3	9	11	4	4	1	2	2	5	1
g) High speed machining	13	21	18	10	23	15	6	24	20	18
h) Near net shape technologies	5	4	6	1	4	1	2	6	4	1
Automated Material Handling	**40**	**23**	**23**	**19**	**45**	**18**	**17**	**18**	**16**	**41**
a) Part identification	38	22	22	18	43	18	16	17	14	40
b) Automated storage/retrieval system	7	1	3	3	10	4	2	5	2	9

Table 3.7 - Advanced Technology Use by Industry (Establishment Weighted) - *continued*

TECHNOLOGIES	Beverages	Rubber Products	Plastic Products	Leather and Allied Products	Primary Textile	Textile Products	Clothing	Wood	Furniture and Fixtures	Paper and Allied Products
	(percentage of establishments)									
Inspection	**34**	**18**	**21**	**3**	**38**	**13**	**6**	**13**	**6**	**33**
a) Automated vision-based systems used for inspection/testing	30	6	9	3	30	11	4	10	6	23
b) Other automated sensor-based systems used for inspection/testing	24	18	18	3	22	10	4	10	3	29
Network Communications	**77**	**49**	**54**	**37**	**69**	**48**	**34**	**34**	**36**	**66**
a) Local area network (LAN) for engineering or production	50	29	40	23	40	26	17	21	22	38
b) Company-wide computer networks	65	39	38	24	43	36	22	27	21	56
c) Inter-company computer networks	57	45	33	22	50	28	22	18	17	49
Integration and Control	**77**	**51**	**59**	**42**	**70**	**51**	**36**	**43**	**37**	**66**
a) Manufacturing Resource Planning	47	25	23	16	41	18	12	14	17	18
b) Factory floor computers	42	20	34	30	45	30	23	27	26	42
c) Computer integrated manufacturing	20	19	18	20	31	19	14	16	23	42
d) Supervisory control and data acquisition (SCADA)	21	14	17	14	32	6	13	11	14	35
e) Use of inspection data for control	43	35	40	16	50	21	14	19	17	40
f) Digital, remote controlled process plant control	18	6	2	1	8	8	1	4	5	16
g) Knowledge-based software	25	17	19	12	17	14	15	13	10	28

Table 3.7 - Advanced Technology Use by Industry (Establishment Weighted) - *continued*

TECHNOLOGIES	Printing, Publishing and Allied	Primary Metal	Fabricated Metal Products	Machinery	Transportation Equipment	Electrical and Electronic Products	Non-Metallic Mineral Products	Refined Petroleum and Coal Products	Chemical and Chemical Products	Other Manufacturing
	(percentage of establishments)									
Design and Engineering	**36**	**80**	**71**	**70**	**66**	**79**	**38**	**42**	**36**	**52**
a) CAD/CAE	24	68	62	66	58	75	26	24	26	44
b) CAD/CAM	26	40	52	50	46	46	24	27	17	35
c) Modelling/simulation technologies	8	25	23	30	28	35	8	17	12	14
d) Electronic exchange of CAD files	28	70	54	40	46	63	16	19	22	35
Processing, Fabrication and Assembly	**30**	**67**	**56**	**60**	**55**	**59**	**49**	**33**	**48**	**42**
a) Flexible manufacturing systems	12	23	12	27	30	29	12	5	12	13
b) Programmable logic controllers	16	62	42	43	43	47	42	32	44	19
c) Lasers for materials processing	14	9	7	11	8	12	5	1	3	10
d) Robots with sensing	3	9	7	10	22	10	7	1	6	4
e) Robots without sensing	2	9	5	12	25	10	6	1	4	3
f) Rapid prototyping systems	5	17	6	7	8	11	2	0	2	6
g) High speed machining	9	16	26	18	17	15	13	2	7	13
h) Near net shape technologies	4	27	11	12	13	5	5	0	2	5
Automated Material Handling	**16**	**30**	**10**	**19**	**40**	**27**	**15**	**16**	**22**	**15**
a) Part identification	10	30	10	19	39	25	11	13	20	11
b) Automated storage/retrieval system	9	6	3	6	10	8	8	4	6	5

Table 3.7 - Advanced Technology Use by Industry (Establishment Weighted) - *concluded*

TECHNOLOGIES	Printing, Publishing and Allied	Primary Metal	Fabrica-ted Metal Products	Machi-nery	Transport-ation Equip-ment	Electrical and Electronic Products	Non-Metallic Mineral Products	Refined Petroleum and Coal Products	Chemical and Chemical Products	Other Manufac-turing
	(percentage of establishments)									
Inspection	**12**	**29**	**14**	**20**	**33**	**23**	**11**	**21**	**24**	**10**
a) Automated vision-based systems used for inspection/testing	10	15	9	19	16	13	8	12	15	7
b) Other automated sensor-based systems used for inspection/testing	7	24	12	14	29	20	8	17	20	6
Network Communications	**58**	**62**	**52**	**61**	**57**	**71**	**39**	**33**	**65**	**49**
a) Local area network (LAN) for engineering or production	40	58	36	44	53	65	27	31	48	30
b) Company-wide computer networks	38	46	31	40	44	47	32	29	50	32
c) Inter-company computer networks	33	43	26	28	43	35	19	19	43	28
Integration and Control	**45**	**61**	**54**	**60**	**58**	**72**	**53**	**51**	**58**	43
a) Manufacturing Resource Planning	15	36	15	29	34	45	20	12	27	14
b) Factory floor computers	29	44	30	32	38	38	38	42	36	19
c) Computer integrated manufacturing	16	19	17	17	19	21	24	22	17	13
d) Supervisory control and data acquisition (SCADA)	17	32	13	15	19	18	21	19	24	14
e) Use of inspection data for control	17	44	27	25	41	41	25	24	34	17
f) Digital, remote controlled process plant control	3	8	4	10	5	6	7	20	12	3
g) Knowledge-based software	21	24	18	20	17	24	18	31	21	15

3.5 Investment in Technology

Incidence and intensity of use are two important measures of technology diffusion. Incidence of use measures whether a technology is being used. Intensity of use measures the extent to which that technology is being used.

Intensity of use is being measured here as the percentage of total investment in machinery and equipment devoted to advanced technology. This provides a measure of the relative importance of advanced technology to more conventional technology.

Plant managers were asked to indicate what percentage of their total investment was spent on advanced technology. They were provided with five possible investment categories—zero percent, 1% to 25%, 26% to 50%, 51% to 75%, and 76% or more. The findings are that almost three-quarters of manufacturing establishments had invested in advanced technology (column 1, Table 3.8).

Relatively few establishments invested more in advanced technology than in conventional technology. Of those investing in advanced technology, only twenty percent had their advanced technology investments exceed their conventional technology investments (column 2, Table 3.8). Further, only nine percent of these investors had more than three-quarters of their total investments in advanced technology. For most plants (64%), investments in advanced technology did not exceed one-quarter of their total investments in machinery and equipment.

Table 3.8
Investment in advanced machinery and equipment (Establishment Weighted)

INVESTMENT	ALL ESTABLISHMENTS	INVESTORS ONLY
	(1)	(2)
	(percentage of establishments)	
Zero percent	26	---
1% to 25%	47	64
26% to 50%	12	16
51% to 75%	9	12
76% to 100%	6	9

3.6 Technological Competitiveness

Plant managers were asked to evaluate their production technologies against that of their competitors—both in Canada and in the United States. They were asked to do so using a five-point scale where 1 refers to less advanced, 5 as more advanced and 3 as about the same. This type of question provides a means for comparing levels of technology between Canada and the United States in the absence of comparable technology use data.

Examination of the results for domestic competitors shows that 43% of managers feel their production technology to be as good as their competitors (score of 3), while twice as many consider their technologies to be superior (extreme scores of 4 and 5) than inferior (extreme scores of 1 and 2) to their domestic competitors. Against their U.S. counterparts, 33% feel their technologies are as good, while equal numbers (24%) feel they are ahead of their competitors as behind their competitors.

Table 3.8
Technological Competitiveness Evaluation (Establishment Weighted)

COMPETITORS	**SCORE**					
	Less advanced			More advanced		
	1	2	3	4	5	N/A
	(percentage of establishments)					
a) Domestic producers	4	12	43	24	10	8
b) U.S. producers	7	16	33	18	6	19

3.7 Communications Networks

The use of communications networks such as Intranet, Extranet, and Internet is rapidly growing. Earlier, in Section 3.2, we found that network communications technologies were among the leaders when it comes to adoption. Half of all manufacturing plants have adopted at least one type of advanced network communications technology (Table 3.1). According to these results, about a third have adopted a local area network, and a similar number have adopted a company-wide computer network (including Intranet and Wide Area Networks). Slightly less (29%) have acquired inter-company computer networks such as Extranets.

These emerging technologies are fast becoming an integral part of the day-to-day operations of firms. Intranets are computer networks internal to a firm that are used to distribute information among different parts of the firm. Extranets differ from intranets in that they also include business partners, such as suppliers and distributors. This section explores the purposes for which these technologies are being used.

More establishments use their communication networks as a general reference tool than for any other reason. Fifty-two percent of establishments use it for that purpose. This is followed by marketing and customer information, and accounting and financing purposes—46% of plants use it for each of these reasons. Tracking sales and inventory is next, followed closely by sharing information on technology.

Table 3.9
Use of communications networks (Establishment Weighted)

PURPOSE	YES	NO	N/A
	(percentage of establishments)		
general reference	52	25	23
marketing/customer information	47	30	24
accounting and financing	46	31	24
tracking sales and inventory	38	35	28
sharing technology information	36	35	29
consumer information	34	39	27
financial transactions	34	40	26
ordering products	31	44	26
production status information	30	43	28
management planning system	27	46	28
human resources purposes	26	45	28
tracking production flow	25	45	30
tracking distribution	22	46	32
on-line maintenance	12	54	34
other	5	33	62

4. Business Practices

Business strategies are often implemented through the adoption of certain business practices. Gordon and Wiseman (1995) report that the adoption of business practices provide more successful plants with a comparative advantage. They serve as complements to advanced technologies. In a recent study examining technology use in the Canadian food processing sector, Baldwin and Sabourin (1999) find that, as an input into the innovation process, engineering practices are as important as R&D. Business practices are, therefore, an important part of the technological regime of a firm.

The extent to which business practices are being used by manufacturing plants is provided in Table 4.1. They are listed in descending order of use. Continuous improvement has the highest usage rate with almost half of the establishments having adopted it. This technique involves an incremental approach to quality improvement. Next in importance are just-in-time inventory, certification of suppliers, benchmarking and plant certification with between 34% and 40% of plants using each of these techniques. Just-in-time inventory is a low inventory system in which suppliers agree to deliver a product immediately on request. Benchmarking is the ongoing practice of comparing a plant's standards against that of the industry leaders, while plant certification—such as ISO9000—refers to any program that includes quality certification by a third party. On the other hand, process simulation and distribution resource planning practices are the least used with an adoption rate of only 10%.

Table 4.1
Use of business practices and techniques (Establishment Weighted)

PRACTICES	YES	NO	N/A
	(percentage of establishments)		
Continuous improvement	49	30	21
Just-in-time inventory	40	40	21
Certification of suppliers	36	43	21
Benchmarking	35	41	24
Plant certification	34	43	22
Electronic work order management	29	48	22
Cross-functional design teams	29	44	27
Concurrent engineering	29	43	28
Statistical process control	23	53	24
Quality function deployment	22	52	25
Distribution resource planning	10	61	29
Process simulation	10	63	27

5. Development and Implementation of Advanced Technologies

This section investigates the development and implementation of advanced technologies within the plant. Establishments that had introduced an advanced technology were asked to indicate the method by which the technology was introduced. Managers were permitted to select more than one method as many of them had introduced more than one technology, some of them by different methods. The preferred method is by purchasing it off-the-shelf with 84% of technology-using plants having adopted this method. Next most popular method is by customizing or significantly modifying an existing technology. Half of the plants had used this method. Few had introduced it through licensing (18%), while a significant percentage (29%) prefer to develop the technologies themselves.

Table 5.1
Method of introducing advanced technologies into a plant (Establishment Weighted)

METHOD	**YES**	**NO**
	(percentage of establishments)	
a) by purchasing off-the-shelf equipment	84	16
b) by licensing new technology	18	82
c) by customizing or significantly modifying existing technology	50	50
d) by developing brand new advanced technologies	29	72

Firms acquire ideas for the adoption of advanced technologies from different sources. Some sources are internal to the firm while others are external. Internal sources include such sources as R&D units, production divisions, sales and marketing units, related plants, and head office. External sources include such sources as trade fairs, conferences, publications, suppliers, customers and competitors.

Both internal and external sources are important. Among internal sources, the production unit is the most important. Sixty-nine percent of establishments claim that production staff play a key role in providing ideas about advanced technology. Similarly, the production engineering department is found to be an important source of ideas for 55% of plants. Other important sources include the design staff (58%), the research unit (53%), and the sales and marketing department (56%).

Among external sources, trade fairs, conferences and publications are used the most frequently with three-quarters of establishments obtaining their ideas this way. Suppliers and customers are next in importance. At close to 70%, they are used as frequently as the most often-cited internal source of ideas—production staff.

Competitors are another valuable source of ideas. Forty-four percent of establishments report their competitors play an important role in providing ideas about the adoption of advanced technology. Competitors are as important as consultants and related firms in this regard. Relatively few establishments, however, use universities, governments and institutes, and patents as sources of ideas.

Table 5.2
Sources of ideas for the adoption of advanced technology (Establishment Weighted)

SOURCES	**YES**	**NO**	**N/A**
	(percentage of establishments)		
INTERNAL			
a) research	53	37	11
b) experimental development	46	43	11
c) production engineering	55	36	9
d) corporate head office	43	43	14
e) related plants	30	51	19
f) technology watch program	23	62	15
g) production staff	69	25	6
h) design staff	58	32	10
i) sales and marketing	56	37	7
j) other	2	46	52
EXTERNAL			
k) trade fairs, conferences, publications	76	20	5
l) patents	14	73	12
m) consultants/service firms	42	51	7
n) suppliers	70	26	4
o) customers	66	30	4
p) related firms	39	52	9
q) universities	15	76	10
r) governments, institutes, associations	19	71	10
s) other producers in your industry	44	48	8
t) other	1	50	50

6. Skill Developments

A set of questions was developed to investigate the issue of changing skill requirements as the result of technological change. Firms lacking workers with the necessary skills to effectively operate and maintain the new technology may choose to introduce training programs for their current workforce. Or they may elect to search for and recruit new employees with the necessary skills. Or, perhaps more likely, they may do both. Both ways of dealing with these skill shortages will be explored in this section.

Plant managers were asked whether their employees had received any training relating to the use of advanced technology over the past three years. Only the establishments using at least one of the advanced technologies listed in question B1 of the survey were asked to complete the questions in this section. The results presented in this section, therefore, are based on this technology user group. As shown in Table 6.1, almost three-quarters of technology users had done some training pertaining to the adoption of advanced technology in the past three years.

Table 6.1
Training related to the adoption of advanced technology (Establishment Weighted)

	YES	**NO**
	(percentage of establishments)	
Training	74	26

A further question explored the areas in which training is being done. Given that an establishment trains, what type of training does it do? Not surprisingly, computer skills and technical skills rank highest (Table 6.2). Safety skills training also rank high. Nine out of every ten establishments provided training geared to improving technical skills, while almost as many had provided computer literacy training. Safety skills and quality control training are also important with roughly eight out of every ten plants providing these types of training. Few, however, provided training in basic literacy and numeracy skills.

Table 6.2
Areas of training (Establishment Weighted)

TRAINING	**YES**	**NO**	**N/A**
	(percentage of establishments)		
a) basic literacy/numeracy	31	61	8
b) computer literacy	85	15	1
c) technical skills	88	11	1
d) quality control skills	80	19	1
e) safety skills	84	15	2
f) other	6	44	51

Another question dealt with skill shortages. Managers were asked in which occupations they experienced shortages pertaining to the operation of advanced technology. Twenty occupational categories were listed belonging to four broad categories—professionals, management, technicians and technologists, and skilled trades. Six individual occupations are covered under the professional category; three under the management category; seven under technicians and technologists; and four under skilled trades.

Overall, two-thirds of technology users have experienced a shortage of skilled personnel during the past year. More specifically, many plants have experienced shortages in at least two of the broad occupational categories. Shortages are greatest for the professional and skilled trade categories. About forty percent of technology users report experiencing a shortage in both of these areas. Technicians and technologists are not far behind as 37% of managers report a shortage in this area. Fewer establishments (31%) report shortages in the management category.

Although a larger percentage of establishments report shortages for the professionals and skilled trades categories than do for the management category, this could be due, at least in part, to the greater number of occupations covered by these categories in the survey. It is therefore important to examine the results at the individual occupation level as well.

Two occupations dominate the professionals category—industrial and manufacturing process engineers, and electronic engineers with shortages of 25% and 19%, respectively. For skilled trades, the most critical shortages were for machine operators (27%) and machinists (24%). For technicians and technologists, the most notable shortages were in computer-aided design technicians (18%), computer programmers (16%) and electronics and computer hardware specialists (15%). Shortages of production managers and design managers were the most often cited for the management category, hovering around 20%. Although shortages for the professionals and skilled trades categories may be greater, individual differences within these categories are much less pronounced.

Table 6.3
Skilled personnel shortages (Establishment Weighted)

OCCUPATION	YES	NO	N/A
	(percentage of establishments)		
ALL OCCUPATIONS	***66***		
PROFESSIONALS WITH UNIVERSITY DEGREE	**41**		
a) mechanical/aerospace	13	51	36
b) electronic/computer	19	55	26
c) chemical/chemical process	4	56	39
d) industrial/manufacturing process	25	52	23
e) science professionals	3	58	39
f) computer scientists	8	57	35
MANAGEMENT	**31**		
g) production management	21	71	8
h) design management	17	69	14
i) human resources management	8	79	13
TECHNICIANS and TECHNOLOGISTS	**37**		
j) electronics/computer hardware	15	63	22
k) science technicians	3	62	36
l) engineering science technicians	10	59	31
m) computer programmers	16	62	22
n) communications network administration	10	67	23
o) computer aided design	18	64	19
p) instrumentation	6	67	28
SKILLED TRADES	**40**		
q) machinist (including tool, die mould)	24	58	18
r) machine operator	27	61	12
s) electrical equipment operator	7	69	24
t) process plant operator	11	68	21
OTHER	**7**		
u) other	7	22	72

Managers, who indicated that they were suffering skill shortages, were then asked if they had taken any action to deal with these shortages and, if so, what action did they take. Slightly more than three-quarters of the managers indicated that they had taken some steps to deal with the shortages. Most (93%) said that they searched for skilled personnel. Almost as important is training with 84% of managers opting for this route. Other options offered to managers were improving their wages and benefits package and establishing stronger links with educational institutions. Improving the wages and benefits package was preferred to stronger educational links. Two-thirds of establishments opted for improved wages and benefits while half have established stronger links with educational institutions.

Table 6.4
Percentage of plants which have taken steps to deal with shortages (Establishment Weighted)

	YES	NO
	(percentage of establishments)	
Steps Taken	79	21

Table 6.5
Steps taken to deal with shortages (Establishment Weighted)

STEPS	YES	NO	N/A
	(percentage of establishments)		
a) provided training	84	16	1
b) improved wages and benefits	64	32	4
c) established stronger links with educational institutions	50	45	5
d) searched for skilled personnel	93	6	0
e) other	5	33	62

Managers overwhelmingly prefer to search locally when trying to recruit new personnel. Virtually all have done so. They are also prepared to search elsewhere in Canada. Forty-four percent have actively recruited outside their own region but still within Canada. A relatively small percentage (13%) have searched outside of Canada.

Table 6.6
Geographic scope of search for skilled personnel (Establishment Weighted)

	YES	NO
	(percentage of establishments)	
a) within your region	97	3
b) outside your region (in Canada)	44	56
c) outside Canada	13	87

7. Results of Adoption

7.1 Introduction

Establishments adopt advanced technology for a variety of reasons. They do so in order to increase production, to reduce production costs, to improve product quality, and to increase production efficiency and flexibility (OECD, 1991). Firms typically adopt a new technology when the internal rate of return from the investment is positive, i.e., when the benefits obtained from adopting the technology outweigh the costs. However, it is often difficult to predict the expected benefits prior to investment.

Five main categories of benefits or effects of adoption were covered in this survey. They are:

- Improvements in productivity
- Product improvements
- Organizational changes
- Plant efficiencies
- Market performance

Productivity can be improved in a number of different ways. One way is through a reduction in input requirements. This can be achieved through a reduction in labour requirements, material consumption, or capital requirements per unit of output. Alternatively, improvements in productivity can be the result of reductions in either the set-up time or in the rejection rates. Being able to set-up quickly results in less downtime, while reductions in rejection rates means less wastage.

Another important benefit, though difficult to predict, is product improvement. It is difficult to predict the impact on consumer demand of a product of superior quality or one with novel features. Besides improvements in the quality of a product or the introduction of new product features, a reduction in the time it takes to market a product is also a form of product improvement.

Plant organizational changes are other possible effects of adoption. Adoption of advanced technology may result in increased production flexibility, whereby, a wide range of products may be produced by the same machine. This is especially important for firms that rely on the production of high volume customized products. Use of advanced technology may also require a more highly skilled workforce.

Adoption of technology is expected to have a positive impact on the market performance of a firm. In a recent study (Baldwin, Diverty, and Sabourin, 1995), technology users were found to have gained market share at the expense of non-users. In addition to increases in market share, increased profitability was also investigated.

Finally, new technology may result in an increase in the equipment utilization rate, that is, the production equipment will be used more efficiently.

7.2 Results of Adoption

Plants using at least one of the 26 advanced technologies listed on the survey (technology users) were asked to rate, on a scale of 1 to 5, the benefits and effects they received from adoption. A score of one indicates low importance, three moderate importance, and five high importance. Thirteen effects, classified to five main categories, were investigated. The five main categories are: productivity improvements, product improvements, plant organizational changes, plant efficiencies, and market performance. Table 7.1 provides the distribution of responses for each of the benefits or effects of adoption. In order to facilitate comparisons of the relative importance of these effects, *extreme scores* are used (Figure 7.1). The extreme scores presented here are based on the percentage of technology users reporting an importance of 4 or 5.

Table 7.1
Effects of adoption of advanced technology (Establishment Weighted)

EFFECTS	**IMPORTANCE**					
	low				high	Don't know
	1	2	3	4	5	
	(percentage of establishments)					
Improvement in productivity due to						
a) reduced labour requirements per unit of output	13	7	20	27	28	5
b) reduced material consumption per unit of output	19	11	21	23	20	5
c) reduced capital requirements per unit of output	18	11	27	20	17	8
d) reduced set-up time	13	8	20	28	27	5
e) reduced rejection rate	11	5	16	26	36	6
Product improvement						
f) new product features	15	10	24	23	19	8
g) reduced time to market	16	9	23	24	24	6
h) improvement in product quality	7	3	16	30	40	4
Plant organization changes						
i) increased production flexibility	8	6	21	32	28	7
j) increased skill requirements	11	8	30	27	18	7
Plant efficiencies						
k) increased equipment utilization rate	11	5	21	33	25	5
Market performance						
l) increased market share	10	7	20	30	27	8
m) increased profitability	5	4	15	29	41	6
Other						
n) other	0	0	1	0	1	97

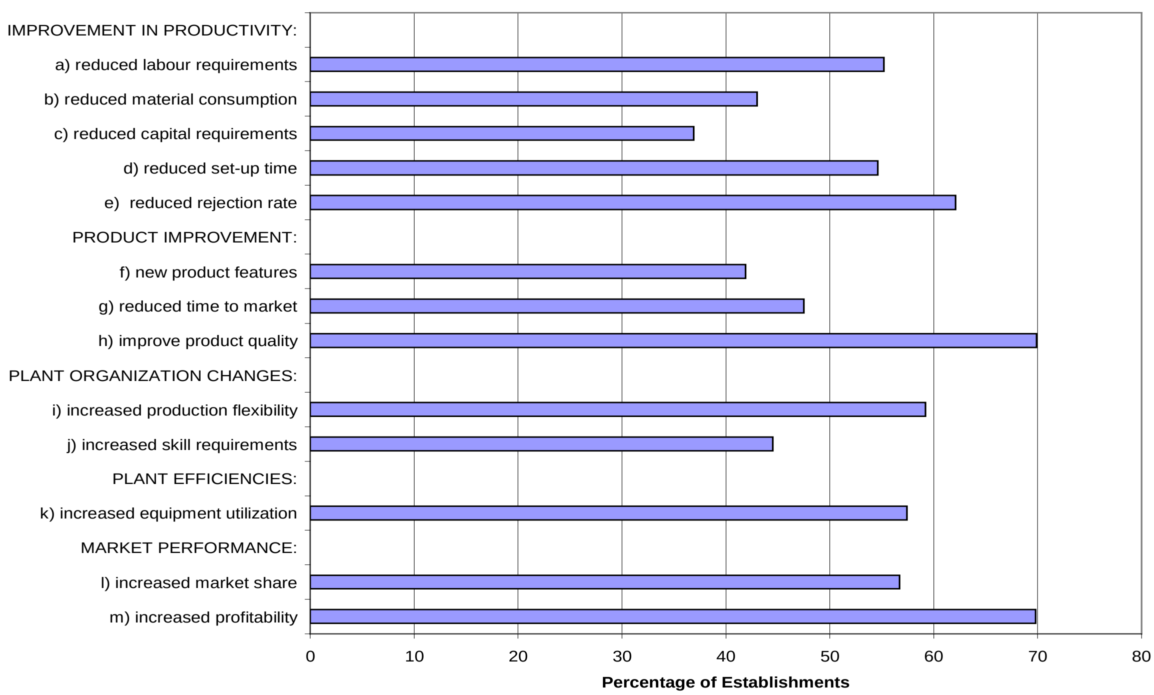
Examination of the results indicates that there is greater variation within the categories than across the categories. Important benefits are found from all five categories. In all, eight of the thirteen effects were reported as being important by over half of the population.

Improvements in product quality, increased profitability, and *improvements in productivity due to a reduction in the rejection rates* are the most important benefits from technology adoption. Roughly two-thirds of establishments report them as important.

Next in importance is *increased production flexibility, increased equipment utilization, increased market share*, and productivity improvements due to *reduced labour requirements* and *reduced set-up time*. Roughly 55% of establishments rate all of these highly. This is consistent with the findings from the previous survey[4] (Baldwin, Sabourin, and Rafiquzzaman, 1996) that improvements in productivity, reductions in labour requirements, improvements in product quality, and reductions in the product rejection rate are among the highest-rated effects.

Productivity improvements due to reductions in capital requirements are the least important. Only one-third of establishments consider them to be an important effect.

Figure 7.1
Extreme Scores for Importance of Effects of Technology Adoption
(Establishment Weighted)



4 Increased profitability was not included as a choice on the previous survey.

8. Obstacles to Adoption

8.1 Introduction

While the previous section dealt with the benefits associated with the adoption of advanced technologies, this section investigates the negative impacts. Although these disincentives tend to reduce the net benefit from adoption, the net benefits may still be large enough to justify the adoption of the technology. Or they may be significant enough to dissuade a firm from adopting a technology altogether.

There are a variety of costs associated with the adoption of advanced technology. These include equipment costs, financing costs, software development costs, problems finding adequate technical support, costs associated with skill shortages, and the inability to properly evaluate the impact of the new technology. In all, ten factors—classified to four main categories—were considered. The four main categories are financial justification, human resources, management and support services.

Establishments are likely to adopt new technologies when the investment is financially justified, that is, when the net benefit from the adoption is positive. Investments may not be financially justified if equipment costs, software development costs, integration costs or financing costs are too high relative to the expected stream of benefits. The size of the market may also pose a problem. A firm might not be able to recoup their costs if the market is too small.

There are also obstacles on the human resource side. Adoption of new technology may require a firm to increase the skill level of its employees. They can do this by upgrading the skills of their existing workforce or by hiring new employees with the necessary skills. Either way, it is costly to the firm. If they choose to train, they may encounter resistance from employees who are unwillingly to invest the time to acquire new skills. Alternatively, if they elect to hire new staff, they may have problems finding and attracting individuals with the necessary skills.

Investment in technology is also influenced by the competencies of its management team. Management may be adverse to risk taking. The introduction of new technology into the organization may be met with resistance. Or the establishment may be unable to effectively evaluate the expected net benefit from adoption.

Finally, the necessary external technical support may be lacking.

8.2 Obstacles to Adoption

Managers from all plants—technology users and non-users alike—were asked to rate, on a scale of one (low) to five (high), the importance of a set of factors as obstacles to adoption of advanced technology. The factors relating to lack of financial justification were generally seen to be the most important, followed by human resource issues. For example, 29% of establishments rated *equipment costs* highly, compared to 16% for *skill shortages* (Table 8.1). The relative importance of these factors is best measured through the use of an extreme score—calculated as the percentage of technology users that reported a score of 4 or 5 for a particular factor. These results are provided in Figure 8.1.

Table 8.1
Obstacles to advanced technology adoption (Establishment Weighted)

OBSTACLES[5]	**IMPORTANCE**				
	Low				High
	1	2	3	4	5
	(percentage of establishments)				
Lack of financial justification due to					
a) small market size	26	14	28	18	15
b) high cost of equipment	12	6	22	32	29
c) cost of capital	14	11	26	27	23
d) costs to develop software	27	14	22	17	20
e) cost of integration of new technology	19	12	26	23	21
Human resources					
f) shortage of skills	23	14	27	19	16
g) worker resistance	36	22	24	12	6
Management					
h) resistance to introduction of new technology	41	22	22	10	4
i) inability to evaluate new technology	36	21	26	12	5
External support services					
j) lack of technical support or service	35	21	28	11	6

High equipment costs is seen to be the biggest obstacle to adoption with about 60% of plants rating it to be of reasonably high importance. *Cost of capital* (50%) is next, followed by *integration costs* (43%). Of the financial justification costs, *small market size* appears to be least important. Still, one-third of the plants consider it to be an important impediment.

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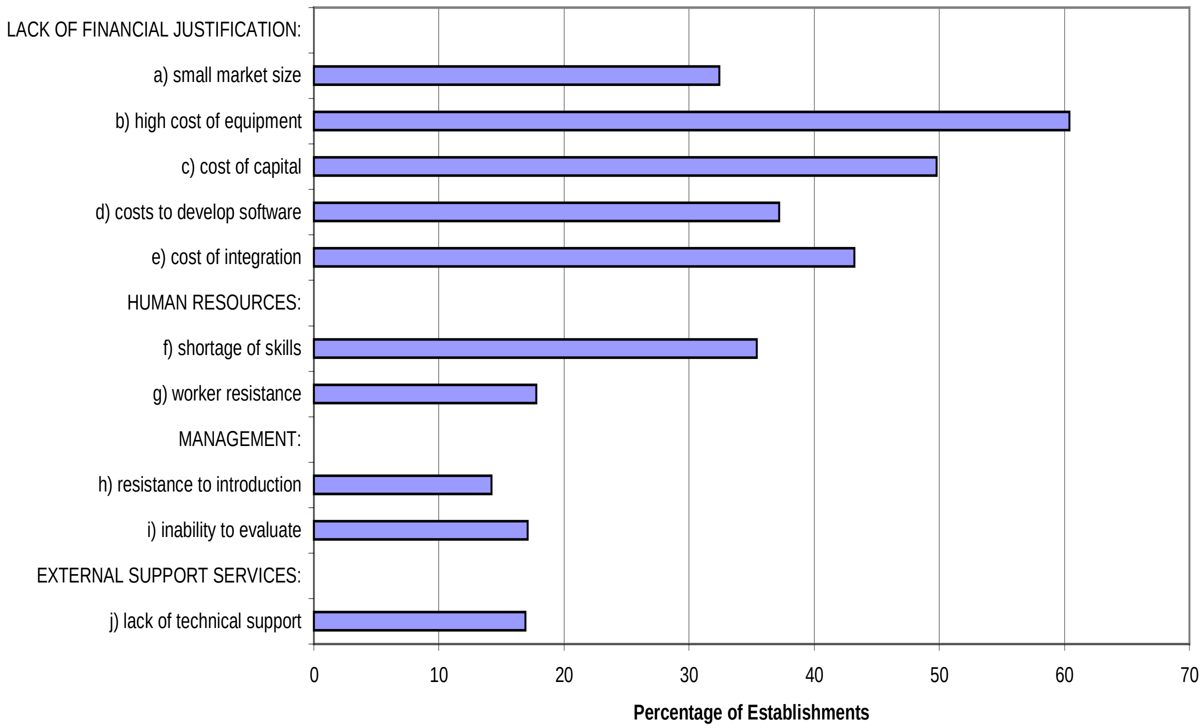
5 The actual questionnaire included an 'other' category as a possible response. The results for this category are not included in the table since they are based on only six percent of the establishments that provided an answer. Almost half of this group rated it of low importance anyway.

Lack of skilled workers is an important obstacle for 35% of establishments. This rivals *software development costs* in importance, and trails *integration costs* by only eight percentage points.

Although management attitudes and lack of adequate support services are ranked lowest, still roughly 15% of establishments report *inability to evaluate technology*, *management's resistance to new technology* and *lack of adequate technical support* to be obstacles. For some plants, management attitudes and lack of adequate support services pose a problem.

Figure 8.1
Extreme Scores for Importance of Obstacles to Technology Adoption
(Establishment Weighted)



9. Research and Development

The topic of research and development (R&D) is of considerable interest. R&D is seen to be an important input into the innovation process. Firms engage in R&D not just to create new products and processes but to be more receptive to the technological advances made by others (Mowery and Rosenberg, 1989).

Firms can pursue R&D in a number of different ways. It can be performed alone or in collaboration with others. There can be a unit dedicated to it or it can be spread throughout the whole firm. It may even be contracted out. As for frequency, some firms prefer to perform R&D on a continuous basis, while others prefer to do it on an occasional basis.

Fifty-five percent of plants indicated that their firm engaged in some type of R&D activity over the past three years (Table 9.1). Most preferred to do it in-house. Almost half (49%) of all manufacturing establishments reported that their firm performs R&D in-house. Twenty percent stated that the R&D was done jointly with another firm, while 14% indicated that R&D was contracted out.

A substantial number of firms use more than one method. Twenty percent of plants, in addition to performing R&D in-house, either collaborate with other firms or contract out the R&D. Only six percent of plants engage in R&D activity that does not have an in-house component.

Table 9.1
Firm’s R&D activities in the last three years (Establishment Weighted)

R&D Activity	**YES**	**NO**
	(percentage of establishments)	
a) does your firm do R&D in-house?	49	51
b) does your firm do R&D jointly with another firm?	20	80
c) does your firm contract out R&D?	14	86
Any R&D activity	55	45

Firms can perform R&D on an ongoing or occasional basis. Survey results indicate that close to two-thirds of firms that perform R&D, do so on an ongoing basis, while 43% perform it on an occasional basis. Very few firms do both (6%).

Table 9.2
Frequency of Firm's R&D (Establishment Weighted)

Frequency of R&D	**YES**	**NO**
	(percentage of establishments)	
a) R&D are performed on an ongoing basis	63	37
b) R&D are performed on an occasional basis	43	57
R&D performed on ongoing **and** occasional basis	6	94

Firms engage in R&D for a number of reasons. R&D is performed to create new products and new processes. It provides firms with a capability for finding out about the technological advancements of others. Or it can be used for modifying technology acquired from others.

Most firms engage in R&D to create original products (Table 9.3). Three-quarters of plants use it for this purpose. Creation of new technology and substantial adaptation of technologies acquired from others are next in importance with slightly over half the establishments using it for either purpose. Although ranked last, using R&D for the introduction of off-the-shelf technology is still important, as 43% of firms use it for this purpose.

Table 9.3
Objectives of Firm's R&D Program (Establishment Weighted)

Objectives	**YES**	**NO**
	(percentage of establishments)	
a) creating original products	74	26
b) creating original production equipment or new process technology	56	44
c) substantially adapting technology acquired from others	53	47
d) introducing off-the-shelf equipment or process technology	43	57

10. Electronic Communication

Slightly more than two-thirds of establishments indicate that their firm uses e-mail. A similar percentage also use the Internet (Table 10.1).

Table 10.1
Firm's Use of electronic mail (Establishment Weighted)

	YES	**NO**
	(percentage of establishments)	
USE e-mail	69	31
USE Internet	70	30

The purposes for which firms use the Internet are provided in Table 10.2. The vast majority of firms (89%) use the Internet as a browsing facility, that is, they perform searches on the World Wide Web. Advertising and marketing of a firm's goods and services is also important with 57% of establishment using it for this purpose. In addition, two out of every five firms use the Internet to sell their products. A similar number use it to purchase goods and services as well.

Table 10.2
Purposes for Firm's Use of the Internet (Establishment Weighted)

PURPOSE	**YES**	**NO**
	(percentage of establishments)	
a) searching on the World Wide Web	89	11
b) selling your goods and services	39	61
c) advertising/marketing your goods and services	57	43
d) purchasing goods and services	40	60
e) secure electronic transactions	27	73
f) sharing R&D	16	84
g) other	9	91

Fifty-seven percent of firms indicate that they have established a "home page" on the World Wide Web. This is also the same percentage as those that advertise on the World Wide Web.

Table 10.3
Firms with Home pages on the World Wide Web (Establishment Weighted)

	YES	**NO**
	(percentage of establishments)	
Home Page	57	43

Electronic Data Interchange (EDI) is a standard for automated exchange of business documents. It is used by purchasers and suppliers to exchange digital paperwork such as

purchase orders and invoices, and to perform the electronic transfer of funds. One-third of establishments are in firms that use EDI (Table 10.4).

Table 10.4
Firm's Use of Electronic Data Interchange (EDI) (Establishment Weighted)

	YES	**NO**
	(percentage of establishments)	
Use EDI	33	67

Of those firms that use EDI, the majority use the Internet as their EDI communication network while one-third use a Value Added Network. Some firms use more than one communication network for their EDI transactions.

Table 10.5
Communication Network Set-ups used by Firms for EDI (Establishment Weighted)

NETWORK SET-UP	**YES**	**NO**
	(percentage of establishments)	
a) Value Added Network (VAN)	33	67
b) Internet	73	27
c) Extranet	20	80

Appendix A
Industry Stratification

The following table contains the industry strata that were used to select the sample. They are based on the 1980 Standard Industrial Classification (SIC) codes. Because of cost constraints, a mixture of 2-digit and 3-digit SIC codes were used.

Table A.1
Industry strata used for sample selection for the survey

1980 SIC-E	**Description**
11	Beverage Industries
12	Tobacco Product Industries
15	Rubber Products Industries
16	Plastic Products Industries
17	Leather and Allied Products Industries
18	Primary Textile Industries
19	Textile Products Industries
24	Clothing Industries
25	Wood Industries
26	Furniture and Fixture Industries
27	Paper and Allied Products Industries
28	Printing, Publishing and Allied Industries
29	Primary Metal Industries
30	Fabricated Metal Products Industries (except Machinery and Transportation Equipment)
31	Machinery Industries (except Electrical Machinery)
321	Aircraft and Aircraft Parts Industries
323	Motor Vehicle Industries
324	Truck and Bus Body and Trailer Industries
325	Motor Vehicle Parts and Accessories Industries
326	Railroad Rolling Stock Industries
327	Shipbuilding and Repair Industry
328	Boatbuilding and Repair industry
329	Other Transportation Equipment Industries
331	Small Electrical Appliance Industry
332	Major Appliance Industry (Electric and Non-Electric)
333	Electric Lighting Industries
334	Record Player, Radio and Television Receiver Industry
335	Communication and Other Electronic Equipment Industries
336	Office, Store and Business Machine Industries
337	Electrical Industrial Equipment Industries
338	Communications and Energy Wire and Cable Industry
339	Other Electrical Products Industries
35	Non-Metallic Mineral Products Industries
36	Refined Petroleum and Coal Products Industries
371	Industrial Chemicals Industries (not elsewhere classified)
372	Agricultural Chemical Industries
373	Plastic and Synthetic Resin Industry

374	Pharmaceutical and Medicine Industry
375	Paint and Varnish Industry
376	Soap and Cleaning Compounds Industry
377	Total Preparations Industry
379	Other Chemical Products Industries
39	Other Manufacturing Products Industries

Appendix B
Survey Questionnaire and Standard Errors

This appendix provides a copy of the questionnaire used in the survey. The standard errors are also included for each data cell in the questionnaire.

Section A
General Questions

A1. Please indicate the geographic region of the head office of your controlling firm.

Canada	0.7
U.S.A.	0.6
Europe	0.3
Pacific Rim	0.2
Other foreign	0.1

A2. Please indicate the average number of employees working in your plant.

Less than 50	1.1
50 to 99	0.9
100 to 249	0.6
250 or more	0.4

A3. Please indicate in which of the following markets your plant's primary product is sold.

Canadian markets	0.8
U.S. markets	1.4
European markets	0.7
Pacific Rim markets	0.5
Other foreign markets	0.6

A4. Please indicate how many firms (both domestic and foreign owned) offer products directly competing with your plant's primary product.

None	0.7
1 to 5	1.1
6 to 20	1.3
Over 20	1.4

A5. Please rate the importance of the following factors in your firm's business strategy.

	IMPORTANCE				
	low				high
	1	2	3	4	5
Products and Marketing					
a) Developing new products	1.1	1.0	1.1	1.2	1.2
b) Entering new markets	0.9	0.8	1.2	1.3	1.3

Technology					
c) Reducing manufacturing costs	0.7	0.6	1.0	1.2	1.4
d) Developing new manufacturing technology	0.9	1.0	1.3	1.2	1.3
e) Using new materials	1.0	1.1	1.3	1.0	1.2
Human Resources					
f) Using teams (e.g., cross functional, quality improvement)	1.1	0.9	1.2	1.2	1.2
g) Ongoing technical training	0.9	0.9	1.3	1.3	1.2

Section B
Advanced Technologies

B1. Please indicate whether you are currently using, plan to use (within two years), or have no plans to use the following advanced technologies in your plant.

TECHNOLOGIES	In Use	Plan to Use	No Plans
Design and Engineering			
a) Computer-Aided Design/Engineering (CAD/CAE)	1.4	0.9	1.4
b) Computer-Aided Design/Manufacturing (CAD/CAM)	1.4	1.0	1.4
c) Modelling or simulation technologies	1.1	1.0	1.3
d) Electronic exchange of CAD files	1.4	1.0	1.4
Processing, Fabrication and Assembly			
a) Flexible Manufacturing Cells or Systems (FMC/FMS)	1.0	0.9	1.2
b) Programmable Logic Control (PLC) machines or processes	1.4	0.9	1.4
c) Lasers used in materials processing (including surface modification)	0.7	0.9	1.1
d) Robots with sensing capabilities	0.7	0.7	0.9
e) Robots without sensing capabilities	0.6	0.6	0.8
f) Rapid Prototyping Systems (RPS)	0.6	0.8	1.0
g) High speed machining	1.1	1.0	1.4
h) Near net shape technologies	0.8	0.7	1.0
Automated Material Handling			
a) Part identification for manufacturing automation (e.g. bar coding)	1.0	1.1	1.3
b) Automated Storage and Retrieval System (AS/RS)	0.6	0.8	0.9
Inspection			
a) Automated vision-based systems used for inspection/testing of inputs and/or final products	0.8	0.8	1.1
b) Other automated sensor-based systems used for inspection/testing of inputs and/or final products	0.9	0.8	1.1

Network Communications			
a) Local area network (LAN) for engineering and/or production	1.3	1.1	1.4
b) Company-wide computer networks (including Intranet and WAN)	1.3	1.2	1.4
c) Inter-company computer networks (including Extranet and EDI)	1.2	1.2	1.4
Integration and Control			
a) Manufacturing Resource Planning (MRP II)/Enterprise Resource Planning (ERP)	1.0	1.1	1.3
b) Computers used for control on the factory floor	1.3	1.2	1.4
c) Computer-Integrated Manufacturing (CIM)	1.1	1.1	1.3
d) Supervisory Control and Data Acquisition (SCADA)	0.9	1.1	1.3
e) Use of inspection data in manufacturing control	1.2	1.1	1.4
f) Digital, remote controlled process plant control (e.g. Fieldbus)	0.5	0.8	0.9
g) Knowledge-based software	1.1	1.0	1.3

B2. Over the last three years, what percentage of your plant's investment in machinery and equipment was spent on advanced equipment (as listed in question B1 above)?

Zero percent	1.3
1% to 25%	1.4
26% to 50%	0.9
51% to 75%	0.8
76% to 100%	0.8

B3. How would you compare your plant's production technology with that of your most significant competitors?

COMPETITORS	less advanced				more advanced	
	1	2	3	4	5	N/A
a) Other producers in Canada	0.6	1.0	1.4	1.2	0.9	0.7
b) Producers in the U.S.	0.8	1.0	1.3	1.1	0.7	1.2

B4. For what purposes does your plant use communications networks (Internet, Intranet, Extranet, VAN)? Check all that apply.

	YES	**NO**	**NA**
a) ordering products	1.3	1.4	1.3
b) tracking production flow	1.1	1.4	1.3
c) on-line maintenance	0.8	1.4	1.4
d) tracking sales and inventory	1.3	1.4	1.3
e) tracking distribution	1.0	1.4	1.4
f) sharing technology information	1.3	1.4	1.3
g) accounting and financing	1.4	1.4	1.3

h) human resources purposes	1.2	1.4	1.3
i) management planning system	1.2	1.4	1.3
j) marketing/customer information	1.4	1.3	1.3
k) financial transactions (e.g., banking)	1.3	1.4	1.3
l) consumer information	1.4	1.4	1.3
m) production status information	1.2	1.4	1.3
n) general reference (e.g., phone numbers)	1.4	1.3	1.3
o) other	0.5	1.3	1.4

Section C
Business Practices

C1. Are the following practices or techniques regularly used in your plant?

	YES	**NO**	**NA**
a) cross-functional design teams	1.3	1.4	1.3
b) concurrent engineering	1.3	1.4	1.3
c) continuous improvement (including TQM)	1.4	1.4	1.2
d) benchmarking	1.3	1.4	1.2
e) plant certification (e.g., ISO9000)	1.3	1.4	1.2
f) certification of suppliers	1.3	1.4	1.2
g) just-in-time inventory control	1.4	1.4	1.2
h) statistical process control	1.1	1.4	1.2
i) electronic work order management	1.3	1.4	1.2
j) process simulation	0.8	1.4	1.3
k) distribution resource planning	0.8	1.4	1.3
l) quality function deployment	1.2	1.4	1.2

Section D
Development and Implementation of Advanced Technologies

D1. Have any advanced technologies (as listed in question B1) been introduced into your plant?

___ Yes ___ No

If NO, then please go to question G1.

D2. If YES, by which method does your plant introduce advanced technologies?

	YES	NO
a) by purchasing off-the-shelf equipment	1.2	1.2
b) by licensing new technology	1.2	1.2
c) by customizing or significantly modifying existing technology	1.6	1.6
d) by developing brand new advanced technologies (either alone or in conjunction with others)	1.4	1.4

D3. Please indicate which of the following sources play an important role in providing ideas for the adoption of advanced technology in your plant. Please check all that apply.

	YES	NO	NA
INTERNAL to your firm			
a) research	1.6	1.6	1.1
b) experimental development	1.6	1.6	1.1
c) production engineering	1.6	1.6	1.0
d) corporate head office	1.6	1.6	1.2
e) related plants	1.4	1.6	1.4
f) technology watch program	1.4	1.6	1.2
g) production staff	1.6	1.5	0.9
h) design staff	1.6	1.5	1.0
i) sales and marketing	1.6	1.6	1.0
j) other	0.4	1.6	1.6
EXTERNAL to your firm			
k) trade fairs, conferences, publications	1.4	1.3	0.8
l) patents	1.1	1.4	1.1
m) consultants/service firms	1.6	1.6	0.9
n) suppliers	1.6	1.5	0.7
o) customers	1.5	1.4	0.8
p) related firms	1.6	1.6	1.0
q) universities	1.1	1.4	1.1
r) governments, institutes, associations	1.2	1.5	1.0
s) other producers in your industry	1.6	1.6	1.0
t) other	0.1	1.6	1.6

Section E
Skill Requirements

E1. Have your plant employees received any training pertaining to the adoption of advanced technology in the last three years?

1.5% Yes 1.5% No

If NO, then please go to question E3.

E2. If YES, please indicate in which of the following areas training was provided. Please include both on-site and off-site training. Check all that apply.

	YES	**NO**	**NA**
a) basic literacy/numeracy	1.7	1.8	1.0
b) computer literacy	1.4	1.4	0.1
c) technical skills	1.2	1.2	0.5
d) quality control skills	1.6	1.6	0.4
e) safety skills	1.4	1.4	0.5
f) other	0.9	1.9	1.9

E3. In the operation of advanced technology, for which types of skilled personnel have you experienced shortages at your plant during the past year? Please check all that apply.

	YES	**NO**	**NA**
Professionals with university degree:			
a) mechanical/aerospace	1.1	1.6	1.6
b) electronic/computer	1.2	1.6	1.5
c) chemical/chemical process	0.5	1.6	1.6
d) industrial/manufacturing process	1.4	1.5	1.6
e) science professionals	0.6	1.6	1.6
f) computer scientists	0.8	1.6	1.6
Management:			
g) production management	1.3	1.5	1.0
h) design management	1.3	1.6	1.2
i) human resources management	0.9	1.4	1.2
Technicians/Technologists (Community College/CEGEP):			
j) electronics/computer hardware	1.0	1.6	1.5
k) science technicians	0.5	1.6	1.6
l) engineering science technicians	1.0	1.6	1.5
m) computer programmers	1.2	1.6	1.4
n) communications network administration	0.9	1.6	1.5
o) computer aided design	1.3	1.6	1.3
p) instrumentation	0.7	1.6	1.5
Skilled Trades:			
q) machinist (including tool, die mould)	1.5	1.6	1.2
r) machine operator	1.6	1.6	1.1
s) electrical equipment operator	0.8	1.6	1.5
t) process plant operator	1.0	1.6	1.4
Other:			
u) other	0.8	1.3	1.5

If you are NOT experiencing any skill shortages at your plant, then please go to question

F1.

E4. Have you taken any steps at your plant to deal with these shortages?

1.6 % Yes 1.6% No

If NO, then please go to question F1.

E5. If YES, what steps have you taken? Check all that apply.

	YES	NO	NA
a) provided training	1.8	1.8	0.2
b) improved wages and benefits	2.1	2.0	0.8
c) established stronger links with educational institutions (e.g., research scholarships, hired summer students)	2.4	2.4	1.1
d) searched for skilled personnel	1.2	1.2	0.1
e) other	0.8	2.3	2.3

E6. In order to deal with these skill shortages, did you search for personnel

	YES	NO
a) within your region	0.8	0.8
b) outside your region (in Canada)	2.3	2.3
c) outside Canada	1.2	1.2

Section F
Results of Adoption

F1. Rate the importance of the following effects related to the adoption of advanced technology by your plant.

	IMPORTANCE					
EFFECTS	low				high	don't know
	1	2	3	4	5	
Improvement in productivity due to						
a) reduced labour requirements per unit of output	1.1	0.8	1.3	1.5	1.5	0.8
b) reduced material consumption per unit of output	1.3	1.1	1.4	1.4	1.2	0.8
c) reduced capital requirements per unit of output	1.3	1.0	1.4	1.3	1.3	0.9
d) reduced set-up time	1.1	0.8	1.3	1.5	1.5	0.7
e) reduced rejection rate	1.0	0.6	1.3	1.4	1.6	0.8
Product improvement						
f) new product features	1.2	1.0	1.4	1.3	1.3	1.0
g) reduced time to market	1.2	0.8	1.4	1.4	1.4	0.8
h) improvement in product quality	0.9	0.5	1.2	1.5	1.6	0.7

Plant organization changes						
i) increased production flexibility	0.9	0.8	1.3	1.5	1.5	0.9
j) increased skill requirements	1.0	0.8	1.5	1.4	1.3	0.9
Plant efficiencies						
k) increased equipment utilization rate	1.1	0.6	1.3	1.6	1.4	0.8
Market performance						
l) increased market share	0.9	0.8	1.3	1.5	1.4	1.0
m) increased profitability	0.7	0.7	1.2	1.4	1.6	0.9
Other						
n) other	0.1	0.3	0.2	0.1	0.4	0.6

Section G
Obstacles to Adoption

G1. Rate the importance of the following factors as obstacles to advanced technology adoption by your plant.

	IMPORTANCE				
OBSTACLES	low				high
	1	2	3	4	5
Lack of financial justification due to					
a) small market size	1.2	1.0	1.3	1.1	1.0
b) high cost of equipment	0.9	0.5	1.2	1.4	1.3
c) cost of capital	0.9	0.8	1.2	1.3	1.2
d) costs to develop software	1.3	0.9	1.2	1.1	1.2
e) cost of integration of new technology	1.1	0.9	1.3	1.2	1.2
Human resources					
f) shortage of skills	1.2	0.9	1.3	1.2	1.1
g) worker resistance	1.4	1.2	1.2	1.0	0.7
Management					
h) resistance to introduction of new technology	1.4	1.2	1.2	0.9	0.6
i) inability to evaluate new technology	1.4	1.1	1.3	1.0	0.7
External support services					
j) lack of technical support or service (from consultants or vendors)	1.3	1.1	1.3	0.9	0.8
Other					
k) other	0.5	0.1	0.3	0.2	0.5

Section H
Research and Development Activity

H1. Please indicate whether or not your firm has been involved in any of the following R&D activities over the last three years. Please exclude quality control, routine testing, style changes, minor adaptations and market research.

	YES	NO
a) does your firm do R&D in-house?	1.4	1.4
b) does your firm do R&D jointly with another firm?	1.1	1.1
c) does your firm contract out R&D?	0.9	0.9

If you answered NO to all three parts of question H1, then please go to question I1.

H2. Please indicate the frequency of R&D in your firm.

	YES	NO
a) R&D are performed on an ongoing basis	1.9	1.9
b) R&D are performed on an occasional basis	1.9	1.9

H3. What is your firm's R&D program responsible for?

	YES	NO
a) creating original products	1.7	1.7
b) creating original production equipment or new process technology	1.8	1.8
c) substantially adapting technology acquired from others	1.8	1.8
d) introducing off-the-shelf equipment or process technology	1.8	1.8

Section I
Electronic Communication

I1. Does your firm use e-mail?

1.4 % Yes 1.4 % No

I2. Does your firm use Internet?

1.3 % Yes 1.3 % No

If NO, then please go to question I5.

I3. If YES, please indicate for what purposes your firm uses the Internet.

	YES	NO
a) searching on the World Wide Web	1.0	1.0
b) selling your goods and services	1.7	1.7
c) advertising/marketing your goods and services	1.7	1.7
d) purchasing goods and services	1.7	1.7

e) secure electronic transactions	1.4	1.4
f) sharing research and development (R&D)	1.1	1.1
g) other	0.9	0.9

I4. Does your firm have a home page on the World Wide Web?

1.7 % Yes 1.7 % No

I5. Does your firm use electronic data interchange (EDI)?

1.3 % Yes 1.3 % No

If NO, then please go to the end of the questionnaire.

I6. If YES, what type of communication network setup does your firm use for EDI? Check all that apply.

	YES	**NO**
a) Value Added Network (VAN)	2.0	2.0
b) Internet	1.8	1.8
c) Extranet	1.7	1.7

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