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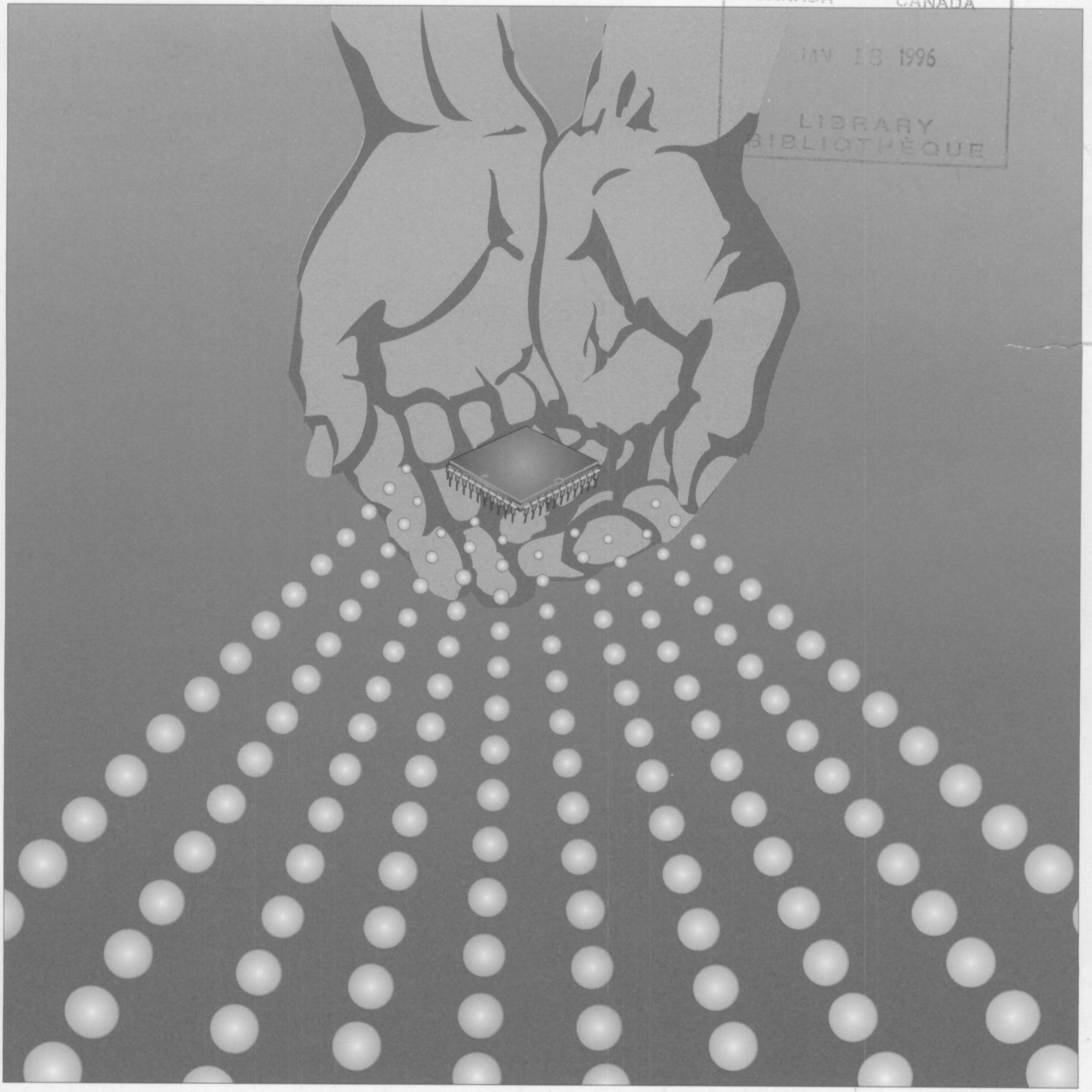
Benefits and Problems Associated with Technology Adoption in Canadian Manufacturing

Survey of Innovation and Advanced Technology 1993

John Baldwin, David Sabourin, Mohammed Rafiquzzaman



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Survey of Innovation and Advanced Technology 1993

John Baldwin, David Sabourin, Mohammed Rafiquzzaman

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Preface

The factors that determine a country's economic growth are of concern to those attempting to understand why some countries forge ahead and why others lag behind. This problem has been addressed in different ways by the economics profession.

Some have focused on the amount of capital accumulation taking place and its relationship to the savings rate. In this world, technical progress was normally treated as exogenous. Others have argued that it is the development of new products and processes that is key to changes in productivity and that productivity gains are endogenous. Productivity is seen to be dependent on the investment that is made in innovative activities like research and development.

Statistical agencies provide the data that are used to study the processes of economic growth. One often-used data series is the amount of investment. When cumulated, investment flows become a nation's capital stock. On the one hand, they are used to estimate production functions and the source of productivity gains. On the other hand, they are used to explain cross-country differences in efficiency. Cross-country comparisons of efficiency, in this context, focus on differences in these aggregates. They ask whether differences in productivity are partially caused by differences in the amount of capital that workers in different countries have available to them.

The most commonly-used capital series aggregates investments of different types into a measure of the dollar value of capital. While it is recognized that some types of investments may be more important than others, rarely is any attempt made to distinguish the types of investment in any detail.

An alternative is to examine the nature of the capital stock in more detail, to investigate the underlying data from a micro perspective. This approach stresses that it is not the size of the capital stock that matters so much as its composition. Recent work on innovation and technology surveys in both Canada and elsewhere are premised on the assumption that the study of growth would be greatly facilitated by micro-economic data on technology use.

The collection of this data requires a definition of what is meant by advanced technologies, surveys of the types of technologies used, an enumeration of the differences in patterns of technological use across regions and industries, investigations of the connection between advanced technology use and the innovation process, the relationship between technology use and the efficiency of Canada's manufacturing sector relative to that of our major trading partners.

This study is one of several that Statistics Canada has devoted to improving our understanding of the state of advanced technology use in the Canadian manufacturing sector. The first study (Technology Adoption in Canadian Manufacturing, Catalogue no. 88-512) deals with the incidence of advanced technology use in the Canadian manufacturing sector. It examines data on the percentage of establishments that use new advanced technologies—technology incidence. Its focus is on differences in usage across functional technology categories—such as design and engineering, and fabrication and assembly—for different industries and regions.

The present publication extends the basic data on the incidence of technology use in several ways. First, it provides characteristics such as intensity of use (as opposed to incidence of use), the magnitude of investments in advanced technologies, the length of time that particular technologies have been in use, and the projected growth rates. Second, it provides information on the nature of the adoption process that affects these usage rates—the sources of information used to obtain new ideas on technologies, the benefits that accrue from technology usage, and the factors impeding the introduction of new technologies. Finally, it provides data that can be used to compare the nature of technology use by Canadian manufacturers that are technologically more-advanced than their foreign rivals to those that are less-advanced than their foreign rivals.

Other studies are forthcoming that will examine additional facets of technology use. Baldwin, Diverty, and Sabourin (1995) investigate the extent to which technology use is associated with superior plant performance—a critical issue in evaluating the effects of technology use on growth. Another study will examine the connection between innovation and technology use.

I believe that these studies will contribute to an informed discussion of the state of technology use in the manufacturing sector, its contribution to growth, and the problems facing this sector.

Stewart Wells
Assistant Chief Statistician
National Accounts and Analytical Studies

Highlights

1) Technological advance is essential for the economic growth of both firms and nations. It is also a key factor in determining the 'competitiveness' of a firm. With increasing globalization of markets, firms are forced to be more competitive. They are expected to produce 'high-quality', customized goods quickly and at a reasonable cost. To do so, they must rely on the use of advanced manufacturing technologies.

2) Many of the advanced manufacturing technologies rely on the integration of computers into the production process. Computers have revolutionized different parts of the production process. They are used in all four functional technology areas—in pre-production *(design and engineering)*, in production (*fabrication and assembly*), in the handling of components and products (*automated material handling*), and in the communication of information both within and outside of the firm (*inspection and communications*). These technologies have been introduced as an integral part of the innovation process that generates new products and new processes. Establishments that use these technologies have been gaining market share at the expense of non-technology users. They also pay higher wages and have a higher labour productivity.

3) Technological adoption is a multi-layered process. It involves the acquisition of information on the type of technologies needed, and an evaluation of the benefits and costs associated with new technologies. The outcome of this process determines the intensity of technology use, the rapidity of diffusion of new technologies into the industrial system and, ultimately, the competitiveness of Canadian manufacturing firms.

4) Ideas for the adoption of technology come from both inside and outside the firm. The pattern of these sources reveals the areas within the firm that are responsible for making a firm technologically competitive and the nature of external information networks that bring new ideas into the firm.

5) Considerable stress has been given to the importance of research facilities as a critical part of the innovation process; however, it is not the *research* department that is relied on most for information about new technologies. Rather it is the *production engineering* department that takes the lead in providing key ideas for the adoption of new advanced technologies. Another key source of information comes from the shop floor—from the *operating staff.*

6) An external network also provides information about new technologies to Canadian firms. External information comes primarily from sources that are involved in the commercial provision of information—ranging from *supplier firms*, *conferences* and *trade fairs*, to *scientific* and *industry publications.* In addition, interfirm cooperation, especially between *related companies*, is an important source of information that facilitates the diffusion process. The transmission of knowledge via subsidiary relationships receives just as much emphasis as commercial sources of information.

7) Establishments adopt advanced technologies in the expectation of realizing benefits. Some benefits are *tangible*, that is, they are estimable prior to investment in the sense that they are both quantifiable and relatively easy to predict. Others are *intangible*, that is, they are more difficult to quantify or to predict. The decision process behind technology adoption is particularly difficult when intangible benefits loom large in the overall assessment procedure.

8) *Improvements in productivity* is the most important benefit associated with adopting advanced technology. About three-quarters of the shipments coming from technology users originated in establishments registering an *improvement in productivity.* Productivity can be increased by reducing labour, materials, energy, or capital inputs for a given level of output. *Reductions in labour requirements* is the most important of these methods—especially in fabrication and assembly—and the second most important effect of technology adoption. Nevertheless, capital savings, via an *increased equipment utilization rate*, lags not far behind *decreased labour requirements.* All three—*improvements in productivity, reductions in labour requirements*, and *increased equipment utilization rate*—are tangible effects.

9) *Improvements in product quality, increased skill requirements*, and *reductions in the product rejection rate* are equally as important. These are intangible effects. They are more difficult to predict. Total benefits of technology adoption are, therefore, very

much determined by difficult-to-measure intangible effects.

10) Of the various impediments to technology adoption that firms face, general out-of-pocket costs, which can be readily assessed before adoption, are the most important. However, a number of other costs that are less easy to forecast are also seen to be relatively important impediments. Costs associated with technology acquisition are important. So too are costs associated with software development. Training costs associated with skill development are seen to be a barrier, as are management attitudes, and the need for organizational change. A number of these areas involve costs that are difficult to quantify in advance of the technology acquisition decision.

11) Differences in information flows, benefits, and impediments cause advanced technologies to be adopted at different rates in the various functional areas—in design and engineering, fabrication and assembly, automated material handling, and inspection and communications. Concomitantly, the characteristics of advanced technologies vary across functional technology groups. They differ with respect to:

a) the incidence of use or the frequency of adoption, which is defined as the percentage of establishments that have adopted a technology;
b) the intensity of use, which is measured by the percentage of total investment of a plant, within a functional class, that is accounted for by advanced technologies;
c) age, which is defined as the length of time in use of a technology within establishments; and,
d) amount of investment per plant.

Together these characteristics determine the level of Canada's technological competitiveness.

12) Advanced design and engineering technologies are characterized by a high incidence of adoption (63%), although the intensity of use is relatively low (39%). Adoption of these technologies require only modest amounts of investment. Some 64% of all shipments in manufacturing come from plants investing less than $1 million in these technologies.

13) Inspection and communications technologies also have a high adoption incidence (73%), with a low intensity of investment (37%). They require a relatively low per-plant investment. Some 51% of shipments come from plants investing less than $1 million in these technologies. Vital to a firm's operations—both in its conventional and advanced forms—and requiring relatively little investment, communications technologies are expected to experience high growth.

14) Fabrication and assembly, by way of contrast, has only a moderate incidence of adoption at 46%. It too has a moderate intensity of use. Only 52% of investment in fabrication and assembly is devoted to the advanced technologies investigated in this study. However, the investment per plant required for these advanced technologies is high. Some 57% of shipments come from plants investing more than $1 million in these technologies. These technologies have penetrated the population at a slower pace than either design and engineering, or inspection and communications technologies, partially because of the higher investment levels required.

15) Automated material handling has a low incidence of adoption (16%) with a moderate intensity of investment (51%). Per-plant investment is also large. Some 65% of shipments come from plants investing more than $1 million in these technologies. The incidence of adoption of these technologies is low, since they are industry-specific technologies requiring appreciable amounts of investment.

16) There is considerable variation in the length of time that individual technologies have been in use in Canadian manufacturing plants. Automated sensor-based inspection technologies, both for incoming material and final products, have been in use the longest—for 12 and 10 years, respectively. Programmable controllers and computers used in control of factories are mature communications-based technologies, having been used for an average of nine years. CAD/CAM design and engineering technologies have been in use about eight years. The technology in fabrication and assembly that has been in use longest is numerically controlled machines—about 10 years. By way of contrast, the technologies that have been used for a shorter time are digital representation of CAD output (four years), materials-working lasers (five years), local area networks (five years), and inter-company computer networks (four years).

17) The length of the adoption lag for advanced technology users—the period between a firm's becoming aware of a new technology and its implementing the technology on the shop floor—is an important determinant of a country's competitive-

ness. For most manufacturing plants using advanced technologies, this lag is under 3 years. The adoption lag is similar across technologies and size classes.

18) Technology strategy is a fundamental determinant of the growth of a firm, its profitability, its efficiency, and its competitiveness. It is therefore important to measure the competitiveness of Canadian manufacturing establishments relative to their foreign competitors. To do so, the survey asked Canadian manufacturing establishments to rank themselves relative to their foreign competitors with regards to their production technologies. About 40% of plant managers rated themselves equal to their competitors. The rest of the population was about equally split between those who felt they were more-advanced and those who felt they were less-advanced than their foreign competitors. While there are some plants that consider themselves to be behind their foreign competitors, they are balanced by those that feel they are ahead.

19) Differences between establishments that are more- and less-advanced than their foreign competitors serve to describe the nature of the 'catch-up' that the latter need to do. More-advanced establishments are more likely to use advanced technologies, to use them more intensively, to spend more on them, to be quicker to adopt them, and to reap greater benefits from adopting them.

20) Incidence of technology use is higher for technologically more-advanced establishments. Those establishments that are more-advanced in all functional areas use, on average, twice as many technologies as do the less-advanced ones—9.4 technologies for the more-advanced compared to only 4.5 for the less-advanced. Similar differences exist for establishments that consider themselves more advanced in individual functional categories. The more-advanced group, based on competitive evaluations specific to design and engineering, use 2.1 design and engineering technologies, on average. The less-advanced group use only 1.3. The more-advanced group in inspection and communications use 5.8 technologies, on average; the less-advanced group only 3.1 technologies, on average.

21) Technologically more-advanced establishments are more intensive users of advanced technology. They put 50% of their design and engineering, and inspection and communications investments into advanced technologies compared to 27% and 33%, respectively, for the less-advanced group. In fabrication and assembly technologies, the more-advanced devote 75% to advanced technologies, while the less-advanced invest only 43%.

22) Greater intensity of investment is accompanied by larger per-plant investment in advanced technology. Between 60% and 80% of the more-advanced establishments invest $1 million or more in each of design and engineering, inspection and communications, and fabrication and assembly—about 60% each for design and engineering, and inspection and communications technologies; 82% for fabrication and assembly. Less-advanced establishments invest relatively less. Only 5% invest $1 million or more in design and engineering technologies; 19% invest a similar amount in inspection and communications; and 60% invest this much in fabrication and assembly technologies.

23) More-advanced establishments are more likely to have a shorter adoption lag. Almost half of the more-advanced establishments adopt design and engineering, and fabrication and assembly technologies within a year. By contrast, less than 20% of the less-advanced group do so.

24) More-advanced technology users not only have a greater incidence and intensity of use, they also reap greater benefits. Generally, a larger percentage of the more-advanced group that are using a particular technology enjoys a particular benefit than do their less-advanced counterparts using the same technology. Most of the more-advanced technology users (82%) reported *increases in productivity* compared to only half of the less-advanced ones, a difference of 32 percentage points. This is mainly due to substantial differences in those reporting that they experienced *reductions in labour requirements* (a difference of 23 percentage points) and *increased equipment utilization rates* (a difference of 41 percentage points) between the two groups, with the more-advanced reporting the highest benefit. Other large differences can be found for *increased skill requirements, improvements in product flexibility, increased capital requirements,* and *reduced set-up time.*

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1. Introduction

Innovation is the key to business success. The development of new technologies is an important part of any innovative strategy. Baldwin et al. (1994) found that the strategy most closely associated with firm growth and profitability is the degree to which firms stress the development and application of new technologies. While other strategies are complementary to an innovative strategy (Baldwin and Johnson, 1995), introducing new products and new processes is the essential element behind success in a world where new products and processes set the competitive agenda. When establishments that adopt new advanced technologies are compared to those who do not, dramatic differences emerge (Baldwin, Diverty, and Sabourin, 1995). Technology users gain market share at the expense of non-users. They pay higher wages and have higher labour productivity than do non-users. More importantly, their productivity gains and wage growth have been *increasing* faster over the last decade than for non-users.

Interest in innovation often focuses on the research and development process. While research and development is an important part of the innovative regime of any company, it is only part of it. New products are often accompanied by new production processes. These new processes usually embed new technologies in them. Technology development is not restricted solely or even mainly to research and development departments. It is the production or engineering departments that are primarily responsible for the incorporation of new technologies into the production process. These new technologies integrate machines and computer systems and have revolutionized manufacturing processes in the last twenty years.

Computers have penetrated all facets of the production process. They are also behind many of the new advanced technologies that have been adopted in the manufacturing sector. Computers have revolutionized design and engineering as CAD/CAM technologies have allowed designs to be completed more quickly and the design function to be integrated more closely with the manufacturing process to permit new products to be launched even faster. Computers are essential to control devices used in the fabrication and assembly process. New machines, like robots, depend on micro-electronic components. Inspection and communications depend on computer local area network (LAN) systems for the transfer of knowledge from one division to another. Computers guide the automated material handling systems that are essential in many factories.

This publication investigates various aspects of advanced technology use in the Canadian manufacturing sector. It is the second of two publications on advanced technology in Canadian manufacturing. The first publication—*Technology Adoption in Canadian Manufacturing*—deals solely with the usage of advanced technologies in this sector (Baldwin and Sabourin, 1995). It measures the incidence of adoption—the percentage of establishments that use new advanced technologies—and describes differences in use across 22 technologies. It describes the trend in adoption rates and reports differences in patterns of use by geographical regions and industries. Finally, it compares usage across functional technology categories. These functional categories are design and engineering, fabrication and assembly, automated material handling, inspection and communications, manufacturing information systems and integration and control. The first four categories correspond to different stages in the production process; the latter two are broad categories that span or affect many stages in the production process.

This publication extends the analysis in three important directions.

First, it focuses on additional characteristics of the importance of advanced technologies and examines the benefits and problems of adopting them. It investigates these issues at the functional technology level for design and engineering, fabrication and assembly, automated material handling, and inspection and communications. The purpose is to provide a more complete picture of usage patterns than incidence of adoption rates alone can give.

Second, this study moves beyond rates of technology use and investigates the determinants of technology adoption. It investigates the diffusion pattern associated with the use of advanced manufacturing technologies in Canada and the length of the time lag between a company's first becoming aware of a new technology and the adoption of that technology. It examines the determinants of the diffusion lag—both the benefits that Canadian establishments perceive to be associated with advanced technology usage and the problems associated with the adoption of these technologies.

Third, the study provides an international context that can be used to evaluate the rates of technology use of Canadian establishments. It divides establishments into those which are more- and those which are less-advanced than their foreign competitors and tabulates the usage rates for each group. This provides benchmarks for the evaluation of the competitiveness of Canadian manufacturing establishments with respect to technology usage.

2. The Survey

2.1 General Background

The data on technology use presented here are taken from the 1993 Survey of Innovation and Advanced Technology. Technology issues make up only one part of the survey. The survey as a whole deals with the nature of the research and development process, general innovative behaviour, the characteristics of a specific recent major innovation, the intensity of technology use, the benefits and problems of adopting technologies, and finally the general characteristics of the responding firm—ownership, export intensity, number of competitors and firm strategies.

The Innovation and Advanced Technology Survey was conducted in 1993 for manufacturing establishments and firms of all sizes. It is based on a frame of all Canadian manufacturing establishments taken from Statistics Canada's Business Register.[1]

There were eight sections on the questionnaire (see Table 1):

Section 1—*general characteristics*
Section 2—*research and development (R&D)*
Sections 3,4—*innovation*
Section 5—*intellectual property*, and
Sections 6, 7, 8—*advanced technology*

Three types of units were sampled: establishments of large firms whose head office is located elsewhere, the corresponding head offices of these firms, and small firms that have both their management and plant located in the same spot. For large firms, the first five sections were put to management in head office, the last three sections were addressed to plant managers. For small firms, all of the sections were sent to the same location.

Consequently, for large firms,[2] the head office responses on general characteristics, R&D, innovation and intellectual property, along with the responses of associated plants to the technology questions, provide a comprehensive overview of the firms' innovative and technological capabilities.

The small firms were handled somewhat differently. In order to reduce response burden, they were separated into two groups. The first group answered Sections 1, 3, 4 and 5—the general, innovation and intellectual property questions while the second group answered Sections 1, 2, 6, 7 and 8—the general, R&D, and technology questions. For certain sections, small firms were only asked selected questions in order to further reduce their response burden.

There were 1,595 head offices (answering the first five sections) sampled, 1,954 large plants (answering the last three sections) sampled, 1,088 of the first group of small firms (answering the first, third, fourth, and fifth sections) sampled, and 1,092 of the second group of small firms (answering the first, second, sixth, seventh and eighth sections) sampled, for a total of 5,729 units sampled.

Table 1
Parts of the Questionnaire Asked by Sampling Unit

Sampling Unit	Parts of Questionnaire				
	General	R&D	Innovation	Intellectual Property	Technology
Head Offices	all	all	all	all	
Small Firms(Group 1)	all		some	all	
Small Firms(Group 2)	all	all			some
Large Plants					all

Note that 'all' means the respondent was asked to answer all questions in the section while 'some' means that they were only asked to answer some of the questions.

The survey was conducted in several steps. Initially, the unit was contacted to determine who within the firm (the head office or the plant) should be sent each section. These individuals were contacted by phone to confirm their ability to answer the survey. Then the questionnaire was mailed out to the designated individuals. The questions on technology that form the subject of this report were sent primarily to the plant managers. Finally, where necessary, telephone follow-ups were performed.

The sample was randomly drawn from a manufacturing establishment population that was stratified by size (large versus small), industry and province. The response rate for the advanced technology part of the survey was 88 percent for all establishments. Small establishments had a higher response rate (93%) than large establishments (86%).

Answers to the survey are presented in this report using two different weighting strategies—shipment and establishment weights. An establishment-weighted proportion reveals the percentage of establishments in the population that have a given characteristic. A shipment-weighted proportion reveals the percentage of total shipments coming from establishments with that characteristic. Shipment weights give greater importance to large establishments. Unless otherwise stated, the results in this study are shipment-weighted. Establishment-weighted results are reported in Appendix C.

2.2 The Technology Section

The technology section of the survey consists of three main parts (see Appendix D). In the first section, data on the incidence of technology use is collected for 22 individual technologies belonging to six functional groups. The 22 technologies, grouped by functional category, are listed in Table 2.

Table 2
Advanced Technologies by Functional Group

Functional Group	*Advanced Technology*
Design and Engineering	Computer-aided design and engineering (CAD/CAE) CAD output to control manufacturing machines (CAD/CAM) Digital representation of CAD output
Fabrication and Assembly	Flexible manufacturing cells/systems (FMC/FMS) Numerically controlled (NC) and computer numerically controlled (CNC) machines Materials working lasers Pick and place robots Other robots
Automated Material Handling Systems	Automated storage/retrieval systems (AS/RS) Automated guided vehicle systems (AGVS)
Inspection and Communications	Automatic inspection equipment for incoming materials Automatic inspection equipment for final products Local area network (LAN) for technical data Local area network (LAN) for factory use Inter-company computer network (ICCN) Programmable controllers Computers used for control in factories
Manufacturing Information Systems	Materials requirement planning (MRP) Manufacturing resource planning (MRP II)
Integration and Control	Computer integrated manufacturing (CIM) Supervisory control and data acquisition (SCADA) Artificial intelligence/expert systems (AI)

Questions about technology adoption (Section 6) were tabulated based on those establishments responding to some part of the technology section of the survey, i.e., they answered something in Sections 6 or 7 or 8. Those who did not answer anything in Sections 6, 7 or 8 were treated as non-respondents.

In the second section, data on investment in technology, factors causing delays to technology acquisition, benefits of technology and sources of ideas for advanced technology adoption, among others, are collected from plants using at least one technology from a particular technology group. When answers to this section are tabulated, the base used for calculating response rates for each functional category is the set of establishments who indicated in question 6 that they use at least one technology in that category (Table 3). For example, only establishments currently using a design and engineering technology are included in the tabulations done for Section 7 for the design and engineering group. This means the number of plants in the base varies across functional groups, since functional technologies are not all used by the same number of plants.

The third section dealing with technology collects information concerning impediments to technology acquisition from both current *users* and *non-users* of any advanced technology. Therefore, comparisons can be drawn between users and non-users about the nature of the impediments that each face. The base used here for calculating response rates for users is the set of establishments indicating they used at least one of the 22 advanced technologies listed in the survey; the base for non-users is the group that indicated they used none of these 22 advanced technologies.[3]

It should be noted that not all questions cover the same population. Because of the detailed nature of the survey, small establishments did not receive every question on advanced technology. Therefore, some questions can be tabulated for both large and small plants, others for large plants only. The differences in the base used and the coverage of each question are presented in Table 3.

Table 3
Tabulation Base by Survey Question

Question		Technology User		Size of Establishment	
		Yes	No	Large	Small
6	Technology Adoption	✓	✓	✓	✓
7.1	Amount of Investment	✓		✓	
7.2	Intensity of Investment	✓		✓	✓
7.3	Factors Delaying Acquisition - Foreign Sources	✓		✓	
7.4	Factors Delaying Acquisition - Canadian Sources	✓		✓	
7.5	Factors Delaying Acquisition - All Sources	✓		✓	✓
7.6	Factors Influencing Acquisition	✓		✓	✓
7.7	Technological Competitiveness Assessment	✓		✓	✓
7.8	Internal Sources of Ideas	✓		✓	
7.9	External Sources of Ideas	✓		✓	
7.10	Regional Sources	✓		✓	
7.11	Diffusion Lag	✓		✓	✓
7.12	Benefits of Acquisition	✓		✓	✓
7.13	Upgrading Existing Technology	✓		✓	✓
8.1	Impediments to Acquisition	✓	✓	✓	✓

3. Characteristics

3.1 Introduction

The importance of advanced technology adoption depends upon the number of plants using the technologies, the intensity of technology use, the length of time the technologies have been employed, and the amount spent on these technologies.

Incidence and intensity of use capture different aspects of the extent of penetration of advanced technologies in the Canadian manufacturing sector. Incidence captures how widely a technology has come to be used across the population of business establishments. It is a measure of dispersion. Intensity, on the other hand, captures how extensively a technology is used within those establishments that have adopted the advanced technology. It measures the depth of technology used. For example, advanced technologies may be used in all plants (a high incidence) but may have only penetrated the shop floor for experimental purposes (a low intensity). Or only a few plants may use the technology (a low incidence) but in these plants, the technologies may be used everywhere on the shop floor (a high intensity).

Other measures capture characteristics that are related to the importance of technology. The age of a technology describes the youth or maturity of the technology. The amount of money invested in advanced technologies reveals the size of investments that are required. Information on the geographic source of the technologies indicate where technologies originate.

Taken together, these characteristics portray different dimensions that define the importance of advanced manufacturing technologies in Canadian manufacturing establishments. Each is dealt with in turn in the following sections.

3.2 Incidence of Advanced Technology Use

Incidence of use is the most common measure of the importance of advanced technology.[4] The incidence of adoption in four functional technology groups[5]—design and engineering, fabrication and assembly, automated material handling systems, and inspection and communications—is presented in Table 4. Incidence is measured as the percentage of shipments originating in plants that use at least one technology from a functional group. Of the various functional categories, inspection and communications technologies have the highest adoption rate. Some 73 percent of shipments originate in establishments using at least one of the technologies from this group. Design and engineering ranks next at 63 percent of shipments.

Table 4
Adoption Rates by Functional Technology Group
All Establishments (Shipment Weighted)

Functional Technology	Use
	(percentage of shipments)
Design and Engineering	62.5
Fabrication and Assembly	45.8
Automated Material Handling	16.1
Inspection and Communications	72.9

The high adoption rate for design and engineering is due to the widespread adoption of one particular technology in this functional group, computer-aided design and engineering, the individual technology with the highest adoption rate (Table 5). The high adoption rate for inspection and communications, on the other hand, is not dependent on the use of only one technology. Rather many different technologies—programmable controllers, computers used for factory control and local area networks—contribute to the overall rate.

Fabrication and assembly is ranked third with 46 percent of shipments coming from establishments using at least one advanced technology from this group (Table 4). As with inspection and communications, several technologies contribute to the overall rate for this category—flexible manufacturing systems, numerically controlled machines and pick and place robots.

Automated material handling technologies is the least-used group, with an adoption rate of only 16 percent (Table 4). Neither of the two underlying technologies (automated storage and retrieval systems, and automated guided vehicle systems) is used by many establishments. Only electrical and electronic products manufacturers use both of the material handling technologies to any extent, while manufacturers of non-metallic mineral products make significant use of automated storage/retrieval systems only.[6]

3.3 Time In Use

The length of time that technologies have been in use in establishments provides a picture of their age structure.

The length of time in use depends on several factors. The first is the maturity of the technology—how many years it has been available for purchase. The second is the average age of a plant. If plants die relatively frequently, then the time in use may be much less than the age of the technology itself. Finally, time in use depends upon the extent to which technologies are being updated. If new and improved versions of older technologies are brought to market, average time in use may be substantially less than the age of the technology. The age structure helps to explain differences in rates of technology adoption. The average length of time in use (age) is presented in Table 5. These averages need to be set against the average age of a manufacturing establishment, which is only about 13 years (Baldwin, 1995, p.19). Generally, more mature technologies have higher penetration rates than newer ones.

Some of the most mature advanced technologies are found among inspection- and communications-based technologies, the technology group with the highest adoption rate. Automated sensor-based inspection

Table 5
Use and Planned Use of Advanced Technology
All Establishments (Shipment Weighted)

Individual Technology	In Use	Plan to Use Within 2 Years	No Plans to Use	Length of Use	Ranking by 'In Use'
		(percentage of shipments)		*(years)*	
Design and Engineering					
CAD/CAE	60.8	7.4	31.8	6.6	1
CAD/CAM	21.1	10.4	68.5	8.3	10
Digital Representation of CAD Output	17.8	9.2	73.0	4.4	13
Fabrication and Assembly					
Flexible Manufacturing Cells/Systems	20.0	10.4	69.6	7.2	12
Numerically Controlled Machines	27.7	3.1	69.2	9.9	9
Materials Working Lasers	7.5	5.6	86.9	5.1	17
Pick and Place Robots	20.5	8.6	70.9	7.1	11
Other Robots	14.2	6.2	79.6	5.5	14
Automated Material Handling					
Automated Storage/Retrieval Systems	13.9	6.0	80.1	6.0	15
Automated Guided Vehicle Systems	8.7	4.3	87.0	7.0	16
Inspection and Communications					
Automatic Inspection Equipment - Inputs	31.6	8.6	59.8	11.7	8
Automatic Inspection Equipment - Outputs	38.7	8.3	53.0	9.6	6
Local Area Network for Technical Data	47.5	13.1	39.4	5.3	4
Local Area Network for Factory Use	40.3	16.8	42.9	5.3	5
Inter-Company Computer Network	33.9	20.1	46.0	3.9	7
Programmable Controllers	57.5	5.6	36.9	9.0	2
Computers Used for Control in Factories	52.7	8.9	38.4	8.7	3

equipment, both for incoming materials and final products, are the oldest with an average length of time in use of 12 years and 10 years, respectively. Programmable controllers and computers used for control in factories are mature communications-based technologies, averaging nine years in service. All three of the remaining advanced communications technologies are relatively new to the market. Local area networks, both for the exchange of technical data within design and engineering departments and for the exchange of information between different points on the factory floor, average five years in use. Inter-company computer networks have one of the lowest adoption rates in the category and are the newest with an average length of time in use of only four years.

In the fabrication and assembly technology group, numerically controlled machines have the highest adoption rate and are the oldest technologies in use in this group at 10 years. Flexible manufacturing systems and pick and place robots have been in use for an average of seven years. Of the other technologies in this group, materials working lasers and other robots have the lowest adoption rates and are relatively new technologies with an average length of time in use of only about five years.

The most mature design and engineering technology—CAD/CAM—has an average age twice that of the newest one—digital representation of CAD output. CAD/CAM has been in use for eight years compared to four years for digital representation of CAD output. Once more adoption rates are correlated with age of technology.

3.4 Investment in Advanced Technology

3.4.1 Intensity of Investment

Measures of technology incidence tell us only whether a technology is being used. To ascertain how widespread advanced technology has become within the factory, measures of intensity are required. The measure of intensity of use captures the extent to which advanced technologies are used comprehensively within the factory.

Measures of intensity of use within plants can be either input- or output-oriented. These indicators can be derived from, for example, the proportion of sales of a plant that are produced with the new equipment, or from the percentage of equipment being used to produce output that consists of advanced technology. This survey uses an input measure because of the inherent difficulty in assigning output to a particular piece of equipment in a large and complex factory. It is easier to ascertain the percentage of investment in machinery that accomplishes a specific purpose (i.e., fabrication) that consists of investment in advanced technologies. Therefore, intensity is measured here as the percentage of total investment within a functional group attributable to advanced technology. Since establishments invest in both advanced technologies and more traditional technologies, calculating the share of the total that is accounted for by advanced technologies gives a measure of the importance of advanced technology relative to all other capital investments.[7]

When weighted by shipments of the reporting establishments, half of the investment in fabrication and assembly technologies and automated material handling technologies is in advanced technologies (Table 6). For design and engineering and inspection and communications, it is lower—slightly less than 40 percent.

Establishment-weighted results show little difference from the shipment-weighted ones for fabrication and assembly as well as design and engineering. They are moderately lower for inspection and communications and are much lower for automated material handling technologies. Since weighting by shipments places more importance on large establishments, the differences in the two sets of results indicate that large establishments invest more heavily in advanced technologies than do smaller ones for automated material handling and for inspection and communications technologies. There is less of a difference between the two size classes for the other two functional groups.

It is noteworthy that the functional group with the highest incidence (inspection and communications) has the lowest intensity of use. While inspection and communications technologies are used frequently, the proportion of total investment in this type of technology that is devoted to advanced technologies is the lowest. On the other hand, fabrication and assembly, which ranked third in terms of incidence, is first when measured in terms of intensity. Thus, plants have a lower probability of investing in new advanced fabrication technologies; but if they do so, they devote a greater percentage of total fabrication investment to advanced technologies.

Table 6
Intensity of Investment in Advanced Technology by Functional Group
All Establishments (Establishment and Shipment Weighted)

Functional Group	Establishment Weighted	Shipment Weighted
	(percentage of establishments)	*(percentage of shipments)*
Design and Engineering	43.4	38.9
Fabrication and Assembly	48.3	52.4
Automated Material Handling	27.5	50.5
Inspection and Communications	28.0	37.3

3.4.2 Distribution by Expenditure Size

The size of investment expenditures on advanced technologies provides another measure of technology use. When used for comparisons across functional groups, it indicates whether certain technologies are inherently more costly. When used for comparisons within functional groups, holding other plant characteristics constant, it can be used to compare intensity of advanced technology use. The following section examines the distribution of technology investment by expenditure size group for large establishments—whether the investment requires less than $100,000, $100,000 to $1 million, $1 million to $5 million, or more than $5 million.

More than two-thirds of shipments (Table 7) come from plants investing less than $5 million in advanced technology during the period 1989 to 1991. Differences exist across functional groups. A greater proportion of establishments invest more than $5 million for fabrication and assembly (25%) than they do for design and engineering (13%) and inspection and communications (13%). Concomitantly, a smaller proportion of establishments invest less than $100,000 for fabrication and assembly technologies (14%) than they do for either design and engineering (32%) or inspection and communications technologies (24%). A similar trend holds for investments under $1 million (Figure 1).

Reasons for this difference have to do with the cost and age structure of the individual technologies belonging to the groups. Computer-aided design and engineering dominates the design and engineering group. While neither a recent nor a mature technology, it has fallen rapidly in cost as desktop computers have become available. This keeps required investment levels relatively low. For inspection and communications, the proportion of establishments reporting no investment (6%), at least not during the period 1989-1991, is at least double that of the other functional groups. This is in accordance with the earlier observation that many of these technologies are fairly mature, and thus that investments in these technologies have already taken place.

Table 7
Total Investment in Advanced Technology
Large Establishments (Shipment Weighted)

Cost Category	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Less than $100,000	32.1	14.2	13.5	24.3
$100,000 - $1 million	31.8	21.5	12.2	26.3
$1 million - $5 million	15.9	32.1	47.0	17.4
$5 million or more	13.0	25.3	18.4	13.0
Not applicable	1.5	2.4	2.3	6.0
Non-response	5.8	4.5	6.7	13.0

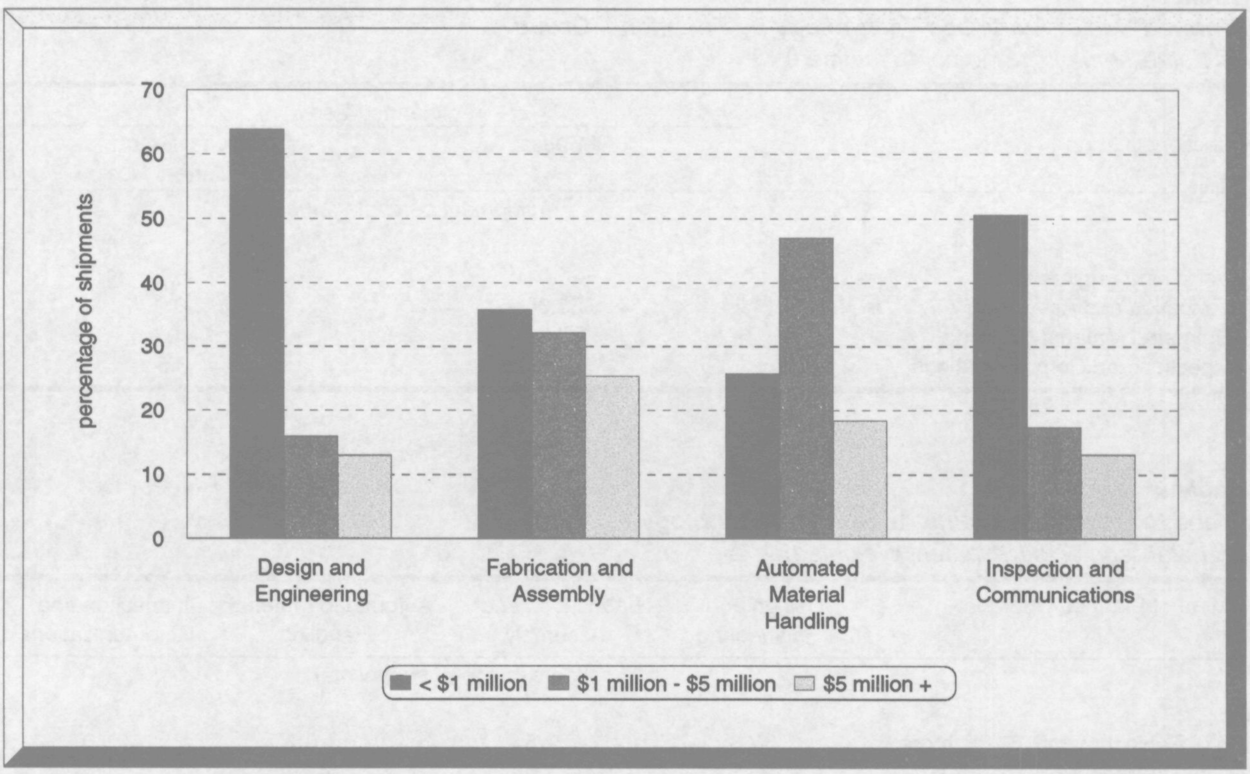
Of those establishments using automated material handling technologies, roughly half invested between $1 million and $5 million each. By comparison, only a third invested a comparable amount in fabrication and assembly and less than a fifth did so for design and engineering as well as for inspection and communications. Automated material handling is the most capital intensive of the technologies.

In summary, the incidence of technology usage is highest for technologies requiring lower levels of investment. Inspection and communications, and design and engineering are the most-used technologies. They also require the least amount of investment per plant. Automated material handling technologies, which are the least used, require the highest levels of investment per plant. Finally, fabrication and assembly falls somewhere in between, both in terms of use and investment.

3.5 Plans to Use

Investment in advanced technologies comes either from new users or through upgrading existing technology. Each of these sources is discussed in turn.

Figure 1
Investment in Advanced Technology by Functional Group
Large Establishments (Shipment Weighted)



3.5.1 Extending Use

Forecasts of planned technology adoption provide useful indicators of future investment. Expected growth in technology use, measured at the functional level, is divided into two categories. The first measures the percentage of establishments that plan to add a particular technology in a functional group, regardless of whether or not they are already using other technologies from the same functional group (second column; Table 8). The second calculates the percentage of establishments that intend to adopt a technology within a functional group, but which are not currently using any of the technologies belonging to that functional group (third column; Table 8). The first measure gives the expected *growth in use* of functional technologies in the Canadian manufacturing sector; the second indicates the expected *growth in new use* for a given functional technology group. The difference between the two measures is the expected growth in multiple technology use.

Growth in new use (last column; Table 8) is expected to be highest for fabrication and assembly, with an increase of 8 percentage points. Design and engineering is next with an expected *growth in new use* of 6 percentage points, followed by automated material handling and inspection and communications, both with an expected growth of 4 percentage points.

A different picture emerges for *growth in use* of functional technologies. *Growth in use* (second column; Table 8) is expected to be highest for inspection and communications technologies (40 percentage points), which currently has the highest overall adoption rate (73%; Table 4). Fabrication and assembly and design and engineering are next with an expected growth of 23 and 21 percentage points, respectively. Relatively little growth is expected for automated material handling (8 percentage points).

Table 8
Planned Use of Advanced Technology by Functional Group
All Establishments (Shipment Weighted)

Functional Group	Planned Use: All Cases	Planned Use: Functional Group Not in Current Use
	(shipment percentage points)	
Design and Engineering	21.0	6.2
Fabrication and Assembly	23.0	8.2
Automated Material Handling	7.7	4.3
Inspection and Communications	39.9	3.5

Table 9
Plans to Upgrade Existing Advanced Technology
All Establishments (Shipment Weighted)

Extent of Planned Upgrade	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of shipments)			
Total Replacement (75% or more)	7.3	2.5	0.2	3.3
Major Upgrade (25% to 74%)	25.3	33.6	43.9	22.6
Minor Upgrade (less than 25%)	27.2	25.5	31.0	30.1
Under Consideration	23.3	21.0	10.2	21.3
None	7.3	4.5	9.3	8.8
Non-response	9.6	12.8	5.4	13.8

3.5.2 *Extent of Upgrading*

Investment may result not only from the purchase of new technologies but also from the replacement of existing technologies. A large percentage of establishments indicated that they planned to upgrade or totally replace their current production technologies (Table 9).

Respondents from all technology groups indicate they expect to perform either major or minor upgrades of their current technologies within the near future—ranging from 53 percent for both design and engineering and inspection and communications to 75 percent for automated material handling. Fabrication and assembly technologies are in the middle at 59 percent.

Upgrading design and engineering technologies is equally divided between minor upgrades and major ones; fabrication and assembly and automated material handling technologies favour major upgrades; while inspection and communications technologies favour minor upgrades.

Very few establishments intend to totally replace their present technologies—less than 10 percent for design and engineering technologies and less than 5 percent for each of the other three functional groups.

A substantial number of establishments indicate that they were considering upgrading but had no firm plans. Roughly one-fifth indicated this to be the case for all functional groups except for automated material handling. For automated material handling, only 10 percent plan to upgrade but have no firm plans.

3.6 *Regional Sources*

Decisions to acquire technology depend on the availability, price and quality of the technology. These vary substantially by supplier, in particular between foreign and domestic producers. To provide a picture of the comparative advantage of different regions, the regional sources of advanced technologies are presented in Table 10. The most important source in all cases is the *United States*. *Canada* is the next most important source; followed by *Europe* and the *Pacific Rim*.[8] There is, however, one significant exception to this. For fabrication and assembly technologies, the *Pacific Rim* countries are just as important a regional source as is *Europe*. *Canada* does relatively well as a supplier in both design and engineering and inspection and communications technologies. At least one-half of establishments use these Canadian produced technologies. *Canada* does poorly in fabrication and assembly, however, coming well behind the *United States*. The *Pacific Rim*, which generally ranks fourth after *Europe*, is equally as important as *Canada* and *Europe* for fabrication and assembly.

Table 10
Regional Sources of Advanced Technology*
Large Establishments (Shipment Weighted)

Regional Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Canada	53.6	34.3	36.1	54.2
United States	72.2	67.7	66.0	60.5
Europe	14.1	30.8	22.0	20.9
Pacific Rim	5.8	32.3	2.3	5.3
Non-response	5.9	7.1	5.5	14.5

* *Note that columns do not sum to 100 since establishments may own more than one technology belonging to each group.*

3.7 Summary

Advanced technologies exhibit characteristics which vary across functional technology groups. They differ in their incidence of adoption, age structure, intensity of investment, amount of investment, and planned growth patterns (Table 11).

Design and engineering is characterized by a high incidence of adoption of middle-aged technologies, although the intensity of investment is relatively low. Investment per plant is also relatively low. The relatively low per-plant investment is a manifestation of the underlying technologies. Most of the investment in design and engineering is in computer-aided design and engineering software. With the advent and proliferation of the personal computer, the cost of adopting this technology has been greatly reduced. Not only have the associated software costs decreased, but also the costs for the hardware necessary to implement these programs. Plants do not require large investments to adopt these technologies.

Inspection and communications technologies also have a high incidence of adoption with a low intensity of investment. Unlike design and engineering, this group contains a mix of new and mature technologies. Inspection equipment and programmable controllers are the more mature technologies in this group, while local area and wide area networks are newer technologies. Investment per plant is also relatively low. Communications technologies are vital to a firm's operations—both in its conventional and advanced forms. Requiring relatively little investment, this is an area of expected high growth.

Fabrication and assembly, on the other hand, has both a moderate incidence of adoption and a moderate intensity of investment. Most of the technologies in this group are middle-aged while investment per plant is high. Firms are adopting these technologies but at a slower pace than either design and engineering, or inspection and communications.

Automated material handling has a low incidence of adoption with a moderate intensity of investment in a set of middle-aged technologies. Investment per plant is high. The incidence of adoption of these technologies is low since they are industry-specific technologies requiring appreciable amounts of investment.

In summary, intensity is lowest where incidence is highest. Even though design and engineering and inspection and communications have penetrated most factories, they have not yet spread throughout the entire factory and there is considerable leeway for growth in these areas. This is borne out by the differences in expected growth. It is highest in inspection and communications, while only moderate growth is expected in fabrication and assembly.

Firms also plan to upgrade existing equipment—with both minor and major changes. Design and engineering and fabrication and assembly systems are expected to undergo equal amounts of major and minor upgrades; automated material handling systems will face mostly major upgrades; while the reverse is true for inspection and communications.

Table 11
Characteristics of Functional Technology Groups
Shipment Weighted Results

Characteristic	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communication
incidence of adoption	high	medium	low	high
age structure	middle-aged	middle-aged	middle-aged	mature and new
intensity of investment	little-to-moderate	moderate	moderate	little-to-moderate
per plant investment	low	high	high	low
planned growth	moderate	moderate	low	high
plans to upgrade	minor-major	minor-major	major	minor

4. The Diffusion Process

4.1 Introduction

Data on the incidence and intensity of technology use provide a description of the outcome of the decision to invest in new technologies. Understanding that decision requires information about the process that affects the length of time it takes establishments to adopt new technologies.

The adoption process is affected both by the benefits perceived to flow from new technologies and also by the costs associated with their implementation. It is facilitated by information flows that allow firms to evaluate these costs and benefits.

This section examines the sources of information about advanced technologies, the benefits, and the costs associated with the adoption of advanced technologies.

4.2 Technological Change

Technological change is a multi-layered process. It spans a number of stages from the conception of ideas to the final adoption of new machinery that embodies the technology. Invention, innovation and diffusion are different stages in the process of technological change. Invention is the generation of a new idea by an inventor, while innovation is its development into commercial production by the first producer. Diffusion occurs as the use of the new product or process spreads across other firms in an industry.

Technology adoption enables establishments to increase both the quality and quantity of outputs. Although the adoption of advanced technologies is crucial to a firm's ability to remain competitive, new technologies are not immediately implemented by all potential adopters. Diffusion occurs with a lag.

Adoption of an advanced technology takes place, as a rule, by installing the equipment embodying it. However, the point at which new equipment is installed is just one stage in a long process. The first stage involves idea generation and the acquisition of information about the new technology. Ideas for adoption may originate either from within the firm or from outside the firm. Outside the firm, information is provided by suppliers of equipment, trade shows, publications, affiliates or subsidiaries of a parent firm, consultants, and various institutions such as university and government laboratories. Inside sources of information include experts on technology from different areas of the firm—in the production, design, engineering, operations, and research and development groups.

Before investing large amounts of capital in new projects, such as the acquisition of advanced manufacturing technology (AMT), firms evaluate each new project as part of the capital budgeting process. This involves comparing the expected profitability of the acquisition to the firm's cost of capital. If the internal rate of return[9] earned by the project exceeds the cost of funds necessary to finance the acquisition, then the acquisition is *financially justified* and firms can be expected to adopt the new technologies.

Associated with each advanced technology is a set of characteristics or attributes—price, maintenance expense, costs of development of software, technical support from vendors, familiarity with the technology, and the degree of risk in dealing with unfamiliar sources. Each of these characteristics affects the desirability of investing in a particular advanced technology. Since establishments have different preferences and technical requirements, potential adopters search for the appropriate combination of these characteristics to maximize profitability.

Despite the potential gains from the use of advanced manufacturing technology, its adoption has progressed rather slowly. Reasons for this have been offered by many authors. The Organisation for Economic Co-operation and Development (OECD, 1991) cites four major barriers to adoption—lack of skilled personnel; organizational problems; problems with software, sensors and networks (technical problems); and economic and financial problems. It claims that technical problems and organizational problems are growing in importance, whereas economic and financial problems are diminishing in importance. Mori (1993) states that, in Japan, lack of financing and skilled labour shortages are the major obstacles manufacturers face in adopting advanced technologies. Schulz-Wild (1991) contends that the adoption of new technologies in Germany is not progressing as rapidly as predicted by promoters, primarily due to high costs and technical problems in connecting all the various components.

Decisions to adopt advanced technologies depend not just upon the impediments but also upon the inducements firms face. Profitability depends both on the costs involved and on expected benefits. The same OECD report (1991) notes that establishments implement advanced technologies expecting benefits in three areas—production flexibility, product quality, and production costs. Expected benefits *before* implementation of the technology and *actual* benefits achieved after the technology has been adopted are not always the same. Many of the *realized* benefits are difficult to estimate in advance. For example, it is difficult to predict the benefits resulting from improvements in product quality or increased flexibility. It is much easier to estimate expected reductions in labour costs or improvements in productivity.

Technology adoption does not always result in *both* increased revenues and decreased costs. In some instances, increases in costs are required to produce increases in revenues. For example, adoption of new, more efficient technologies may require a more skilled work force or an increase in the firm's capital requirements.

This part of the survey looks at the diffusion process. First, it examines the diffusion or adoption lag—the time between a firm's becoming aware of a technology and its eventual adoption of that technology. It investigates the importance of various sources of ideas for the adoption of advanced technologies. It examines the importance of various benefits and effects of technology adoption at the firm level. It investigates the importance of different problems that delay technology acquisition by establishments that use advanced technologies. It seeks to identify the characteristics of advanced technologies that are particularly significant for the acquisition decision. In addition, it outlines the impediments to advanced technology use for both users and non-users.

4.3 Diffusion Lag

Before technology is adopted, establishments must become aware of new possibilities. New technology must be assessed against the old. Once it becomes evident that the new technology is economically justified, the expertise to adopt it has to be developed; the staff has to be trained; the plant layout of the new equipment has to be planned; and the work flow has to be reorganized. Finally, equipment embodying the new technology has to be ordered and delivered. These requirements determine the length of the diffusion lag.

The adoption decision depends on various factors—the technical capability of the firm, the economic and technical advantages of the new technology relative to the old (e.g., profitability, and productive efficiency), financing capabilities, size and structure of the organization, research and development activity, access to information, labour market conditions, product market conditions, and management attitudes.[10]

Diffusion lags are longer when the technical capability, the ability to make effective use of technical knowledge, is lacking. In the early stages of a new technology, the profitability or internal rate of return of the new technology relative to the old may not be sufficiently large to offset the risk of experimenting with the unknown. Lack of financial resources may also delay the adoption of new technology. A firm's inability to reorganize its internal structure for use and implementation of the new technology may further deter adoption. Management or the work force may resist change. Communications may be poor and, thus, the knowledge of new techniques may take a considerable time to spread. The severity of these factors varies from firm to firm and, therefore, the adoption of new technology is heavily influenced by the particular situation of each firm.

The length of the diffusion lag determines whether a country finds itself behind its major trading partners. Longer lags are associated with the use of older, less productive equipment, and thus have a negative effect on productivity. The advanced technologies being investigated here are not major innovations in the sense of micro-chips, lasers, or scanning technology and, thus, diffusion lags may not be as long as have been found for such fundamental technologies (Stoneman and Diederen, 1994). Nevertheless, the length of the diffusion lag can still be an important determinant of international differences in productivity.

The average diffusion lag for Canadian establishments who use advanced technologies is presented in Table 12. Within each functional group, at least 79 percent of shipments are produced by establishments with a diffusion lag of less than five years. A significant portion of shipments (15%-25%) in each technology group comes from those establishments who adopt advanced technologies within one year of their first becoming aware of the technique. However, the largest share is found in the 1-3 year time period. Except for automated material handling, there is a remarkable similarity across functional groups in the distribution of plants by time required for diffusion.

It is well established that the use of advanced technologies is higher in larger firms (Baldwin and Sabourin, 1995). In order to capture the differences in the adoption lag of advanced technologies by size class, the sample was broken into smaller (under 250 employees) and larger establishments (250 or more employees).

The diffusion lag by establishment size across technology groups is similar in that the largest percentage generally falls in the 1-3 year lag category for all technologies (Table 13). Moreover, the distributions are remarkably similar as well. Although the incidence of technology adoption is lower in smaller plants (Baldwin and Sabourin, 1995), the diffusion lag in smaller plants is not very different from large plants.

Table 12
Diffusion Lag of Advanced Technology by Functional Group
All Establishments (Shipment Weighted)

Time Period	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of shipments)			
Less than 1 year	25.1	24.1	15.5	15.0
1 - 3 years	45.1	45.0	72.3	45.5
3 - 5 years	20.1	17.3	5.1	18.9
More than 5 years	3.2	4.9	1.4	3.7
Non-response	6.5	8.7	5.7	16.9

Table 13
Diffusion Lag of Advanced Technology by Functional Group and Employment Size
All Establishments (Shipment Weighted)

Time Period	Design and Engineering		Fabrication and Assembly		Inspection and Communications	
	0-249 employees	250 + employees	0-249 employees	250 + employees	0-249 employees	250 + employees
	(percentage of shipments)					
Less than 1 year	23.1	26.0	22.7	24.6	13.2	16.0
1 - 3 years	43.8	45.6	42.3	46.1	42.8	46.9
3 - 5 years	16.3	21.7	11.9	19.3	15.7	20.4
More than 5 years	5.0	2.5	6.5	4.3	6.2	2.5
Non-response	11.8	4.2	16.6	5.7	22.1	14.2

4.4 Sources of Ideas

4.4.1 Introduction

Lack of information about the existence of a technology is one of the reasons for slow adoption. Diffusion follows information, and as information spreads, so will the use of new technology (Brown, 1981).

Firms acquire ideas for the adoption of advanced technology from different sources. The forces behind innovation can be classified as demand-pull or supply-push. Demand forces that stimulate innovation are those factors like the rate of economic growth that provide greater incentives to innovation. Supply factors consist of forces like the scientific environment that affect the likelihood that research and development expenditures will produce new products or processes (Schmookler, 1966).

The sources of ideas that contribute to technology acquisition can also be classified into two groups—those arising from information-pull and information-push (Schumacher, 1982). Outside sources provide information on new technologies for the firm; inside sources provide the receptor capabilities that allow outside information to be digested, assessed, and acted upon.

Outside the firm, the key role is normally allocated to suppliers of equipment since they have the most to gain from the free flow of information between themselves and users. Inside the firm, experts on technology are found in different areas of the firm—within production, design, engineering, operations and the research and development group. Both inside and outside sources act in concert to determine the amount of information that is processed by a firm.

The importance of each source to the firm is evaluated here in turn. A knowledge of the sources a firm finds most important provides basic information on the nature of the diffusion process governing the adoption of advanced technologies.

4.4.2 Internal Sources

Different parts of an organization provide sources of ideas that facilitate the adoption of advanced manufacturing technology. These ideas may come from the planning and design stages (*research, experimental development, design work,* and *production engineering*), from the operating stages (*operating staff*), and from management (*management* and *corporate head office*).

The percentage of large establishments (shipment weighted) listing such internal sources as in-house *research*, in-house engineering and technical skills (*design work* and *production engineering*), *experimental development, management, operating staff,* and *corporate head office* is presented in Table 14. *Production engineering, management,* and *operating staff* are the most commonly reported internal sources of ideas for all technology groups. *Design work* is also important, but only for design and engineering technologies.

Across all technology groups, *production engineering* is the most often cited internal source of ideas. It is, by far, the most important source for automated material handling (67%) and fabrication and assembly (61%), while it rivals *design work* (both about 47%) for design and engineering and *operating staff* (both about 37%) for inspection and communications.

Although some of the main sources, such as *production engineering,* are common to all technology groups, others are specific to a technology group. In addition to *production engineering,* the main sources of ideas are—*design work* and *operating staff* for design and engineering, *operating staff* for fabrication and assembly, *management* for automated material handling, and *operating staff* as well as *management* for inspection and communications.

Experimental development is moderately important for all but automated material handling, ranging from 22 percent for design and engineering to 38 percent for fabrication and assembly. Except for design and engineering, in-house *research* activity tends to be a relatively less important source of information on advanced technologies. *Corporate head office,* however, tends to be moderately important across all technologies, especially for inspection and communications.

Table 14
Principal Internal Sources of Ideas for Adoption of Advanced Technology
Large Establishments (Shipment Weighted)

Internal Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Research	23.2	8.5	1.0	12.9
Experimental Development	21.9	37.7	10.2	27.1
Design Work	48.3	16.8	12.5	13.6
Production Engineering	47.1	60.6	66.5	36.6
Operating Staff	39.4	47.0	29.9	37.2
Management	31.8	38.0	42.9	36.4
Corporate Head Office	18.6	19.0	22.0	30.9
Other	4.0	2.7	1.9	4.4
Non-response	4.6	6.9	6.8	13.2

Considerable emphasis has been placed on the role of research and development in fostering innovation. Less attention has been paid to other parts of the firm, even though they are equally as important in many respects. The traditional view regards technological progress as dependent upon the application of previously developed basic scientific knowledge. This view of the world depicts innovation as the result of the application of 'upstream' knowledge produced in the research and development division to 'downstream' activities involving production.

While this model is appropriate to some innovative activities, it is by no means universal. Many innovations have been made as scientists and engineers struggle to solve 'downstream' problems on the factory floor (Von Hippel, 1988). These changes make use of scientific knowledge but not necessarily frontier research being done upstream in the company. The information on the sources of ideas that are crucial for the adoption of advanced technologies confirms this. Divisions other than research or experimental development play a more important role as a source of ideas about new advanced technologies. *Production engineering* is the most important internal source of ideas for the adoption of advanced manufacturing technology. *Operating staff* and *management* are also important while *design work* is important only for design and engineering technologies. *Experimental development* is important for all but automated material handling technologies while *research* tends to be an important source of ideas for design and engineering technologies only.

4.4.3 External Sources

Information on advanced technologies also comes from outside the firm. Acquisition of information about the existence of advanced technologies depends on the extent of personal contact, co-operation, and network activities between potential adopters and outsiders. External sources of ideas include affiliates or subsidiaries of a parent firm; research institutions such as government laboratories, university laboratories, provincial research organizations, industrial research firms, and research consortia; customer and supplier firms; trade shows, trade association meetings, and publications; consultants and service firms; and joint ventures and strategic alliances between firms.

The external sources (shipment-weighted) that provide the ideas used for the adoption of advanced technology by large establishments are presented in Table 15. The most commonly reported external sources for all technology groups are *supplier firms*; *publications, trade fairs and conferences*; *a related firm*; and *consultants and service firms*. These sources create a network between producers and users of advanced technological information.

In all technology groups, establishments who produce a significant portion of shipments—between one-quarter and one-half—indicate that *supplier firms* are one of the major external sources of ideas. This is to be expected. Suppliers diffuse knowledge and information about their products through personal contacts and networks. They interact with internal sources such as production engineers to aid firms in adopting new advanced technology. It is these supplier-customer relations that facilitate the adoption of advanced technology. Ettlie (1986, p.6) notes that there are "*always at least two key people, one representative of the vendor and one from the user who work hardest at building a team to integrate the technology in the user's plants*".[11]

Network activities through professional *trade fairs and conferences*, and scientific and technical *publications* also provide a set of major external sources of ideas in all four technology groups (37% to 59% of shipments come from establishments citing these sources). Professionals and professional societies are important factors in the diffusion of information about advanced technology. Professional societies facilitate the spread of new technology, by not only organizing *conferences* and sponsoring *publications*, but also by providing a foundation for members to develop networks. Similarly, *trade fairs* offer another external source for ideas. Even though many of these may be more market- than technology-oriented, new technology developments can often be discovered and personal contacts made during these meetings.

Co-operation and interaction between firms or between firms and research institutions have been recognized as important sources of many innovations. They can occur in a variety of ways—through interaction with *related, unrelated, customer,* or *supplier firms* or through *joint ventures and strategic alliances.* In all four technology groups, co-operation and interaction with a *related firm* is a major source of ideas. It is listed by establishments who produce more than 40 percent of shipments in each group. By way of contrast, *unrelated firms*, and *joint ventures and strategic alliances* are less important sources for ideas, being listed by plants that account for only 4 percent to 15 percent of shipments.

Establishments in all technology groups also indicate that *consultants and service firms* are a principal source of ideas. Ranked after *suppliers* and *trade fairs,* this source is checked off by establishments accounting for 21 percent to 32 percent of shipments. Adoption of advanced technologies is generally firm-specific and a firm may not have the type of detailed knowledge of competing technologies that are required to choose among alternate types. *Consultants* provide this service.

Table 15
Principal External Sources of Ideas for Adoption of Advanced Technology
Large Establishments (Shipment Weighted)

External Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
A Related Firm (with same parent firm)	43.7	44.0	46.6	40.1
An Unrelated Firm	10.4	11.4	14.8	10.5
Government Laboratories	0.8	0.6	0.0	2.5
University Laboratories	6.8	5.2	0.1	2.4
Provincial Research Organization	1.2	2.0	0.4	2.6
Industrial Research Firms	10.1	6.1	2.9	9.0
Research Consortia	4.5	1.8	2.0	3.3
Consultants and Service Firms	31.8	20.7	30.7	31.2
Joint Ventures and Strategic Alliances	10.3	8.2	3.6	5.0
Publications	39.2	52.2	54.9	39.9
Trade Fairs, Conferences	40.4	51.3	58.9	37.4
Customer Firms	12.6	5.8	1.3	4.4
Supplier Firms	37.1	52.0	26.3	42.6
There was no Significant External Input	4.7	5.8	1.5	3.7
Other	6.2	10.2	6.1	7.0
Non-response	7.5	7.3	9.0	13.4

Institutions such as *government laboratories, university laboratories, provincial research organizations, industrial research firms*, and *research consortia* are generally less important as sources of ideas for all technology groups. While a substantial proportion of R&D collaborative agreements are with these groups, they do not offer much support to the process of technological adoption. Given the characteristics of advanced technologies, support for adoption comes more from industrial and commercial sources than research departments.

The importance of the external sources varies from one technology group to another. *Related firms, trade fairs and conferences*, and *publications* are the most important source for design and engineering. *Trade fairs and conferences, publications,* and *related firms* are the most important sources for automated material handling. *Supplier firms, related firms,* and *publications* are the most important source for inspection and communications. For fabrication and assembly, *publications, trade fairs and conferences,* and *supplier firms* are all about equally important.

4.5 Benefits and Effects of Advanced Technology Adoption

4.5.1 Introduction

The benefits from technology adoption fall into two classes—*tangible* and *intangible*. *Tangible* benefits are those that firms are able to estimate with some degree of accuracy prior to investment. *Intangible* benefits (or effects), on the other hand, are more difficult to predict. They can take one of two forms. First, they may be difficult to quantify. Improvements in product quality are an example of this type of benefit, since their impact on demand for the product only emerges after its introduction. Second, they may be potentially quantifiable, yet difficult to predict *ex ante*. For example, the benefits of reduced set-up time are potentially quantifiable but the extent to which these benefits are attainable may be difficult to predict if they depend on the introduction of new skills to the labour force.

The mere purchase of advanced equipment does not guarantee benefits. Plants may never actually attain expected benefits if, for example, new equipment is improperly installed, if there is a shortage of skilled staff to operate it, or if it is not properly maintained after installation. Being able to predict attainability is the key feature distinguishing *tangible* from *intangible* benefits (or effects). Inability to measure or quantify these effects only worsens problems in evaluation.

Because *intangible* benefits are difficult to estimate, establishments tend to focus their investment decisions on expected *tangible* benefits. Unfortunately, the total benefits from technology adoption are very much determined by the *intangible* effects that are actually realized after the technology has been adopted. Unless their importance is properly considered, inappropriate decisions will be made.

A recent OECD report (1991) argues that establishments implement advanced technologies for four reasons—to increase production efficiency and flexibility, to improve product quality, to obtain tighter control over the production process, and to reduce production costs. Of these, reductions in production costs and improvements in production efficiency are tangible benefits, while improvements in product quality, increases in production flexibility, and better control of the production process are best categorized as intangible benefits.

The benefits and effects that were investigated in this survey are:

Tangible Benefits

- increases in productivity
- reduction in labour requirements
- reduction in material consumption
- reduction in energy consumption
- increase in equipment utilization rate
- increased capital requirements
- reduced capital investments
- lower inventory

Intangible Effects

- improvement in product quality
- increased skill requirements
- reduced product rejection rate
- reduced set-up time
- greater product flexibility
- improved working conditions
- reduced environmental damage
- reduced skill requirements
- other benefits

A benefit most commonly associated with technology adoption is *improvements in productivity.* A new process often allows a firm to produce a product more cheaply and efficiently. This may be because fewer workers are required for a given output (*reduction in labour requirements*); less material is needed (*reduction in material consumption*); less energy is used (*reduction in energy requirements*); capital is utilized more efficiently (*increased equipment utilization rate*); less downtime is experienced (*reduced set-up time*); less wastage is produced (*reductions in the product rejection rate*); or *lower inventories* are kept.

Improvement in product quality is another important benefit associated with the adoption of advanced technologies. Its impact is difficult to measure in advance, yet it is one of the more commonly reported benefits of technology adoption (OECD, 1991). Kaplan (1984, p. 96) claims "*To excel as a world-class manufacturer, a company must be totally committed to quality—that is, each component, sub-assembly, and finished good should be produced in conformity to specifications.*" New processes that allow firms to produce higher quality products also allow them to produce more consistent products. This results in *reductions in the product rejection rate*, thereby reducing production costs.

Advanced technologies also permit firms greater product diversity by facilitating custom design. Advanced technology gives firms *greater product flexibility*—the ability to produce a range of different products or parts with the same piece of equipment. This permits mass production of customized products in relatively small batches.

Labour-related effects associated with technology adoption include changes in *skill requirements* and *improvements in working conditions*. The adoption of advanced technology necessitates an increase in the skills of the work force (Baldwin, Diverty, and Johnson, 1995). More highly skilled workers are needed to operate and maintain the new equipment than previously.

Finally, technology may increase or decrease the amount of capital that is required. If the new, more advanced equipment is more expensive than the equipment it replaces, *increased capital requirements* can be expected. Capital requirements will also increase if the net difference, between an increase in capital due to expanded output and a decrease in capital due to improvements in productivity, is positive.

4.5.2 Tangible Benefits

Improvements in productivity is the most important benefit associated with adopting advanced technology. About three-quarters of the shipments from technology users come from establishments registering an *improvement in productivity* (Table 16) for three of the four functional groups—design and engineering, fabrication and assembly, and automated material handling technologies. For inspection and communications, only slightly more than half of shipments come from plants reporting a corresponding *improvement in productivity*. While this is a lower percentage than for the other three functional categories, *productivity improvement* is still the leading benefit for this group.

Productivity can be improved in a number of ways—by *reducing labour requirements, material consumption*, or *energy consumption* per unit of input.[12] Of these, *reductions in labour requirements* is the category most often cited for all four functional groups. Fabrication and assembly report the highest level of labour reductions per unit of output at 72 percent. This is followed by automated material handling, and design and engineering (both at about 50%), and then by inspection and communications at 32 percent.

Reductions in material consumption are more important than *reductions in energy consumption* for all four functional technology groups. However, establishments give less than half the importance to these factors than they do for *labour reductions*. Fabrication and assembly technologies are most likely to result in material and energy savings.

An *increased equipment utilization rate* is important for automated material handling (56%), and fabrication and assembly (43%). It is moderately important for design and engineering (30%), and inspection and communications (29%). It is about as important as *labour reductions* for automated material handling. While it also affects fabrication and assembly, it is about 30 percentage points behind *labour reductions* here. It is much less of a benefit for design and engineering than is *labour reductions*, but about equal to *labour reductions* for inspection and communications.

Lower inventory is an appreciable benefit only for fabrication and assembly and to a lesser extent inspection and communications. At 43 percent, it is as important as gains due to a higher *equipment*

Table 16
Effects Caused by Acquisition of Advanced Technology*
All Establishments (Shipment Weighted)

Effect	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of shipments)			
TANGIBLE:				
Improvements in Productivity	70.1	75.9	77.4	54.6
Reduction in Labour Requirements	48.6	72.1	50.0	31.5
Reduction in Material Consumption	19.0	34.1	15.0	13.8
Reduction in Energy Consumption	9.8	24.3	7.7	11.7
Increased Equipment Utilization Rate	29.5	43.3	56.3	29.3
Increased Capital Requirements	33.2	52.6	58.6	30.1
Reduced Capital Investments	3.9	6.1	5.6	3.0
Lower Inventory	9.3	43.2	20.2	22.1
INTANGIBLE:				
Improvement in Product Quality	46.7	65.2	56.8	51.2
Increased Skill Requirements	54.2	56.0	58.8	47.2
Reductions in Product Rejection Rate	18.3	57.8	52.6	41.3
Reduced Set-up Time	38.7	51.2	46.4	11.0
Greater Product Flexibility	37.4	48.7	52.5	19.0
Improved Working Conditions	28.5	43.8	58.5	19.2
Reduced Environmental Damage	5.3	26.2	7.4	11.2
Reduced Skill Requirements	8.2	15.8	5.0	5.6
OTHER:				
Other	1.9	0.6	0.0	2.0
Non-response	9.8	7.8	11.5	20.4

* *Note that columns do not sum to 100 since establishments may have received more than one benefit or effect.*

utilization rate but substantially less important than *labour reductions* for fabrication and assembly. For inspection and communications, it is a benefit one-fifth of the time but it ranks behind both *reductions in labour requirements* and *increases in the equipment utilization rate.*

4.5.3 Intangible Effects

Among intangible effects, *improvements in product quality* and *increased skill requirements* are most commonly cited, regardless of the functional group. They rival in importance the second most important tangible benefit, *reductions in labour requirements. Product quality improvement* ranks highest for fabrication and assembly (65%) and lowest for design and engineering (47%). *Increased skill requirements* are equally important for design and engineering, fabrication and assembly, and automated material handling—affecting establishments with about 56 percent of shipments. They are less important for inspection and communications (47%).

Greater product flexibility is a significant benefit for design and engineering (37%), fabrication and assembly (49%), and automated material handling (53%). It is least important for inspection and communications (19%).

Improvements in quality control, as measured by *reductions in the product rejection rate*, are significant for fabrication and assembly (58%), and automated material handling (53%), slightly less so for inspection and communications (41%), and much less so for design and engineering (18%).

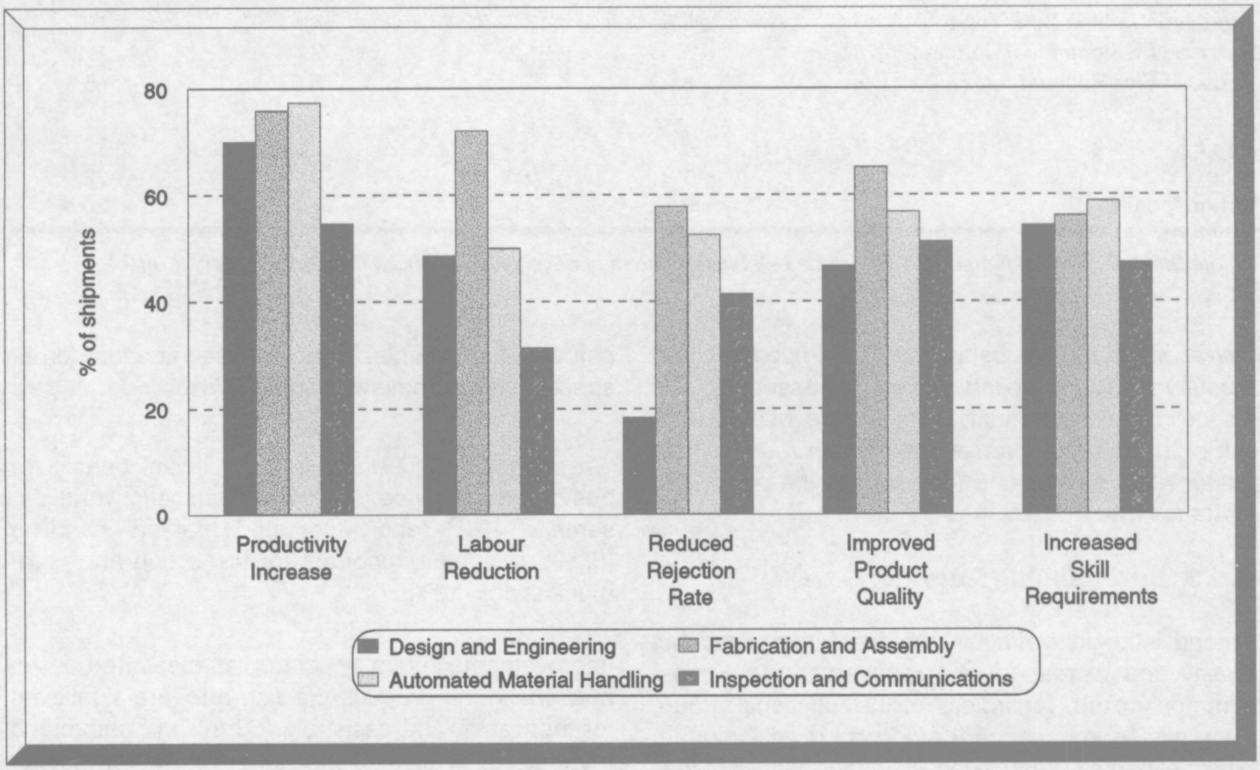
Reduced set-up time, and *improved working conditions* exhibit the same patterns. Both are important benefits for fabrication and assembly (51% and 44%, respectively), and automated material handling technologies (46% and 59%, respectively); moderately important benefits for design and engineering technologies (39% and 29%, respectively); and less important benefits for inspection and communications (11% and 19%, respectively).

Reduced environmental damage is rarely a benefit. Only for fabrication and assembly does it achieve any significance (26%).

4.5.4 Summary of Leading Effects

Improvements in productivity, reductions in labour requirements, improvements in product quality and *increased skill requirements* are the highest-rated effects, regardless of functional group (Figure 2). One other area receives a high score—*reductions in the product rejection rate*—for all but design and engineering. Of these, *improvements in productivity* and *reductions in labour requirements* are tangible effects while *increased skill requirements, improvements in product quality* and *reductions in the product rejection rate* are intangible or difficult to predict.

Figure 2
Leading Effects of Advanced Technology Adoption
All Establishments (Shipment Weighted)



4.6 Impediments to Technology Acquisition

4.6.1 Introduction

The benefits of technology use provide the inducements necessary for investment in new technologies. Impediments provide the disincentives. The relative size of benefits and impediments at the firm level affects the incidence of adoption, the intensity of use and the length of the diffusion lag.

This section investigates the importance of impediments to the adoption of advanced manufacturing technologies. It does so in several related fashions. The first section investigates the areas that both users and non-users perceive to be the greatest problem. It is the most general in that it focuses on the problems the respondents had in adopting *any* technology, irrespective of the functional group to which the technology belonged. The second section revisits the issue for the four technology groups, but only for users of a particular functional technology.

4.6.2 General Impediments

4.6.2.1 Introduction

This section deals with a range of problems such as high costs, management attitudes and other organizational problems, skill shortages, and lack of information that impede establishments from adopting technology in general, that is, from adopting *any* of the advanced technologies. It also investigates whether the problems encountered by users and non-users of advanced technologies differ.

Adoption of advanced technologies generates a stream of benefits and associated costs arising from equipment purchases, maintenance, training, software development, technology acquisition, and debt servicing. When capital budgeting techniques are used to evaluate the desirability of new technology acquisition, firms will adopt new techniques if the net benefit from adoption is positive, i.e., if they are financially justified. The adoption of technologies will not be financially justified if the revenue stream is too low, the cost of capital too high, or if costs are too elevated.

Acquisition of advanced technologies involves a variety of costs, some of which are readily quantified and predictable. Investments in new physical capital (e.g., machines, and equipment), as well as in human capital (e.g., education, skill, and training) are quantifiable. While the former is readily predictable before the purchase, the second is not always so.

There are other components of cost which are not always easy to predict *ex ante*—costs of developing software, costs associated with technology acquisition, and maintenance and repair costs.

In addition to quantifiable costs, there are institutional factors associated with government policy that are meant to offset barriers to acquisition by reducing capital costs of investment in advanced technologies. For example, investment tax credits and capital cost allowances are designed to stimulate business investment by reducing the cost of capital. On the other hand, government regulations and standards may affect the use of certain processes and technologies. To the extent that these institutional factors increase costs, they may act as impediments to advanced technology acquisition.

Labour-related problems may also impede firms from acquiring advanced technologies. Successful adoption of advanced technologies requires firm-specific investments in human capital. The human capital of a firm depends upon the skill levels of its employees. It is, however, costly to increase the stock of human capital. Insufficient financial resources may make firms unable to invest in human capital. Even if financial constraints are overcome, it may be difficult to increase the technological capability of the firm by improving training if workers resist acquiring new skills. Alternately, firms may choose not to train if labour mobility is high. High labour mobility means that the benefits of training are less likely to be captured by the firm that invests in training, thereby reducing a firm's incentive to train. In addition, there may be conflicts within the firm—trade union activities and labour contracts, for example, are sometimes said to impede the acquisition of new technologies.

The acquisition of advanced technology is also influenced by the organizational structure of the firm. There are several organizational problems that firms face when acquiring advanced technologies. First, the introduction of a technology may require comprehensive structural and organizational changes affecting the present administrative practices of the organization. Second, management attitudes may not favour the introduction of new technologies. Some managers may be willing to take more risk than others. Risk averse managers may require higher rates of return or a very short pay-back period, which would make the investment in advanced technologies unprofitable. Some managers may not be willing to learn more about the new technique, thus hindering the technological capability of the firm.

Another barrier may arise from possible deficiencies in the market for information. An inadequate flow of technological information from producers to potential adopters may impede the acquisition of advanced technologies. In the case of conventional techniques, it is relatively easy to master the skills required for operation and maintenance. This is not the case with advanced technologies, where the knowledge of the technique is embodied in specialist skills. Often a firm's in-house technological capability is not adequate to master all technical know-how embodied in new techniques and aid from outsiders has to be sought.

Technological information regarding advanced technologies may not be supplied in optimum quantities by the market system. While some types of information will be adequately supplied by producers, the supply of other types may not be adequate. Knowledge can be divided into that which is technology-specific and that which is general. Technology-specific information is appropriable by the maker of the technology and should be supplied in sufficient quantities by the equipment manufacturers. Non technology-specific information, on the other hand, is a knowledge-good that has the attributes of a public good. Once it is produced, it can be appropriated by others. The incentive to create adequate quantities of this type of new knowledge is limited by the "free-rider" problem (Levin, 1986).

While the decision-making process regarding technology acquisition is often cast in a capital-budgeting or accounting framework, the required calculations are not always straightforward. Many considerations are difficult to quantify. These include obstacles such as government regulations, labour-related problems, a firm's internal organizational problems, management attitudes, and inadequate flow of technological information. Although they may not directly figure in the narrow rate of return calculations, they are included in the list of impediments presented to respondents in this survey because they are part of the acquisition decision process.

The various impediments that are investigated are:

Cost-related Problems

Lack of financial justification

Investment-related costs
- cost of capital
- high cost of equipment
- costs to develop software
- increased maintenance expenses
- cost of technology acquisition

Institution-related costs
- tax regime: R&D investment tax credits
- tax regime: capital cost allowances
- government regulations and standards

Labour-related Problems
- shortage of skills
- training difficulties
- labour contracts

Organizational or Strategic Problems
- difficulties in introducing important changes to the organization
- management attitude
- worker resistance

Information-related Problems
- lack of scientific and technical information
- lack of technological services
- lack of technical support from vendors

Other Problems
- other

Included under investment-related cost problems are costs of equipment, and the cost of capital (financing costs). These are closely related by the formula that calculates the internal rate of return of a project and might, therefore, be expected to receive about the same emphasis. When costs increase or benefits fall, then the profitability of an investment in technology also declines and the less likely the project is to be financially justified. If the decision to invest is constrained at the margin because the internal rate of return from the project is just equal to the cost of capital, then changes in either equipment costs, or the cost of capital, will affect the financial viability of the project. Therefore, to the extent that capital budgeting is used to assess profitability, the cost of equipment, the cost of capital, and financial viability or financial justification are intertwined. If any one is an impediment, the others should also be impediments.

Of course, in situations where it is difficult to formally weigh benefits against costs and to calculate the internal rate of return of the project, financial justification in a narrow formal sense may not be possible. Instead, risk analysis may be employed or the decision-making process may more crudely focus on costs *per se*. Simpler rules of thumb than capital budgeting procedures may be used, such as procedures that focus on estimating both quantifiable and non-quantifiable costs. In this case, financial justification may be emphasized less than costs in general.

Under cost-related problems, firms are not only asked whether it is the cost of equipment that is problematic but also whether other components of cost—such as software, maintenance, or technology acquisition—have impeded the acquisition of technology. In one sense, all cost categories should be equally important—that is, if the level of costs restrain the decision at the margin—an equal change in costs in any of these categories should have the same effect on the investment decision. However, the cost categories will receive different emphasis if firms feel particularly uncomfortable with some components that may not be as easily quantifiable or that may not be readily predicted before the investment decision. Categories like the cost to develop software or maintenance expenses are sometimes not easily quantifiable and may impede the investment decision even if equipment costs are not prohibitive. In these cases, it is the uncertainty about *ex post* costs associated with technology development that are the key factors impeding acquisition.

The labour-related, organizational, and information-related problems that are included in the survey all encompass issues that are cost-related but fall into the category of being difficult to quantify or difficult to predict *ex ante*.

4.6.2.2 Results

The results are tabulated for both users and non-users as well as for both groups combined (Table 17). Thus, some 51 percent of shipments of users come from establishments reporting that the *cost of capital* is an impediment; some 45 percent of shipments of non-users come from establishments who do so, and 50 percent of shipments from both groups combined are in establishments believing that cost is a problem. In addition to the individual impediments, the results for groups of individual categories—*cost-related problems, labour-related problems, organizational problems, information-related problems* and *other problems*—are reported. These results summarize the percentage of firms indicating they experience <u>any</u> of the impediments within a group. For example, 83% indicate that they experience an *investment-related cost problem—cost of capital, high cost of equipment, costs to develop software, increased maintenance expenses* and *cost of technology acquisition.*

A higher percentage of users, than non-users, report that a particular category has created an impediment—probably because users have first-hand experience with the problems. Therefore, it is the users' responses that provide the focus for the discussion here.

Most users report that *investment-related costs,* in some form or other, are an impediment. Some 83% of shipments are in establishments that mention either that the *cost of capital*, the *high cost of equipment, costs to develop software, increased maintenance expenses,* or the *cost of technology acquisition* is a problem (Table 17). *High cost of equipment*, and *cost of capital* are the most important of this type of impediment, being cited by technology users with 58, and 51 percent of shipments, respectively. *Lack of financial justification*—a *non investment-related* cost—is as frequent an impediment as *cost of capital.*

Among the other *investment-related cost* factors, *cost of technology acquisition,* and *cost to develop software* are both important. Establishments producing 29% of shipments claim *costs of technology acquisition* as an impediment; while 23% report *costs to develop software* as an impediment. *Increased maintenance expenses* is the least important impediment in the group.

In the *institution-related costs* category, establishments find that inadequate *R&D tax credits, capital cost allowances*, and *government regulations and standards* are all relatively unimportant—with none of these factors affecting establishments with more than 9 percent of shipments.

Users indicate that *labour-related* and *organization-related* problems are generally the next most important impediments, being given about half the importance of *cost-related problems*. Of the *labour-related* impediments, *shortage of skills* (24%) and *training difficulties* (21%) are of roughly equal importance, with *labour contracts* (15%) slightly less important. The stock of human capital is extremely important to the successful adoption of advanced technologies. Specific skills and knowledge are required to use advanced technologies effectively.

Organizational problems are reported about as frequently as *labour-related* issues (37% and 40%, respectively). *Difficulties in introducing important changes to the organization* and *management attitudes* are the most important impediments associated with the organizational structure of the establishments. Between 17 and 25 percent of shipments originate from establishments whose plant managers felt that there are substantial challenges to management from technology adoption. Thus, an important subset of Canadian firms face the need to make changes in structure and administrative practices when introducing advanced technology. About the same percentage find that *management attitudes* impede the adoption of advanced technologies.

Information-related impediments are the least important. Establishments do not generally face problems associated with the flow of *scientific and technical information* about advanced technologies. This suggests that the "free-rider" problem is not severe in the advanced technology market. Adequate *technical support* is provided by supplying firms. As was indicated in the analysis of sources of ideas, most of the flow of information about advanced technologies originates from external sources such as *publications, trade fairs, conferences,* and *supplier firms* (Table 15). As a consequence, establishments do not feel that they generally face the problem of getting adequate technical support from vendors.

Each of the above factors affects the costs derived from technology use. Sometimes they affect cost directly; sometimes they have an indirect or unpredictable effect. Costs may be said to be an impediment to investment in technology where a small change in the magnitude of costs would either increase or decrease the amount of investment that firms make in technology. Where the profitability (internal rate of return) of new technology is substantially above the cost of capital, a small change in costs will not deter the adoption process.

While the *cost of equipment* is reported as an impediment by the largest percentage of plants (accounting for 58% of shipments), this is much less than 100% of the population. When assessing the importance of the secondary factors, it is best to compare their importance relative to the importance of *equipment costs*. Thus, the *cost of technology acquisition* (as opposed to *equipment*) is listed by plants that account for only 29 percent of shipments, but this is one-half the importance of the *cost equipment* category. *Shortage of skills* are a problem in plants that account for 24 percent of shipments. This is less than half the importance given to *equipment costs*. The *labour* and *organizational* categories then are relatively important. On the other hand, *information problems* have only about one-fifth the importance of *equipment costs*.

While the responses of users best illustrate the relative importance of impediments since they have actually implemented the technologies, the responses of non-users are nonetheless of interest. They can be examined to see whether non-users generally have the same appreciation of the problems that users actually face.

Generally the relative importance of impediments for users and non-users in each group follows the same pattern. The Pearson correlation coefficient across categories for users and non-users is .9, indicating an extremely close relationship between the relative importance given by users and non-users to the various impediments. *Cost-related* impediments, especially *investment-related costs*, are the most important to both groups. *Labour-related* and *organization-related* impediments are the second most important. As in the case of the combined group, the *information-related* impediments are the least important to both groups.

While users and non-users rank the importance of impediments in a similar order, it is noteworthy that non-users significantly underestimate the problems that they will face in the area of *labour-related* problems and *organizational* problems. About three-quarters as many non-users as users see *cost-related factors* as a problem while only half as many acknowledge *labour-related* and *organizational* problems. *Lack of scientific and technical information*, however, is viewed to be just as much an impediment for non-users as it is for users (13% versus 12%). In other words, non-users adequately evaluate problems with the *lack of scientific and technical information* but underestimate *labour-related* and *organizational* problems.

Table 17
Significant Impediments to Advanced Technology Acquisition
All Establishments (Shipment Weighted)

Impediment	Users	Non-Users	Combined
		(percentage of shipments)	
COST-RELATED PROBLEMS	**90.7**	**74.2**	**87.4**
Lack of Financial Justification	**54.2**	**44.6**	**52.2**
Investment-related Costs	**82.9**	**61.4**	**78.6**
Cost of Capital	51.0	45.3	49.8
High Cost of Equipment	58.3	44.7	55.6
Costs to Develop Software	23.0	13.1	21.0
Increased Maintenance Expenses	13.8	11.7	13.4
Cost of Technology Acquisition	29.3	22.2	27.9
Institution-related	**16.1**	**14.6**	**15.8**
Tax Regime: R&D Investment Tax Credits	7.7	7.1	7.6
Tax Regime: Capital Cost Allowances	9.4	5.7	8.6
Government Regulations and Standards	7.8	7.8	7.8
LABOUR-RELATED PROBLEMS	**39.5**	**23.0**	**36.2**
Shortage of Skills	24.4	14.7	22.5
Training Difficulties	20.6	12.1	18.8
Labour Contracts	14.7	6.5	13.1
ORGANIZATIONAL OR STRATEGIC PROBLEMS	**36.9**	**19.0**	**33.3**
Difficulties in Introducing Important Changes to the Organization	25.4	12.2	22.8
Management Attitude	17.4	7.8	15.5
Worker Resistance	11.6	8.6	11.0
INFORMATION-RELATED PROBLEMS	**26.6**	**17.2**	**24.7**
Lack of Scientific and Technical Information	12.0	13.2	12.3
Lack of Technological Services	9.6	7.4	9.2
Lack of Technical Support from Vendors	12.0	8.2	11.2
OTHER PROBLEMS	**10.5**	**25.6**	**13.6**
Other	10.5	25.6	13.6
Non-response	5.7	9.6	6.5

4.6.3 Factors Hindering Acquisition of Advanced Technologies at the Functional Level

4.6.3.1 Overall

In the previous section, the discussion centered on those factors that are most likely to impede an establishment in its acquisition of *any* advanced technology. This section examines impediments at the functional level—for design and engineering, fabrication and assembly, automated material handling, and inspection and communications technologies.

The impediments that are investigated at the functional level cover basically the same issues that were dealt with in the previous section under cost-related, labour-related and other problems. The categories surveyed are:

- Cost-related Problems
  - non-specific cost
  - any specific cost
    - technology acquisition cost
    - software development costs
    - education and training costs
    - increased maintenance expense

- Lack of Financial Justification

- Labour-related Problems
  - worker uncertainty

- Other Problems
  - software development time
  - lack of technical support
  - need for market expansion
  - other reasons

Cost-related problems include both cases where the establishment indicated cost to be a problem without additional specifications—*non-specific costs*—and cases where a specific mention of a problem was made—*cost of technology acquisition, cost to develop software, cost of education and training,* and *increased maintenance expense. Financial justification* is considered here as a separate category, though as noted earlier, it is related to *cost* problems. *Labour-related* problems include *worker uncertainty* and, of course, skill problems that are caught in the cost category—*education and training costs.* Finally, a set of other problems deal with a group of miscellaneous issues. *Software development time* is included to investigate whether the direct cost of software development, captured in the *specific cost* category, is more or less important than the indirect cost of lost opportunities that occur when delays associated with software development prevent technology from being implemented quickly. *Lack of technical support* is also included here as it was previously. Finally, *need for market expansion* is included to test whether new technologies are so costly that economies of scale require larger markets in order to fully exploit these technologies.

Consistent with the earlier findings, *cost-related* problems are the most significant factor delaying acquisition of advanced technology. Establishments affected by them account for between 50 and 60 percent of shipments (Table 18), regardless of the functional technology group. There are, however, differences in emphasis across functional groups. *Cost-related* problems have about the same effect on design and engineering (50%), and inspection and communications (52%). While its effect is greater for automated material handling (58%), and fabrication and assembly (57%), these differences are not statistically significant.

Lack of financial justification is a somewhat less important factor. It is quite important for automated material handling (52%), moderately important for fabrication and assembly (42%), and less important for design and engineering (28%) as well as inspection and communications (22%). The functional technologies with the highest adoption rates—design and engineering, and inspection and communications—are also the ones for which problems due to the *lack of financial justification* are the least important. In these categories, *financial justification* is less important than the *cost-related* categories by a wide margin. These categories also require the least amount of investment (see Section 3.4.2). Thus, firms do not apply traditional financial justification procedures equally across all technology groups. They appear to be applied more rigorously to fabrication and assembly, and automated material handling technology acquisitions. This may occur because they involve larger investments, or it may be that the benefits of advanced technology use in these categories are easiest to quantify and, therefore, easiest to justify. Design and engineering, and inspection and communications technologies have higher adoption rates, despite or because of this relaxed justification process.

Establishments consider cost, be it *specific* or *non-specific*, to be an important impediment. They tend to be more concerned, however, with *non-specific cost* problems than with *specific* ones. This holds true for most functional categories, with the exception of inspection and communications. The decisions taken here are especially affected by the *specific cost* factors—those that are either less quantifiable or less predictable.

The most important of the *specific-cost* categories is the *cost of technology acquisition. Technology acquisition cost* includes all those expenses that are associated with the acquisition of knowledge or know-how associated with advanced equipment. Included are payments for licences, patents, trade secrets, or general knowledge in terms of technical support. Its importance as an impediment varies considerably across functional groups. It is most important for fabrication and assembly (30%), moderately so for inspection and communications (23%), and for design and engineering (21%), and insignificant for automated material handling (4%).

The *cost of technology acquisition* category receives about half the emphasis that the *non-specific cost* category does, except for automated material handling. This is in accordance with the previous findings that cost of technology acquisition receives about one-half the emphasis that the cost of equipment does. However, its relative importance varies considerably by category. It is higher in fabrication and assembly as well as inspection and communications. It is lowest in automated material handling.

In the previous section, it was noted that *software development costs* ranked just behind *technology acquisition costs* as an impediment to the acquisition of any technology. In order to examine the software development factors that impede acquisition at the individual technology level, both *costs to develop software* and *time to develop software* were included as separate categories at the functional level. Manufacturing establishments indicate that *time to develop software* is generally perceived to be a greater problem than the out-of-pocket *costs of software development.* For example, establishments using design and engineering technologies, that accounted for 23 percent of shipments, indicated that *time to develop software* is a problem; only 12 percent indicated that direct out-of-pocket *software development costs* are an important impediment. Longer development time, of course, involves other costs—the costs of unused capacity and of lost sales. That time-to-develop is more important than out-of-pocket costs once more emphasizes the problem that firms face with the indirect, less predictable expenses associated with technology acquisition. These costs are among the greatest impediments in design and engineering as well as inspection and communications. Both the design and engineering group and the inspection and communications group are heavily reliant on software that is constantly changing. It is here that *software development time* is particularly important.

Among the other *cost-related* factors, *increased maintenance expense* is unimportant everywhere. Establishments with less than 5 percent of shipments report it as a hindrance. This too parallels the earlier results.

Problems related to worker skills were previously found to be relatively more important than worker attitudes and about one-third the importance of the costs of equipment. For the individual functional technologies, the *cost of training* is more important than *worker uncertainty* for design and engineering and inspection and communications, though not significantly so. In fabrication and assembly, *worker uncertainty* is seen to be a greater problem than the *costs of education and training. Training costs* are given about one-third the importance of *non-specific* costs (as before) for design and engineering as well

Table 18
Significant Factors Hindering Acquisition of Advanced Technology
All Establishments (Shipment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Cost-related	49.6	56.8	57.5	51.5
Non-specific Cost	40.1	47.6	54.5	33.2
Any Specific Cost	27.4	37.0	8.4	32.7
Cost of Technology Acquisition	21.1	30.3	3.7	23.4
Cost to Develop Software	11.8	10.9	6.4	12.0
Cost of Education and Training	13.0	9.4	0.4	8.9
Increased Maintenance Expense	1.3	5.0	1.4	2.2
Lack of Financial Justification	28.0	41.9	51.6	22.4
Labour-related				
Worker Uncertainty	7.9	15.3	7.5	7.9
Other Factors				
Time to Develop Software	22.7	12.9	9.4	21.5
Lack of Technical Support from Vendors	7.5	8.5	13.6	5.4
Need for Market Expansion	3.2	6.1	1.4	3.0
Other	22.9	29.2	31.5	12.7
Not Applicable	28.7	29.9	25.1	35.7
Non-response	8.4	6.1	4.6	10.4

as inspections and communications. However, they are relatively less important as a hindrance to the acquisition of fabrication and assembly technologies, and virtually unimportant for automated material handling technologies.

As was the case previously, the *lack of technical support* is generally perceived to be unimportant as an impediment. For automated material handling, however, *lack of technical support* is one of the more important factors hindering acquisition. At 14 percent, it is behind only *lack of financial justification and other reasons.*

Finally, the *need for market expansion*, a category not previously examined, has little importance. Problems with the small Canadian market and the inability of Canadian establishments to exploit economies of scale associated with the use of certain types of capital equipment sometimes are blamed for the technological backwardness of Canadian plants. The low importance given to the *need for market expansion* indicates that this is not a significant problem.

4.6.3.2 Canadian vs. Foreign Vendors

Establishments purchase advanced technology from both Canadian and foreign vendors. Problems causing delays in technology acquisition may differ between Canadian and foreign sources. In order to investigate this possibility, large establishments were asked for factors hindering acquisition by geographical source—Canadian versus foreign. A comparison of the problems that were encountered is presented in Tables 19 and 20. The tabulations are performed solely for those establishments that evaluated the problems they had for both domestic and foreign sources.

The profiles of the factors hindering technology acquisition are similar in the case of both Canadian-sourced and foreign-sourced technologies. The Pearson correlation coefficients between the problems associated with domestic and foreign sources, are .98 for design and engineering, .92 for fabrication and assembly, .70 for automated material handling, and .98 for inspection and communications.

The *cost-related* categories provide impediments more frequently for domestic acquisitions than for foreign acquisitions for all functional groups with the

Table 19
Significant Factors Hindering Acquisition of Advanced Technology from Canadian Sources
Large Establishments (Shipment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Cost-related	46.4	52.4	23.1	47.2
Non-specific Cost	38.8	32.8	20.1	30.8
Any Specific Cost	22.1	34.1	5.2	28.9
Cost of Technology Acquisition	16.6	28.7	0.5	21.0
Cost to Develop Software	11.2	9.6	3.3	10.5
Cost of Education and Training	11.0	8.7	0.3	7.9
Increased Maintenance Expense	1.0	2.4	1.4	2.2
Lack of Financial Justification	23.8	28.6	19.0	19.6
Labour-related				
Worker Uncertainty	8.0	15.5	7.6	8.0
Other Factors				
Time to Develop Software	14.9	11.7	9.5	20.2
Lack of Technical Support from Vendors	5.0	5.7	11.9	3.8
Need for Market Expansion	2.9	5.5	1.2	2.1
Other	22.7	28.6	31.8	12.0
Not Applicable	18.9	21.9	22.1	24.8
Non-response	11.0	6.7	4.5	11.9

Table 20
Significant Factors Hindering Acquisition of Advanced Technology from Foreign Sources
Large Establishments (Shipment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Cost-related	40.3	50.1	55.4	43.3
Non-specific Cost	31.5	40.8	49.8	26.2
Any Specific Cost	22.0	22.6	7.0	27.4
Cost of Technology Acquisition	18.1	16.7	3.8	20.5
Cost to Develop Software	10.6	9.5	6.1	10.6
Cost of Education and Training	7.8	8.6	0.3	7.8
Increased Maintenance Expense	0.4	4.3	0.0	0.3
Lack of Financial Justification	22.6	38.3	49.6	17.9
Labour-related				
Worker Uncertainty	7.0	14.5	7.5	6.8
Other Factors				
Time to Develop Software	12.3	3.7	5.1	8.8
Lack of Technical Support from Vendors	2.7	5.8	6.2	3.3
Need for Market Expansion	1.1	4.5	1.1	1.8
Other	11.8	13.4	3.0	9.1
Not Applicable	26.9	26.7	22.4	32.6
Non-response	11.5	7.9	11.5	11.7

exception of automated material handling.[13] The *non-specific costs* are significantly higher for domestic suppliers in design and engineering as well as in inspections and communications. In automated material handling, *cost-related factors* and *lack of financial justification* are perceived to be greater impediments for foreign than domestic sources.

The only other area of consistent and significant difference is *software development time*.[14] In fabrication and assembly, automated material handling, and inspection and communications, domestic suppliers have more difficulties with software. In design and engineering, *training costs* and *technical support* are seen to be a significantly greater problem for domestic producers than for foreign producers. In fabrication and assembly, *maintenance costs* are a significantly greater problem for foreign producers, while in inspection and communications they are a significantly greater problem for domestic producers.

4.7 Factors Influencing Acquisition of Advanced Technologies

A distinction is drawn in the survey between those factors that impede technology acquisition in general and factors that influence the brand or type of equipment purchased once the decision to acquire has been made in principle. For this purpose, the decision-making procedure is best represented as a two-stage process. During the first stage, decisions about the use of technology, in general, are made without specific decisions being made about particular vendors or brands of equipment. During the second stage, decisions about particular vendors or brands of equipment are made. The factors that influence the decisions at each stage are not necessarily the same. For example, cost may not be a very important factor at the first stage if the profitability of the new technology is so large that it is sensible to immediately incorporate the technology into the production process. Nevertheless, the vendors' prices may turn out to be important at the second stage if there are differences in prices that lead one vendor's equipment to be preferred to that of another. This section examines whether the factors influencing the decision at the second stage differ from the first.

An establishment's decision to acquire advanced technology at this second stage of the decision-making process will be influenced by a number of factors. An establishment may decide to adopt a technology because it is offered at an attractive price, or because it is easily maintained at a reasonable cost. Both offer purchasers a direct cost saving. Indirect savings are offered by other characteristics. The technology may be particularly familiar to the establishment and, thus, offers savings in terms of learning costs. The vendor or some other party may offer particularly good technical support and, thereby, reduce the risk of unforeseen costs due to mechanical breakdown.

Determining the relative importance of these factors allows us to better understand the process establishments follow in adopting advanced technology. It identifies those areas of greatest concern to the establishment and, alternately, the factors that have little or no influence on the technology decision.

The importance of the following factors for the second stage of the decision-making process was investigated:

- Price
- Internal familiarity with technology
- Better technical support
- Lower maintenance expense
- Lower costs and shorter development time for software
- Ease of communication
- Faster delivery time
- Higher risk in dealing with unfamiliar sources
- Special arrangements
- Other reasons

Some of these categories have also been used to measure the impediments to acquisition at the first stage. Price,[15] maintenance, and software problems were included previously. The other categories—familiarity with technology, delivery time, technical support, and special arrangements—are more specific to the final purchase decision. Whether any of these turn out to have a different importance in the second stage than in the first will depend on whether technology adoption involves a two-stage decision process. If there is only one stage, the emphasis should be the same. It may be that even in the case where there are two distinct stages, the answers are similar. However, different emphases would show that there are two stages in the decision process.

Lower price and *internal familiarity* with a particular technology are the two reasons most often cited as influencing establishments to acquire advanced technology (Table 21). This is true for all but automated material handling technologies, whose users consider *lower maintenance expense* to be much more important than *internal familiarity*. For purchasers in the other three functional groups, *lower price* and *internal familiarity* are equally important, with between one-third and one-half of shipments[16] coming from establishments claiming they are important.

The importance given to both of these categories is consistent with the emphasis on costs as a major impediment to technology acquisition. The emphasis given to the *price of equipment* is not surprising, since it is a primary component of costs. The emphasis given to *internal familiarity* indicates that adoption costs are important. Digesting new technologies requires a firm to implement new organizational forms, train workers, and adjust existing production lines. All of these costs are lower when the technology is well-understood.

For design and engineering, fabrication and assembly, automated material handling, and inspection and communications, two other factors are also significant—*lower maintenance expense* and *better technical support*. The first is an inducement for establishments accounting for between 19 and 50 percent of shipments; the second for those accounting for between 30 and 42 percent of shipments. It is significant that neither of these factors receives the same emphasis in the first part of the decision-making process. While they have only a minor influence on the decision to buy a technology—the first stage of the decision process—they have a much greater influence as to which equipment is purchased—the second stage of the process. Vendors that offer equipment with *better maintenance expense* or which offer *better technical support* are more likely to capture markets. The difference in emphasis that these factors receive substantiates the existence of a two-stage decision process.

Other factors are important, but are specific to functional groups. *Software development* (23%) and *ease of communication* (22%) are significant for design and engineering. Vendors of design and engineering technologies, where CAD/CAE is the leading technology, derive their competitive advantage from software that is easy to adapt and which offers good communication between the product-design and fabrication divisions.

Purchasers of inspection and communications technologies also place a heavy emphasis on both *software development* (29%) and *ease of communication* (32%), as would be expected of technologies which are both software-driven and communications-oriented. Of significance is the fact that ease of *communication* (30%) is also important for

Table 21
Factors Influencing Acquisition of Advanced Technology
All Establishments (Shipment Weighted)

Factor	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Lower price	45.5	53.6	49.5	36.9
Internal familiarity with technology	46.6	53.2	30.4	34.1
Better technical support	42.0	30.8	35.1	32.2
Lower maintenance expense	19.2	35.1	50.2	21.8
Lower costs and shorter time of development of supporting software	23.3	10.6	6.3	28.6
Ease of communication	21.9	29.7	11.4	31.9
Faster delivery time	13.2	12.6	6.7	15.0
Higher risk in dealing with unfamiliar sources	11.2	21.6	6.7	11.5
Special arrangements	10.6	5.0	5.8	10.9
Other	11.9	9.5	8.3	11.8
Non-response	12.1	10.8	12.8	21.9

purchasers of fabrication and assembly technologies. Advanced technologies in almost all areas are driven by the advantages of monitoring and controlling different aspects of the production process. This requires that almost all production divisions must be able to communicate effectively with one another to co-ordinate the process.

Of the four functional groups, adoption of inspection and communications technologies is least influenced by any of the specific factors listed. For all the other groups, half of shipments come from establishments claiming to be influenced by at least one of these factors; it is generally no higher that one-third for inspection and communications. Despite ranking *lower price* as the most important factor, only one-third of plants using inspection and communications claim price to be important. Inspection and communications technologies not only require the least amount of investment per plant (see Section 3.4), they are also less sensitive to a drop in price.

The factors that matter in inspection and communications—*lower price, internal familiarization with a technology, better technical support* and *ease of communication*—are all considered to be about equally important, affecting establishments producing about one-third of shipments. These differences between inspections and communications and the other functional groups are consistent with the earlier results that suggest the evaluation procedure for technologies in this group is inherently more complex and difficult.

4.8 Summary

A firm's technological competitiveness depends upon its ability to identify the technology it needs, to acquire it, and to integrate it into the production process. The quicker that it is able to perform these tasks, the greater will be its capability to position its products in the appropriate price/quality niche that is required to gain or to retain customers.

Pressures associated with the competitive process will determine the length of the adoption or diffusion lag. Those who take too long to adopt best-practice techniques will be driven from business. Those that manage to absorb technologies optimally will gain market share (Baldwin, Diverty, and Sabourin, 1995).

The adoption lag is relatively similar in the different functional groups. More technology-using establishments incorporate advanced technology within one to three years of becoming aware of that technology than for any other time period. Slightly more take less than one year than take more than three years, except for inspection and communications.

Technology adoption is determined by at least three major factors—the effectiveness of the information dissemination process, the size of the benefits associated with those technologies, and the impediments that establishments face in adopting them.

While great stress has been laid upon the nature of the research and development process as a determinant of the success of innovation programs, it is not the *R&D* department that most establishments rely upon for technological adoption. Rather it is the *production engineering* department that takes the lead in providing the key ideas for the adoption of advanced technologies. Other departments are also important—*operations*, *design*, and *management* all generally rank ahead of the *research* department as a source of ideas for new technology.

External sources of information regarding advanced technology come from those sources that are involved in the commercial provision of information—*supplier firms, trade fairs*, and *publications*. Specialized suppliers are also important. *Consultants* fill an important gap and are recognized by the adopters as being almost as important as commercial *suppliers*. Finally, *related firms* (parents or affiliates) play a role in almost half of all establishments. The transmission of knowledge via subsidiary relationships receives just as much importance as commercial sources of information. Information is clearly not perfectly transmitted just via *consultants* and *suppliers* in arm's-length relationships. Special relationships between affiliates are also used to transmit information on the benefits of the technologies and how they need to be integrated into the production process in order to best benefit from them.

The benefits that technologies offer fall into two categories—those that are more tangible and those that are less tangible. The former are easier to quantify and predict; the latter are less easy to quantify and predict before the decision is made to invest in advanced technologies. With regards to tangible benefits, *productivity improvements* are listed as the most important category. These *productivity improvements* arise both because *of reductions in labour requirements* and because of *increased equipment utilization rates*—that is, a reduction in capital required per unit of output. On the intangible side, *product quality improvements* are most often associated with technology adoption. Moreover, establishments note that the importance of intangible effects often rivals that of the tangible effects. Making decisions about the adoption of advanced technologies is particularly difficult when the intangible benefits like *product quality, reductions in rejection rates, greater product flexibility, and reduced set-up time* are so important. To a great extent, these determine the overall benefits from the use of advanced technologies but their benefits are usually best manifested only after adoption. Moreover, the size of the benefits that are associated with these categories do not come solely with the purchase of new equipment; they depend on whether this equipment is integrated successfully into the factory.

On the impediment side, narrowly-defined out-of-pocket costs associated with equipment purchases are found to be the most important impediment to the adoption of advanced technologies. Establishments with about 60 percent of shipments indicate that the *cost of equipment* is an impediment. Of interest is the relative importance of the other categories of costs—those that are less easy to forecast in advance of the purchase decision. Costs associated with *technology acquisition* are about half as important. Costs associated with *software development* are less—about 40 percent as important. In other words, implementing advanced manufacturing technologies does not involve just the purchase of equipment. It involves substantial expenditures on technology for licences, and other know-how. The latter includes the *development of software*, due to the reliance of many of these technologies on computers. In fact, establishments indicated that problems involved with the *time required for software development* were more important than the out-of-pocket *costs of software development*.

There is another set of factors, whose costs are even more difficult to quantify, that also impede technology adoption. They are *labour-related* and *organizational* problems. Costs associated with *skill development* are about 40 percent as important as the *cost of equipment*—posing about the same problem as *software costs*. Implementation of advanced technologies generally increases the skill level required and consequently, increases training costs (Baldwin, Diverty, and Johnson, 1995). Once again, these costs are not always easy to quantify in advance because they depend on the nature of the existing labour force and the ease with which workers can learn how to function with the new equipment.

Training costs are not the only organizational uncertainty. The plant managers who answered the survey noted that there were significant difficulties with *management attitudes* and a need to *introduce important changes to the organization*. These problems are even more difficult to quantify. But they are seen to be just as important as labour-related *training* problems.

The study also finds evidence to support the hypothesis that the acquisition decision is a two-stage process. The first stage involves decisions-in-principle; the second stage, decisions to acquire. Both are heavily influenced by *costs* and *prices*. But there are two areas where differences in emphasis occurred. Both *lower maintenance costs* and *better technical support* influence the decision to acquire but are not regarded as major impediments to the acquisition process.

In summary, the technology adoption process requires firms to evaluate the importance of a number of intangible benefits and a number of cost categories that are difficult to quantify. Dean (1987, p. 11) states:

A primary hindrance to the adoption rate of AMT is the justification process by which firms calculate the financial return to be expected from AMT (or any other capital investment) and decide whether to devote funds to it. In many cases, the justification process determines that AMT does not provide adequate return to justify its cost, and thus it is not pursued ... this outcome is often a function of the intangibility and long-term nature of AMT's benefits, as compared with the very tangible and substantial short-term expenditures required for initial investment in AMT.

While Dean observes that certain benefits from technology adoption are intangible or difficult to quantify, he ignores the fact that a large portion of the costs are equally difficult to predict or quantify. Problems in evaluation exist both on the benefit and on the cost sides. Decisions to acquire technologies require that a number of hard-to-quantify benefits be balanced against an equal number of hard-to-estimate costs. Those who make the correct decisions are able to garner substantial advantages for their companies. They gain market share, and they are able to pay their employees higher wages. They displace the less successful in the market place (Baldwin, Diverty, and Sabourin, 1995).

5. Competitiveness of Technology Users

5.1 Comparison with Producers in Other Countries

Competencies relating to production processes occupy a central place in a firm's business strategy set. They are the key to success. Baldwin et al. (1994) find that the single factor that best discriminates between more- and less-successful small and medium-sized firms is their degree of innovativeness. One of the most important aspects of innovativeness is the technological capability of the firm. As Nelson (1986, p. 453) notes:

Firms that have better routines—production technologies, procedures for choosing alternative mixes of inputs and outputs, pricing rules, investment-project screening rules, mechanisms for allocating the attention of management and the operations research staff, R&D policies, etc.—will tend to prosper and to grow relative to those firms whose capabilities and behaviour are less-suited in the current situation.

Technology strategy is a fundamental determinant of the growth of a firm, its profitability, its efficiency and its competitiveness. A nation's technological competitiveness depends first on the incidence of adoption and secondly on the intensity of use of advanced technologies.

Previous studies have compared the incidence of technology adoption in Canada to that in the United States (McFetridge, 1992). These inter-country comparisons are inherently difficult because the coverage of industries and populations of firms are not the same for surveys done in different countries.[17] More importantly, a comparison of incidence rates presumes that higher incidence is necessarily better. In reality, every industry consists of some firms that can benefit from the use of advanced technologies and some that cannot. The optimal rate of technological use may, therefore, differ across countries.

The alternate strategy that is pursued in this survey is to have industry participants evaluate themselves relative to their competitors on a five-point scale—*1 (much less advanced), 2 (less advanced), 3 (about the same), 4 (more advanced),* and *5 (much more advanced).* While this information stems from self-evaluations, there are several reasons to presume that it provides a reasonable estimate. First, competitive forces constantly require firms to assess themselves against their competitors. Second, the practice of benchmarking means that many firms also carefully assess themselves against industry leaders.

Competitors faced by Canadian establishments are located both within Canada and abroad. In order to investigate technological competitiveness, the evaluation was requested of Canadian establishments with regards to domestic competitors and foreign competitors separately. If foreign competitors are generally more advanced, there should be differences in the evaluations presented for these two groups.

Evaluations are requested only for establishments using the functional technology being investigated. Since not all domestic firms use advanced technologies, the advanced technology users might be expected, on average, to rank themselves as slightly superior to their domestic competitors. However, to the extent that technology users consider their competitors to be mainly other advanced technology-using firms, their evaluations should centre around a value of 3—about the same as their competitors.

The mode of the distributions in all cases is three (Figure 3, panels 1-3).[18] More establishments feel that they are equal to competitors than feel they are either superior or inferior. This occurs both for foreign and domestic competitors.

The mean scores of technology-using establishments in each of the three[19] functional categories are presented in Table 22. For domestic competitors, the mean score within each category is slightly higher than 3—<u>the same as their competitors</u>. The distributions of these scores, which are presented in Figure 3, panels 1-3, are all skewed. A larger proportion of establishments feel that they are superior (more advanced) to domestic competitors than feel they are inferior (less advanced) to domestic competitors. For example, 44 percent of respondents using advanced technologies in design and engineering (Figure 3, panel 1) indicate that their technologies are superior to their domestic counterparts (scores of 4 and above), while only 12 percent feel their technologies are inferior (scores of 2 and below) to them. The difference between those considering themselves

Table 22
Average Competitive Ranking by Functional Group
All Establishments (Establishment Weighted)

	Design and Engineering	Fabrication and Assembly	Inspection and Communications
		(competitiveness score)	
Other Canadian Producers	3.4	3.3	3.2
Producers Abroad	3.0	3.0	2.8

more- and less-advanced is significant.[20] These differences are also significant for fabrication and assembly, and inspection and communications.

Manufacturing establishments that are technology users do not perceive themselves to have the same advantage over foreign competitors. But neither do they feel that they are generally behind. The average score for their competitiveness compared to foreign producers is slightly lower than for their position relative to domestic competitors, though not significantly so. The mean score in the former case tends to be about 3.0—*the same as their competitors*—compared to about 3.3 in the latter case (Table 22). Between 35 and 45 percent of technology users, depending on the functional group, feel they are equally advanced as their foreign competitors. The rest are more or less equally distributed between those who feel they are superior to foreign competitors and those who feel they are behind.

In contrast to the distribution for domestic competitors, these distributions are not significantly skewed. A slightly larger proportion of manufacturing establishments feel they are behind their foreign competitors than feel they are ahead. However, these differences are not significant—except for inspection and communications equipment.

While there is little evidence that more establishments are behind their international competitors than are ahead, it may be the case that shipments are not equally distributed into those coming from plants that are more-advanced and those that are less-advanced than foreign competitors. If the larger establishments are behind and the smaller are ahead, then most production will come from plants that are uncompetitive.

In order to assess this possibility, the distribution of shipments for the three groups is depicted in Figure 4. Generally, there is a larger percentage of shipments in establishments that are ahead of competitors than are behind—32% versus 24% in design and engineering, 33% versus 22% in inspection and communications, and 52% versus 22% for automated material handling. Only in fabrication and assembly is the reverse the case. Here 37% of shipments are in plants that are less competitive and only 31% are more competitive. Since all of these distributions are more heavily concentrated in the more-advanced classes when shipment weights are used than when establishment weights are used, it is the larger plants that tend to be more competitive internationally.

5.2 Differences Between More- and Less-Advanced Technology Users

While Canadian technology-users may not consider themselves, on average, to be behind their foreign competitors, there is a significant dispersion in their competitive position. About 40 percent consider themselves to be about the same as their competitors; while some one-third consider themselves to be behind and one-quarter consider themselves to be ahead.

Differences in the technological characteristics between those establishments who consider themselves more- and less-advanced serve to outline the nature of the deficiencies suffered by the less-advanced establishments. These differences can be measured either in terms of the incidence of technology, the intensity of technology use, the diffusion lag, or any of the other characteristics that have been described. Such a comparison serves to indicate the extent to which establishments perceive that their own competitive advantage or disadvantage is related to their investment in technology.

Figure 3 Panel 1
Distribution of Competitiveness Scores for Design and Engineering
(Establishment Weighted)

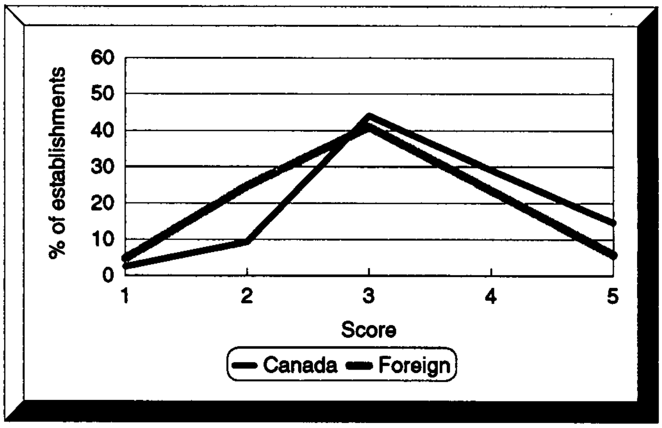


Figure 3 Panel 2
Distribution of Competitiveness Scores for Fabrication and Assembly
(Establishment Weighted)

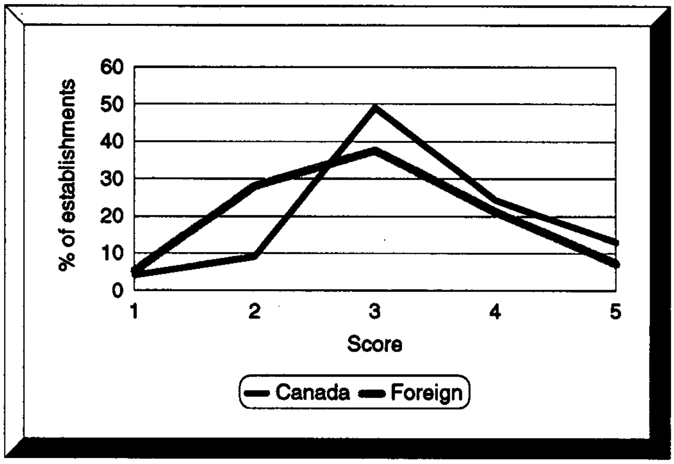


Figure 3 Panel 3
Distribution of Competitiveness Scores for Inspection and Communications
(Establishment Weighted)

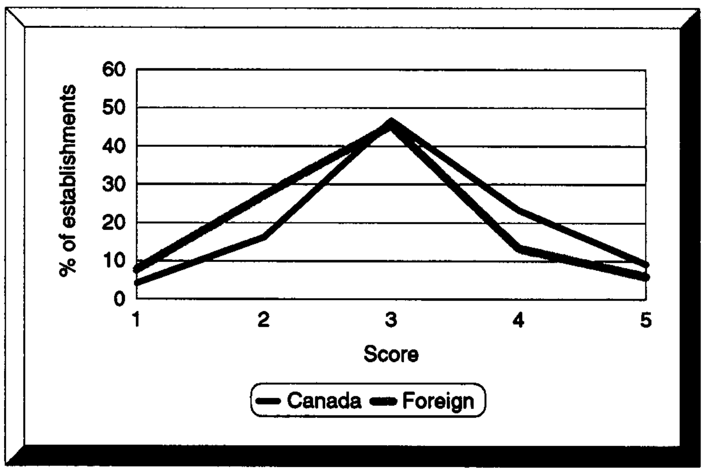
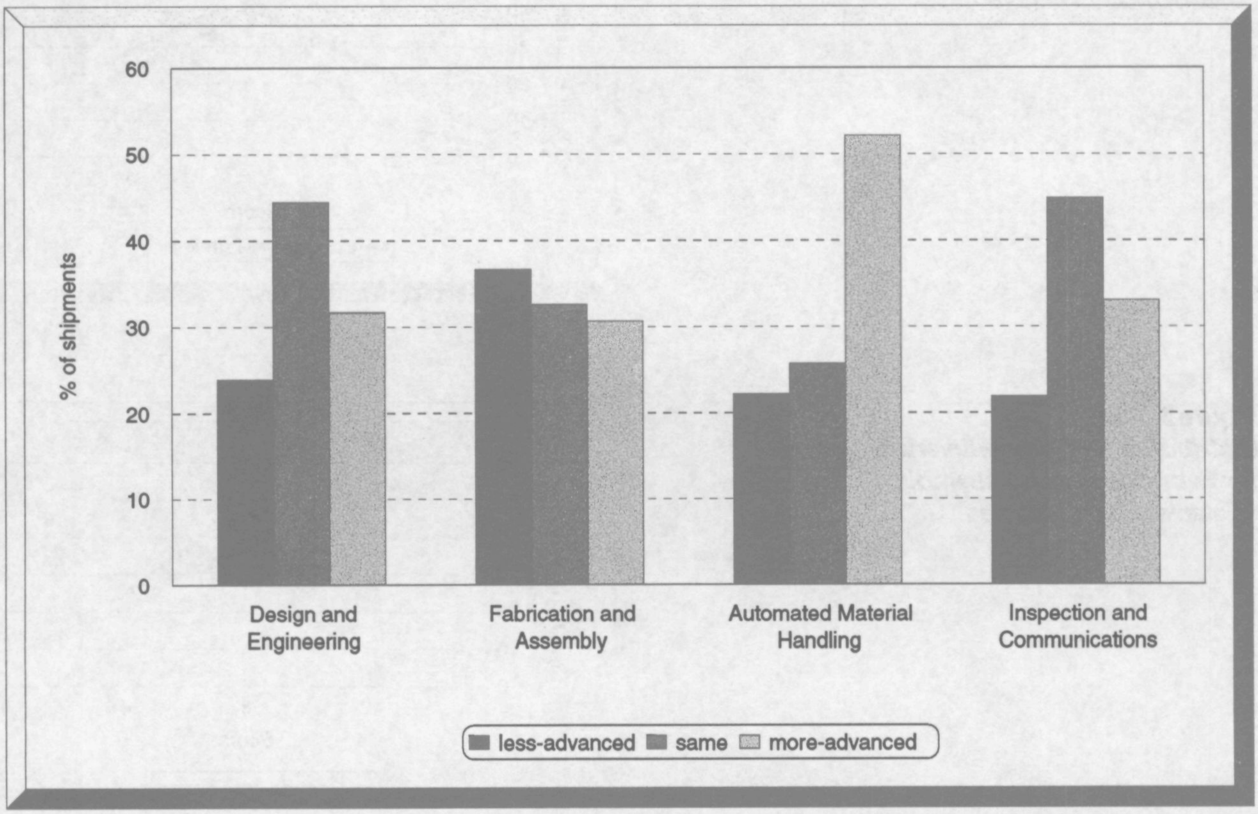


Figure 4
Distribution of Shipments by Competitive Ranking Against Foreign Competitors
(Shipment Weighted)



To examine these differences, technology-using establishments are divided into those considering themselves *more-advanced*, *less-advanced* and *about the same* as their foreign competitors. The technological intensity of the more-advanced and less-advanced establishments is compared. Most of these comparisons are done at the functional technology level, i.e., the categorization of more- or less-advanced is done for each functional technology category.

The competitiveness assessment scores are used to create the two groups. Less-advanced establishments are classified as those with a score of either 1—*much less advanced* or 2—*less advanced*. More-advanced establishments are those with scores of 4—*more advanced* or 5—*much more advanced*. In most cases, the assessment of competitiveness at the functional level (e.g., design and engineering) is used to investigate a particular characteristic, such as the diffusion lag for design and engineering technologies. This is the most appropriate assessment technique for reporting characteristics that differ substantially by functional group.

In other cases, the assessment of the technological status of an establishment is done not at the individual functional technology level but for all functional technologies taken together. This is done by summing the scores over all functional technology groups. These aggregate scores range from 4 to 20. The scores are then used to divide the sample into three equal-sized groups or tertiles. The bottom and top tertiles are used to represent the less- and more-advanced groups of establishments, respectively. This technique is used when the results are basically similar at the functional technology level or when an overview is required.

5.2.1 Incidence of Use at the Individual Technology Level

For the purpose of evaluating the incidence of individual technology use, establishments are divided into more- and less-advanced groups using their competitive scores summed over all functional groups. The more-advanced group uses, on average, 9.4 advanced technologies; the less-advanced group only 4.5 technologies. The more-advanced group has a higher incidence rate for all of the 22 individual technologies (Table 23). Some 89 percent of the more-advanced group use CAD/CAE technologies; while only 59 percent of the less-advanced use them. The difference between the incidence of CAD/CAE use in the two groups is some 30 percentage points. Large percentage point differences also exist for most of the other individual technologies. These differences are largest for the inspection and communications functional group where most are in the 30 and 40 percentage point range. They are lowest in the fabrication and assembly group. Integrated technologies, such as computer integrated manufacturing and supervisory control and data acquisition also demonstrate substantial differences.

Table 23
Advanced Technology Use by Individual Technology
All Establishments (Shipment Weighted)

Individual Technology	Competitive Position		
	More Advanced	Less Advanced	Difference
	(percentage of shipments)		*(percentage points)*
Design and Engineering			
CAD/CAE	89.3	58.8	30.5 *
CAD/CAM	38.5	13.9	24.6 *
Digital Representation of CAD Output	38.7	7.8	30.9 *
Fabrication and Assembly			
Flexible Manufacturing Cells/Systems	36.5	15.0	21.5 *
Numerically Controlled Machines	44.1	28.4	15.7 *
Materials Working Lasers	20.0	3.8	16.2 *
Pick and Place Robots	43.5	19.8	23.7 *
Other Robots	24.3	21.6	2.7
Automated Material Handling			
Automated Storage/Retrieval Systems	42.1	15.5	26.6 *
Automated Guided Vehicle Systems	31.6	7.4	24.2 *
Inspection and Communications			
Automatic Inspection Equipment - Inputs	64.4	21.4	43.0 *
Automatic Inspection Equipment - Outputs	76.6	35.2	41.4 *
Local Area Network for Technical Data	78.8	22.5	56.3 *
Local Area Network for Factory Use	80.4	32.5	47.9 *
Inter-Company Computer Network	65.2	26.1	39.1 *
Programmable Controllers	84.7	68.5	16.2 *
Computers Used for Control in Factories	85.4	54.4	31.0 *
Manufacturing Information System			
Materials Requirement Planning	81.8	60.3	21.5 *
Manufacturing Resource Planning	70.4	30.0	40.4 *
Integration and Control			
Computer Integrated Manufacturing	63.4	17.8	45.6 *
Supervisory Control and Data Acquisition	71.2	36.0	35.2 *
Artificial Intelligence	17.7	7.2	10.5 *

* *Results are statistically significant at the 5% level*

5.2.2 *Incidence and Intensity of Use by Functional Category*

In order to examine differences in the characteristics of more-advanced and less-advanced plants within each functional level, establishments are divided into the less- and more-advanced groups based on their scores for each functional category. Differences in the average number of technologies used exist for each functional grouping (Table 24). The more-advanced group, based on competitive evaluations specific to design and engineering, use 2.1 design and engineering technologies, on average; the less-advanced use only 1.3. The more-advanced group in inspection and communications use 5.8 technologies, on average; the less-advanced group only 3.1 technologies. The differences in incidence of use are associated with substantial differences in intensity of use. The more-advanced establishments are not only more likely to use a technology, they use that technology more intensively. The percentage of investment in each functional grouping that is accounted for by advanced technologies is higher for the more-advanced group (Table 25).

The more-advanced group puts 50 percent of its design and engineering investments into advanced technologies; the less-advanced group puts only 27 percent into advanced design and engineering technologies—for a difference of 23 percentage points. The differences for fabrication and assembly, and inspection and communications are 32, and 18 percentage points, respectively.

The investment level of the more-advanced group, by itself, is of interest. An earlier section noted that the average intensity of investment by functional category is relatively low—with the fabrication and assembly category highest at 52 percent (Table 6). One explanation for these relatively low percentages is that the advanced technologies being measured here may not be appropriate in many situations. However, the level of investment in the more-advanced fabrication and assembly group suggests this argument is not compelling. While those who feel they are *about the same* as their foreign competitors in fabrication and assembly put 53 percent[21] of investment into the advanced technologies being examined here, those who are more competitive put 75 percent (Table 25) into them.

However, in inspection and communications as well as design and engineering, even the intensity of investment percentages for those who are more-advanced are only in the 50 percent range. Here, there is still room for expansion of these technologies even for those who consider themselves to be the most-competitive.

Table 24
Number of Technologies Used by Functional Group
All Establishments (Shipment Weighted)

Functional Technology	Competitive Position		
	More Advanced	Less Advanced	Difference
		(number of technologies)	
Design and Engineering	2.1	1.3	0.8 *
Fabrication and Assembly	2.3	2.0	0.3 *
Inspection and Communications	5.8	3.1	2.7 *

** Results are statistically significant at the 5% level.*

Table 25
Intensity of Investment by Functional Group
All Establishments (Shipment Weighted)

Functional Technology	Competitive Position		
	More Advanced	Less Advanced	Difference
	(percentage of shipments)		*(percentage points)*
Design and Engineering	50.2	27.1	23.1 *
Fabrication and Assembly	74.5	42.7	31.8 *
Inspection and Communications	51.3	32.9	18.4 *

** Results are statistically significant at the 5% level.*

Greater intensity of investment in advanced technologies is accompanied by larger investments per plant in the advanced technologies. Tables 26 to 28 depict the percentage distribution of plants by the size of the investment per plant in advanced technologies for each of the three functional groups. The less-advanced producers have smaller-sized investments than do the more-advanced group.[22] For example, in design and engineering, 46 percent of the less-advanced spend less than $100,000 per plant; only 15 percent of the more-advanced spend less than $100,000 per plant (Table 26). In fabrication and assembly, 82 percent of the more-advanced spend more than $1 million per plant; only 60 percent of the less-advanced spend this amount (Table 27).

Table 26
Investment in Advanced Design and Engineering Technologies
Large Establishments (Shipment Weighted)

Cost Category	More Advanced	Less Advanced
	(percentage of shipments)	
Less than $100,000	14.9	46.4
$100,000 - $1 million	20.5	46.1
$1 million or more	63.5	5.4
Not applicable	0.9	1.1
Non-response	0.2	1.0

Table 27
Investment in Advanced Fabrication and Assembly Technologies
Large Establishments (Shipment Weighted)

Cost Category	More Advanced	Less Advanced
	(percentage of shipments)	
Less than $100,000	9.8	12.8
$100,000 - $1 million	6.4	21.7
$1 million or more	81.9	59.7
Not applicable	0.8	0.8
Non-response	1.1	5.0

Table 28
Investment In Advanced Inspection and Communications Technologies
Large Establishments (Shipment Weighted)

Cost Category	More Advanced	Less Advanced
	(percentage of shipments)	
Less than $100,000	14.5	22.6
$100,000 - $1 million	21.3	39.4
$1 million or more	61.3	18.9
Not applicable	0.4	12.5
Non-response	2.5	6.6

5.2.3 Diffusion Lag by Functional Category

Establishments that are more advanced than their competitors are not only more likely to use a technology, to use it more intensively and to spend more on it; they are also quicker to adopt it. The distribution of the less- and more-advanced group by the length of diffusion lag is presented in Tables 29 to 31.[23] More-advanced establishments are more likely to have a short adoption lag, while less-advanced establishments are more likely to have a longer adoption lag. For example, 46 percent of the more-advanced adopt their design and engineering technologies within a year compared to only 18 percent of the less-advanced group. Some 51 percent of the more-advanced adopt their fabrication and assembly technologies within a year, while only 10 percent of the less-advanced group do so. The advantage in inspection and communications technologies is not as dramatic. In fact, very few establishments, be they more-advanced or less-advanced, have an adoption lag of less than one year for inspection and communications technologies. More-advanced establishments, however, are more likely to adopt these technologies within three years—73 percent for the more-advanced compared to 56 percent for the less-advanced.

Table 29
Diffusion Lag for Design and Engineering Technologies
All Establishments (Shipment Weighted)

Time Period	More Advanced	Less Advanced
	(percentage of shipments)	
Less than 1 Year	46.1	17.7
1 - 3 Years	33.1	43.7
More than 3 Years	19.6	36.0
Non-response	1.2	2.6

Table 30
Diffusion Lag for Fabrication and Assembly Technologies
All Establishments (Shipment Weighted)

Time Period	More Advanced	Less Advanced
	(percentage of shipments)	
Less than 1 Year	50.9	10.3
1 - 3 Years	43.2	44.7
More than 3 Years	4.9	43.0
Non-response	1.0	2.0

Table 31
Diffusion Lag for Inspection and Communications Technologies
All Establishments (Shipment Weighted)

Time Period	More Advanced	Less Advanced
	(percentage of shipments)	
Less than 1 Year	5.8	13.5
1 - 3 Years	66.8	42.4
More than 3 Years	25.4	31.9
Non-response	2.0	12.2

5.2.4 Source of Equipment by Functional Category

Advanced technologies are available from both domestic and foreign sources. At issue is the extent to which the more-advanced group concentrates its acquisitions particularly on one or another source.

Establishments that are more-advanced than their foreign competitors are more likely to use advanced technologies. Therefore, the percentage of the more-advanced establishments that use technologies from any particular regional source is likely to be higher than the percentage of less-advanced establishments that do so. It is the relative usage of different sources that indicates whether the more-advanced make relatively greater use of one source, Canadian producers for example, than they do of others—American, European or Pacific Rim sources.

The regional sources for more- and less-advanced establishments are presented in Tables 32-34. In the case of inspection and communications technology users, the more-advanced group make relatively greater use of Canadian sources than does the less-advanced group (Table 34). The more-advanced group use Canadian sources 91 percent as frequently as they do American sources;[24] the less-advanced group use Canadian sources only 70 percent as frequently. In the case of design and engineering technologies, Canadian sources are used just as frequently relative to American sources by the more-advanced group as by the less-advanced group (Table 32). By way of contrast, the more-advanced establishments are relatively less likely to use Canadian technologies in the fabrication and assembly area (Table 33).

Table 32
Regional Sources for Design and Engineering Technologies
Large Establishments (Shipment Weighted)

Regional Source	Competitive Position		
	More Advanced	Less Advanced	Difference
	(percentage of shipments)		*(percentage points)*
Canada	80.3	53.6	26.7
United States	89.1	62.9	26.2
Europe	29.1	17.9	11.2
Pacific Rim	17.1	3.6	13.5
Non-response	1.0	2.1	n/a

Table 33
Regional Sources for Fabrication and Assembly Technologies
Large Establishments (Shipment Weighted)

Regional Source	Competitive Position		
	More Advanced	Less Advanced	Difference
	(percentage of shipments)		*(percentage points)*
Canada	28.7	42.1	-13.4
United States	85.7	66.2	19.5
Europe	13.1	41.8	-28.7
Pacific Rim	47.6	44.5	3.1
Non-response	1.6	3.3	n/a

Table 34
Regional Sources for Inspection and Communications Technologies
Large Establishments (Shipment Weighted)

Regional Source	Competitive Position		
	More Advanced	Less Advanced	Difference
	(percentage of shipments)		*(percentage points)*
Canada	78.0	43.5	34.5
United States	85.7	62.7	23.0
Europe	48.0	18.3	29.7
Pacific Rim	15.9	1.6	14.3
Non-response	2.3	11.1	n/a

5.3 Benefits from Technology Use

The more-advanced technology users might be expected to reap the benefits of greater incidence and greater intensity of use. In order to test this, the benefits of technology use were tabulated for those technology users who were generally more-advanced and those who were generally less-advanced across *all* functional technology groups. The percentages of each group that indicated a specific benefit accrued to them from technology use are tabulated in Table 35.

Generally, a larger percentage of the more-advanced group indicate that they enjoy a particular benefit from the adoption of advanced technologies than do the less-advanced group. Over 80 percent of the more-advanced attribute an *improvement in productivity* to the use of advanced technologies; about 50 percent do so in the less-advanced group—a difference of 30 percentage points. Productivity differences occur basically because of *reductions in labour requirements* and from *increased equipment utilization rates.* There is a 23 percentage point difference between the groups with respect to the impact of technology adoption on *reducing labour requirements* and a 41 percentage point difference between them in terms of *improved equipment utilization rates.*

Another large difference between the two groups—some 36 percentage points—is to be found in the extent to which technology use leads to *greater product flexibility.* Associated with this are smaller but significant differences between the more- and less-advanced groups with respect to the benefits associated with *reductions in the product rejection rate* and *in improvements in product quality,* some 17 percentage points and 25 percentage points, respectively.

Finally, the adoption of technology is seen to lead more frequently to *increases in skill requirements* and *improvements in working conditions.* Advanced technologies require higher skill levels. The more advanced the technologies, the higher are these skill levels. Accompanying the introduction of advanced technologies comes improved working conditions.

Table 35
Benefits and Effects from Advanced Technology Use
All Establishments (Shipment Weighted)

Result	Competitive Position		
	More Advanced	Less Advanced	Difference
	(percentage of shipments)		*(percentage points)*
Tangible :			
Improvements in Productivity	82.2	50.7	31.5*
Reduction in Labour Requirements	61.7	38.3	23.4*
Reduction in Material Consumption	25.5	9.1	16.4*
Reduction in Energy Consumption	20.5	13.6	6.9
Increased Equipment Utilization Rate	58.8	17.9	40.9*
Increased Capital Requirements	62.3	24.8	37.5*
Reduced Capital Investments	6.2	4.3	1.9
Lower Inventory	5.6	21.0	-15.4*
Intangible :			
Improvement in Product Quality	40.6	16.1	24.5*
Increased Skill Requirements	72.4	35.1	37.3*
Reductions in Product Rejection Rate	26.8	10.3	16.5*
Reduced Set-up Time	60.5	23.3	37.2*
Greater Product Flexibility	56.9	21.3	35.6*
Improved Working Conditions	41.1	21.8	19.3*
Reduced Environmental Damage	1.3	11.6	-10.3*
Reduced Skill Requirements	20.3	3.1	17.2*
Other :			
Other	0.9	3.9	-3.0
Non-response	3.5	27.1	n/a

* *Results are statistically significant at the 5% level.*

5.4 Summary

Canadian manufacturing establishments that are more-advanced technologically than their foreign competitors differ substantially from the less technologically advanced. The more-advanced group use more technologies and invest in them more heavily. The more-advanced group also have a shorter diffusion lag. They are able to react more quickly to information about new developments and put the new technologies in place more quickly.

The more-advanced group benefit from this greater technological intensity. They are much more likely to indicate that they obtained both tangible and intangible benefits from the adoption of advanced technologies. Productivity increases, due both to savings on labour and capital inputs, are more likely to accrue to the more-advanced technology users. They also are greater beneficiaries from product quality improvements. Finally, these establishments are more actively involved in skill upgrading.

Appendix A - Definition of Terms

Computer-Aided Design and Engineering (CAD/CAE): Use of computers for drawing and designing parts or products for analysis and testing of designed parts or products.

Computer-Aided Design for Computer-Aided Manufacturing (CAD/CAM): Use of CAD output for controlling machines used to manufacture the part or product.

Digital Data Representation: Use of digital representation of CAD output for controlling machines used to manufacture the part or product.

Flexible Manufacturing Cells (FMC): Machines with fully integrated material handling capabilities controlled by computers or programmable controllers, capable of single path acceptance of raw material and delivery of finished product.

Flexible Manufacturing Systems (FMS): Two or more machines with fully integrated material handling capabilities controlled by computers or programmable controllers, capable of single or multiple acceptance of raw material and multiple path delivery of finished product.

NC/CNC Machines: A single machine either numerically controlled (NC) or computer numerically controlled (CNC) with or without automated material handling capabilities. NC machines are controlled by numerical commands, punched on paper or plastic mylar tape while CNC machines are controlled electronically through a computer residing in the machine.

Materials Working Laser(s): Laser technology used for welding, cutting, treating, scribing and marking.

Robots: A reprogrammable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks.

Pick and Place Robots: A simple robot, with one, two or three degrees of freedom, which transfers items from place to place by means of point-to-point moves. Little or no trajectory control is available.

Automated Storage and Retrieval System (AS/RS): Computer-controlled equipment providing for the automatic handling and storage of materials, parts, sub-assemblies or finished products.

Automated Guided Vehicle Systems (AGVS): Vehicles equipped with automatic guidance devices programmed to follow a path that interfaces with work stations for automated or manual loading and unloading of materials, tools, parts or products.

Automatic Inspection Equipment-Inputs: Automated sensor-based equipment used for inspecting and/or testing incoming or in-process materials.

Automatic Inspection Equipment-Final Products: Automated sensor-based equipment used for inspecting and/or testing final products.

Technical Data Network: Use of local area network (LAN) technology to exchange technical data within design and engineering departments.

Factory Network: Use of local area network (LAN) technology to exchange information between different points on the factory floor.

Inter-Company Computer Networks: These are wide area networks that connect establishments with their sub-contractors, suppliers and customers.

Programmable Controller: A solid state industrial control device that has programmable memory for storage of instructions, which performs functions equivalent to a relay panel or wired solid state logic control system.

Computers Used for Control on the Factory Floor: This excludes computers imbedded within machines or computers used solely for data acquisition or monitoring. It includes computers on the factory floor that may be dedicated to control, but which are capable of being reprogrammed for other functions.

Materials Requirement Planning (MRP): Computer-based production management and scheduling system to control order quantities, inventory and finished goods.

Manufacturing Resource Planning (MRP II): A development of MRP for computer-based production management of machine loading and production scheduling, as well as inventory control and material handling.

Computer Integrated Manufacturing (CIM): Totally automated production, in which all manufacturing processes are integrated and controlled by a central computer.

Supervisory Control and Data Acquisition (SCADA): On line, computer-based monitoring and control of process and plant variables at a central site.

Artificial Intelligence (AI): The ability of a machine to learn from experience and perform tasks normally attributed to human intelligence, e.g., problem solving, reasoning, and understanding natural language.

Expert Systems: The computerization of knowledge of experts in narrowly defined fields, such as fault finding and designing.

Appendix B - Standard Error Estimates

This appendix provides standard errors for the tables in sections three and four in the publication.

Table B.1
Standard Errors for Table 4
Adoption Rates by Functional Technology Group
All Establishments (Shipment Weighted)

Functional Technology	Use
	(percentage of shipments)
Design and Engineering	2.7
Fabrication and Assembly	4.3
Automated Material Handling	3.8
Inspection and Communications	2.8

Table B.2
Standard Errors for Table 5
Use and Planned Use of Advanced Technology
All Establishments (Shipment Weighted)

Individual Technology	In Use	Plan to Use Within 2 Years	No Plans to Use	Length of Use
	(percentage of shipments)			*(years)*
Design and Engineering				
CAD/CAE	2.8	1.2	2.5	0.8
CAD/CAM	4.1	2.5	4.2	1.5
Digital Representation of CAD Output	4.0	1.7	4.0	0.6
Fabrication and Assembly				
Flexible Manufacturing Cells/Systems	4.0	2.1	4.2	1.0
Numerically Controlled Machines	3.9	1.0	3.8	1.2
Materials Working Lasers	2.9	2.5	3.5	0.7
Pick and Place Robots	4.0	2.5	4.6	0.9
Other Robots	3.5	1.5	4.3	0.6
Automated Material Handling				
Automated Storage/Retrieval Systems	3.9	2.0	4.0	0.5
Automated Guided Vehicle Systems	3.9	1.9	4.2	0.7
Inspection and Communications				
Automatic Inspection Equipment - Inputs	4.3	1.5	4.5	1.5
Automatic Inspection Equipment - Outputs	3.8	1.1	3.5	1.0
Local Area Network for Technical Data	3.8	1.7	3.7	0.8
Local Area Network for Factory Use	4.3	2.3	3.3	0.7
Inter-Company Computer Network	4.9	2.6	4.1	0.3
Programmable Controllers	3.2	1.7	2.8	0.6
Computers Used for Control in Factories	3.3	1.5	2.8	0.8

Table B.3
Standard Errors for Table 6
Intensity of Investment in Advanced Technology by Functional Group
All Establishments (Establishment and Shipment Weighted)

Functional Group	Establishment Weighted	Shipment Weighted
	(percentage of establishments)	*(percentage of shipments)*
Design and Engineering	2.3	5.6
Fabrication and Assembly	2.9	6.7
Automated Material Handling	3.0	16.1
Inspection and Communications	1.7	5.9

Table B.4
Standard Errors for Table 7
Total Investment in Advanced Technology
Large Establishments (Shipment Weighted)

Cost Category	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Less than $100,000	4.1	3:3	5.2	3.1
$100,000 - $1 million	4.4	4.0	4.8	3.5
$1 million - $5 million	4.6	6.9	15.6	4.3
$5 million - or more	6.9	8.5	8.7	6.0
Not applicable	0.5	0.8	1.3	1.2

Table B.5
Standard Errors for Table 8
Planned Use of Advanced Technology by Functional Group
All Establishments (Shipment Weighted)

Functional Group	Planned Use All Cases	Functional Group Not in Current Use
	(shipment percentage points)	
Design and Engineering	2.8	1.1
Fabrication and Assembly	3.7	1.7
Automated Material Handling	2.3	1.2
Inspection and Communications	3.2	0.6

Table B.6
Standard Errors for Table 9
Plans to Upgrade Existing Advanced Technology
All Establishments (Shipment Weighted)

Extent of Planned Upgrade	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Total Replacement (75% or more)	2.9	1.1	0.2	1.1
Major Upgrade (25% to 74%)	6.1	8.2	16.1	5.5
Minor Upgrade (less than 25%)	3.9	4.6	10.4	4.0
Under Consideration	4.4	4.1	4.1	3.8
None	1.7	1.1	4.0	1.9

Table B.7
Standard Errors for Table 10
Regional Sources of Advanced Technology
Large Establishments (Shipment Weighted)

Regional Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Canada	5.3	6.4	11.9	4.7
United States	3.7	5.6	11.1	4.2
Europe	4.7	6.8	8.6	6.3
Pacific Rim	4.0	9.1	1.5	3.4

Table B.8
Standard Errors for Table 12
Diffusion Lag of Advanced Technology by Functional Group
All Establishments (Shipment Weighted)

Time Period	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Less than 1 year	6.1	8.6	7.2	3.2
1 - 3 years	5.1	6.7	9.4	4.9
3 - 5 years	4.5	5.6	2.5	4.1
More than 5 years	0.8	2.3	1.1	1.0

Table B.9
Standard Errors for Table 13
Diffusion Lag of Advanced Technology by Functional Group and Employment Size
All Establishments (Shipment Weighted)

Time Period	Design and Engineering		Fabrication and Assembly		Inspection and Communications	
	0-249 employees	250 + employees	0-249 employees	250 + employees	0-249 employees	250 + employees
	(percentage of shipments)					
Less than 1 year	1.3	6.0	1.6	8.4	0.8	3.1
1 - 3 years	1.3	4.9	1.3	6.6	1.4	4.7
3 - 5 years	1.1	4.4	1.1	5.5	1.1	4.0
More than 5 years	0.4	0.7	0.9	2.1	0.6	0.8

Table B.10
Standard Errors for Table 14
Principal Internal Sources of Ideas for Adoption of Advanced Technology
Large Establishments (Shipment Weighted)

Internal Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of shipments)			
Research	6.4	4.1	0.6	3.1
Experimental Development	4.9	8.7	6.4	6.2
Design Work	5.6	5.9	6.8	4.0
Production Engineering	5.6	6.6	10.6	5.3
Operating Staff	6.2	7.2	10.1	4.6
Management	6.2	7.9	16.2	5.3
Corporate Head Office	6.2	4.2	8.2	5.3
Other	1.4	1.2	1.4	1.3

Table B.11
Standard Errors for Table 15
Principal External Sources of Ideas for Adoption of Advanced Technology
Large Establishments (Shipment Weighted)

External Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of shipments)			
A Related Firm (with same parent firm)	5.8	7.7	15.7	5.2
An Unrelated Firm	2.5	3.2	7.0	2.2
Government Laboratories	0.4	0.6	0.0	1.3
University Laboratories	3.0	4.0	0.2	1.0
Provincial Research Organization	0.5	1.1	0.4	1.3
Industrial Research Firms	6.5	3.4	2.6	5.7
Research Consortia	2.8	1.0	1.8	1.4
Consultants and Service Firms	5.2	6.0	10.7	4.6
Joint Ventures and Strategic Alliances	3.6	2.9	2.3	1.7
Publications	5.3	7.1	13.5	5.4
Trade Fairs, Conferences	5.4	7.2	12.7	5.5
Customer Firms	3.3	1.8	1.0	1.0
Supplier Firms	5.3	7.1	9.4	5.3
There was no Significant External Input	1.7	2.0	0.7	1.0
Other	4.0	5.6	2.6	3.5

Table B.12
Standard Errors for Table 16
Effects Caused by Acquisition of Advanced Technology
All Establishments (Shipment Weighted)

Effect	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
TANGIBLE:				
Improvements in Productivity	4.0	4.9	8.6	4.5
Reduction in Labour Requirements	5.5	5.8	14.5	4.2
Reduction in Material Consumption	4.5	6.5	5.9	2.8
Reduction in Energy Consumption	3.9	5.9	3.7	2.8
Increased Equipment Utilization Rate	6.7	7.8	13.2	5.9
Increased Capital Requirements	6.2	6.9	12.8	5.7
Reduced Capital Investments	1.5	3.9	3.9	1.3
Lower Inventory	2.9	7.5	6.9	4.1
INTANGIBLE:				
Improvement in Product Quality	5.3	6.5	13.0	4.7
Increased Skill Requirements	5.1	6.8	12.6	5.0
Reduction in Product Rejection Rate	4.1	6.5	13.9	5.2
Reduced Set-up Time	6.0	7.0	15.3	2.5
Greater Product Flexibility	6.1	7.2	13.8	3.4
Improved Working Conditions	6.1	7.4	12.7	5.3
Reduced Environmental Damage	1.5	8.3	3.0	2.3
Reduced Skill Requirements	4.0	6.0	3.7	3.4
OTHER:				
Other	0.8	0.5	0.0	0.8

Table B.13
Standard Errors for Table 17
Significant Impediments to Advanced Technology Acquisition
All Establishments (Shipment Weighted)

Impediment	Users	Non-Users	Combined
	(percentage of shipments)		
COST-RELATED PROBLEMS	**1.9**	**2.6**	**1.7**
Lack of Financial Justification	**4.4**	**3.1**	**3.6**
Investment-related Costs	**2.4**	**2.9**	**2.1**
Cost of Capital	4.5	3.1	3.6
High Cost of Equipment	4.1	3.0	3.4
Costs to Develop Software	4.0	1.6	3.3
Increased Maintenance Expenses	3.6	1.8	2.9
Cost of Technology Acquisition	4.1	2.2	3.3
Institution-related	**3.6**	**2.2**	**3.0**
Tax Regime: R&D Investment Tax Credits	3.2	1.9	2.6
Tax Regime: Capital Cost Allowances	3.3	1.0	2.7
Government Regulations and Standards	2.0	1.5	1.6
LABOUR-RELATED PROBLEMS	**4.3**	**2.3**	**3.4**
Shortage of Skills	3.8	1.9	3.1
Training Difficulties	3.6	1.8	2.9
Labour Contracts	2.7	1.5	2.1
ORGANIZATIONAL OR STRATEGIC PROBLEMS	**4.2**	**2.1**	**3.4**
Difficulties in Introducing Important Changes to the Organization	3.9	1.9	3.1
Management Attitude	3.7	1.4	3.0
Worker Resistance	2.0	1.4	1.6
INFORMATION-RELATED PROBLEMS	**4.0**	**2.4**	**3.3**
Lack of Scientific and Technical Information	3.7	2.3	3.0
Lack of Technological Services	2.3	1.6	1.9
Lack of Technical Support from Vendors	2.1	2.0	1.8
OTHER PROBLEMS	**5.1**	**2.6**	**4.0**
Other	5.1	2.6	4.0

Table B.14
Standard Errors for Table 18
Significant Factors Hindering Acquisition of Advanced Technology
All Establishments (Shipment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Cost-related	5.4	6.6	13.1	4.7
Non-specific Cost	5.2	7.3	13.7	4.3
Any Specific Cost	4.9	8.3	4.1	5.7
Cost of Technology Acquisition	4.6	8.7	2.7	6.0
Cost to Develop Software	4.4	5.4	3.7	4.0
Cost of Education and Training	4.4	5.4	0.3	3.5
Increased Maintenance Expense	0.4	1.8	0.8	1.4
Lack of Financial Justification	4.1	7.4	14.0	3.1
Labour-related				
Worker Uncertainty	3.9	6.0	5.8	3.5
Other Factors				
Time to Develop Software	6.7	5.5	4.5	6.1
Lack of Technical Support from Vendors	1.8	2.3	6.1	1.3
Need for Market Expansion	0.9	1.5	0.7	0.9
Other	6.7	8.7	18.7	3.7
Not Applicable	3.0	4.8	7.3	3.3

Table B.15
Standard Errors for Table 19
Significant Factors Hindering Acquisition of Advanced Technology from Canadian Sources
Large Establishments (Shipment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Cost-related	5.5	7.1	7.6	5.1
Non-specific Cost	5.4	6.6	6.7	4.4
Any Specific Cost	4.7	8.6	2.8	5.9
Cost of Technology Acquisition	4.6	9.0	0.3	6.2
Cost to Develop Software	4.5	5.6	2.4	4.0
Cost of Education and Training	4.2	5.6	0.3	3.5
Increased Maintenance Expense	0.4	1.0	0.9	1.4
Lack of Financial Justification	3.6	5.4	7.1	2.9
Labour-related				
Worker Uncertainty	4.0	6.2	5.9	3.6
Other Factors				
Time to Develop Software	4.6	5.6	4.5	6.3
Lack of Technical Support from Vendors	1.5	1.8	5.8	1.2
Need for Market Expansion	0.9	1.5	0.7	0.7
Other	6.9	9.0	18.8	3.8
Not Applicable	3.1	5.2	8.5	3.6

Table B.16
Standard Errors for Table 20
Significant Factors Hindering Acquisition of Advanced Technology from Foreign Sources
Large Establishments (Shipment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Cost-related	5.4	7.3	13.7	5.2
Non-specific Cost	5.2	8.1	14.8	4.2
Any Specific Cost	4.9	6.0	3.8	6.0
Cost of Technology Acquisition	4.8	5.8	2.8	6.2
Cost to Develop Software	4.5	5.6	3.7	4.0
Cost of Education and Training	4.1	5.6	0.3	3.5
Increased Maintenance Expense	0.2	1.8	0.0	0.2
Lack of Financial Justification	3.9	7.9	14.6	2.8
Labour-related				
Worker Uncertainty	4.1	6.2	5.9	3.6
Other Factors				
Time to Develop Software	6.5	1.6	3.1	2.7
Lack of Technical Support from Vendors	0.9	1.7	3.4	0.9
Need for Market Expansion	0.4	1.4	0.6	0.7
Other	4.2	5.7	2.3	3.6
Not Applicable	3.9	5.5	8.6	4.1

Table B.17
Standard Errors for Table 21
Factors Influencing Acquisition of Advanced Technology
All Establishments (Shipment Weighted)

Factor	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of shipments)		
Lower price	5.6	6.8	14.4	5.2
Internal familiarity with the technology	5.5	6.8	10.3	4.5
Better technical support	5.9	5.3	11.5	4.5
Lower maintenance expense	4.5	7.9	14.6	4.1
Lower costs and shorter time of development of supporting software	5.0	2.7	3.2	5.8
Ease of communication	4.8	8.7	4.6	5.6
Faster delivery time	4.4	2.8	2.8	6.1
Higher risk in dealing with unfamiliar sources	4.2	8.4	2.8	3.6
Special arrangements	6.4	2.2	2.4	5.6
Other	3.4	2.8	4.0	2.3

Appendix C - Establishment Weighted Tables

This appendix provides establishment weighted tables for sections three and four in the publication.

Table C.1
Adoption Rates by Functional Technology Group
All Establishments (Establishment Weighted)

Functional Group	Use
	(percentage of establishments)
Design and Engineering	23.8
Fabrication and Assembly	16.2
Automated Material Handling	3.1
Inspection and Communications	18.9

Table C.2
Use and Planned Use of Advanced Technology
All Establishments (Establishment Weighted)

Individual Technology	In Use	Plan to Use Within 2 Years	No Plans to Use	Length of Use	Ranking by 'In Use'
	(percentage of establishments)			*(years)*	
Design and Engineering					
CAD/CAE	20.8	7.5	71.7	4.3	1
CAD/CAM	10.0	5.3	84.7	4.2	4
Digital Representation of CAD Output	4.5	4.5	91.0	3.4	10
Fabrication and Assembly					
Flexible Manufacturing Cells/Systems	4.4	3.7	91.9	5.0	11
Numerically Controlled Machines	10.9	4.1	85.0	5.8	3
Materials Working Lasers	2.1	2.3	95.6	4.2	16
Pick and Place Robots	2.6	2.4	95.0	5.0	14
Other Robots	2.4	1.9	95.7	4.0	15
Automated Material Handling					
Automated Storage/Retrieval Systems	2.8	2.2	95.0	5.3	13
Automated Guided Vehicle Systems	0.8	0.6	98.6	6.3	17
Inspection and Communications					
Automatic Inspection Equipment - Inputs	4.3	2.9	92.8	6.1	12
Automatic Inspection Equipment - Outputs	5.1	3.5	91.4	6.0	8
Local Area Network for Technical Data	7.6	6.2	86.2	3.6	6
Local Area Network for Factory Use	5.5	6.3	88.2	4.4	7
Inter-Company Computer Network	5.1	7.4	87.5	3.2	8
Programmable Controllers	11.1	3.5	85.4	6.1	2
Computers Used for Control in Factories	9.8	6.1	84.1	5.1	5

Table C.3
Total Investment in Advanced Technology
Large Establishments (Establishment Weighted)

Cost Category	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of establishments)			
Less than $100,000	55.3	26.8	32.8	39.5
$100,000 - $1 million	23.8	31.8	20.1	21.9
$1 million - $5 million	5.4	16.8	18.0	6.2
$5 million or more	1.1	6.6	9.7	1.6
Not applicable	4.0	5.3	5.9	9.9
Non-response	10.4	12.7	13.4	20.8

Table C.4
Planned Use of Advanced Technology by Functional Group
All Establishments (Establishment Weighted)

Functional Group	Planned Use	
	All Cases	Functional Group Not in Current Use
	(establishment percentage points)	
Design and Engineering	12.7	7.3
Fabrication and Assembly	9.8	6.4
Automated Material Handling	2.5	2.4
Inspection and Communications	15.3	6.9

Table C.5
Plans to Upgrade Existing Advanced Technology
All Establishments (Establishment Weighted)

Extent of Planned Upgrade	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of establishments)			
Total Replacement (75% or more)	4.6	2.5	0.6	3.5
Major Upgrade (25% to 74%)	18.2	16.2	18.2	14.9
Minor Upgrade (less than 25%)	20.9	25.7	24.8	21.4
Under Consideration	21.4	21.2	25.5	19.0
None	12.6	13.6	10.8	14.5
Non-response	22.3	20.9	20.2	26.9

Table C.6
Regional Sources of Advanced Technology
Large Establishments (Establishment Weighted)

Regional Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of establishments)			
Canada	52.2	39.5	48.0	45.1
United States	48.3	44.5	46.8	42.1
Europe	7.8	20.7	15.6	6.6
Pacific Rim	2.4	10.1	4.4	2.7
Non-response	14.3	18.8	15.1	26.9

Table C.7
Diffusion Lag of Advanced Technology by Functional Group
All Establishments (Establishment Weighted)

Time Period	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of establishments)			
Less than 1 year	23.0	17.8	19.0	17.5
1 - 3 years	40.1	36.4	41.4	31.4
3 - 5 years	11.7	14.9	10.7	9.6
More than 5 years	3.9	2.7	2.0	4.5
Non-response	21.3	28.2	26.9	37.0

Table C.8
Diffusion Lag of Advanced Technology by Functional Group and Employment Size
All Establishments (Establishment Weighted)

Time Period	Design and Engineering		Fabrication and Assembly		Inspection and Communications	
	0-249 *employees*	250+ *employees*	0-249 *employees*	250+ *employees*	0-249 *employees*	250+ *employees*
	(percentage of establishments)					
Less than 1 year	24.1	14.2	18.8	10.8	17.5	17.4
1 - 3 years	37.8	58.5	32.8	62.2	29.5	42.8
3 - 5 years	11.2	15.5	14.5	17.6	9.0	13.5
More than 5 years	3.7	6.0	2.6	4.1	4.6	3.7
Non-response	23.2	5.8	31.4	5.3	39.5	22.6

Table C.9
Principal Internal Sources of Ideas for Adoption of Advanced Technology
Large Establishments (Establishment Weighted)

Internal Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of establishments)		
Research	18.5	6.9	4.0	8.8
Experimental Development	17.6	14.5	7.0	8.9
Design Work	29.4	11.7	10.3	5.9
Production Engineering	31.8	41.7	37.8	19.5
Operating Staff	29.9	40.5	44.4	35.1
Management	34.1	38.4	31.8	37.7
Corporate Head Office	14.3	14.2	18.1	20.7
Other	2.8	2.7	3.5	4.3
Non-Response	12.9	16.8	18.8	24.2

Table C.10
Principal External Sources of Ideas for Adoption of Advanced Technology
Large Establishments (Establishment Weighted)

External Source	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of establishments)		
A Related Firm (with same parent firm)	27.5	26.1	29.4	26.7
An Unrelated Firm	10.0	12.1	19.1	9.8
Government Laboratories	1.0	0.7	0.2	0.5
University Laboratories	3.6	1.2	1.0	1.8
Provincial Research Organization	2.7	2.2	1.6	1.2
Industrial Research Firms	4.1	3.2	0.7	2.9
Research Consortia	1.4	1.4	1.6	0.9
Consultants and Service Firms	19.0	14.2	21.0	18.9
Joint Ventures and Strategic Alliances	6.3	5.6	3.7	3.8
Publications	33.3	28.8	33.5	26.1
Trade Fairs, Conferences	30.1	34.8	38.2	24.2
Customer Firms	13.6	11.5	3.9	8.7
Supplier Firms	28.5	30.4	34.3	25.2
There was no Significant External Input	10.0	10.4	3.5	7.7
Other	2.3	5.0	7.5	2.9
Non-response	14.6	16.6	18.1	24.2

Table C.11
Effects Caused by Acquisition of Advanced Technology
All Establishments (Establishment Weighted)

Effects	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of establishments)		
TANGIBLE				
Improvements in Productivity	56.0	55.7	54.2	34.3
Reduction in Labour Requirements	35.3	47.6	54.2	21.7
Reduction in Material Consumption	17.2	24.0	15.2	10.7
Reduction in Energy Consumption	7.3	15.1	8.7	6.6
Increased Equipment Utilization Rate	13.0	23.8	20.2	12.4
Increased Capital Requirements	25.6	35.2	27.3	18.8
Reduced Capital Investments	3.0	4.7	3.7	1.5
Lower Inventory	8.0	22.0	23.0	9.7
INTANGIBLE				
Improvement in Product Quality	43.1	52.9	32.6	33.7
Increased Skill Requirements	34.0	32.4	25.1	26.4
Reduction in Product Rejection Rate	20.9	39.9	24.2	22.5
Reduced Set-up Time	26.8	38.7	19.6	10.8
Greater Product Flexibility	30.1	32.2	18.3	12.7
Improved Working Conditions	18.0	33.5	29.8	15.2
Reduced Environmental Damage	8.4	15.7	11.6	8.4
Reduced Skill Requirements	4.8	9.7	7.6	3.1
OTHER				
Other	1.3	0.6	0.0	1.4
Non-response	26.0	28.7	32.4	45.4

Table C.12
Significant Impediments to Advanced Technology Acquisition
All Establishments (Establishment Weighted)

Impediment	Users	Non-Users	Combined
		(percentage of establishments)	
COST-RELATED PROBLEMS	**86.2**	**75.2**	**79.0**
Lack of Financial Justification	**41.0**	**43.9**	**42.9**
Investment-related costs	**76.2**	**64.7**	**68.7**
Cost of Capital	48.9	47.5	48.0
High Cost of Equipment	58.9	49.3	52.6
Costs to Develop Software	23.7	14.9	17.9
Increased Maintenance Expenses	15.3	13.7	14.3
Cost of Technology Acquisition	30.3	26.3	27.7
Institution-related	**19.7**	**16.8**	**17.9**
Tax Regime: R&D Investment Tax Credits	11.4	5.9	7.8
Tax Regime: Capital Cost Allowances	11.7	8.3	9.5
Government Regulations and Standards	9.2	12.0	11.1
LABOUR-RELATED PROBLEMS	**34.9**	**25.3**	**28.6**
Shortage of Skills	22.0	19.1	20.1
Training Difficulties	21.6	14.8	17.2
Labour Contracts	7.0	4.4	5.3
ORGANIZATION OR STRATEGIC PROBLEMS	**25.3**	**16.2**	**19.3**
Difficulties in Introducing Important Changes to the Organization	15.5	9.9	11.8
Management Attitude	9.1	6.6	7.5
Worker Resistance	11.6	8.1	9.3
INFORMATION-RELATED PROBLEMS	**21.3**	**15.4**	**17.4**
Lack of Scientific and Technical Information	10.6	11.0	10.8
Lack of Technological Services	8.2	8.2	8.2
Lack of Technical Support from Vendors	12.6	8.2	9.7
OTHER PROBLEMS	**6.2**	**22.7**	**17.0**
Other	6.2	22.7	17.0
Non-response	9.9	9.5	9.7

Table C.13
Significant Factors Hindering Acquisition of Advanced Technology
All Establishments (Establishment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of establishments)			
Cost-related	47.0	45.0	37.0	36.9
Non-specific Cost	33.4	36.8	34.7	27.3
Any Specific Cost	28.0	25.6	9.7	20.0
Cost of Technology Acquisition	17.7	17.2	4.5	12.3
Cost to Develop Software	7.2	8.9	4.3	6.3
Cost of Education and Training	13.2	7.3	2.0	6.8
Increased Maintenance Expense	3.8	8.2	1.5	2.1
Lack of Financial Justification	19.5	24.4	17.9	17.6
Labour-related				
Worker Uncertainty	6.3	8.9	3.0	3.4
Other factors				
Time to Develop Software	8.8	9.6	7.7	8.1
Lack of Technical Support From Vendors	7.8	9.5	8.4	5.2
Need for Market Expansion	10.4	15.5	7.0	6.2
Other	4.7	7.7	4.6	5.6
Not Applicable	24.6	25.3	25.1	33.3
Non-response	23.8	22.8	29.9	24.0

Table C.14
Significant Factors Hindering Acquisition of Advanced Technology from Canadian Sources
Large Establishments (Establishment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
	(percentage of establishments)			
Cost-related	43.4	43.0	36.9	35.3
Non-specific Cost	32.2	32.8	32.5	26.4
Any Specific Cost	22.2	22.5	12.8	18.8
Cost of Technology Acquisition	13.7	13.2	3.8	10.7
Cost to Develop Software	7.0	6.8	5.1	6.1
Cost of Education and Training	8.4	4.9	1.9	6.0
Increased Maintenance Expense	2.1	3.9	2.5	1.6
Lack of Financial Justification	22.3	25.8	24.7	18.6
Labour-related				
Worker Uncertainty	4.3	7.5	4.4	3.8
Other Factors				
Time to Develop Software	8.0	6.8	11.2	7.0
Lack of Technical Support from Vendors	4.5	6.7	7.2	4.3
Need for Market Expansion	7.4	9.2	2.7	3.5
Other	7.4	10.1	7.0	6.4
Not Applicable	22.5	20.2	22.0	24.8
Non-response	17.0	16.6	18.4	21.5

Table C.15
Significant Factors Hindering Acquisition of Advanced Technology from Foreign Sources
Large Establishments (Establishment Weighted)

Problem Area	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of establishments)		
Cost-related	29.4	34.1	36.7	28.6
Non-specific Cost	23.3	27.3	32.8	21.7
Any Specific Cost	13.1	15.8	11.6	13.8
Cost of Technology Acquisition	8.9	10.8	6.7	7.8
Cost to Develop Software	3.9	4.1	5.7	4.8
Cost of Education and Training	4.1	3.8	2.3	4.3
Increased Maintenance Expense	1.6	4.7	0.0	1.0
Lack of Financial Justification	16.7	23.1	20.6	16.4
Labour-related				
Worker Uncertainty	1.7	4.3	4.6	2.1
Other factors				
Time to Develop Software	4.1	3.3	6.7	4.5
Lack of Technical Support from Vendors	4.5	8.2	10.0	3.5
Need for Market Expansion	2.9	5.9	2.6	2.3
Other	6.1	7.5	4.0	5.8
Not Applicable	35.8	29.9	21.6	33.7
Non-response	21.1	19.5	25.3	23.1

Table C.16
Factors Influencing Acquisition of Advanced Technology
All Establishments (Establishment Weighted)

Factor	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
		(percentage of establishments)		
Lower price	38.0	39.5	29.0	28.1
Internal familiarity with the technology	27.9	25.8	26.7	22.2
Better technical support	25.2	27.2	19.5	18.0
Lower maintenance expense	12.1	18.2	21.5	10.9
Lower costs and shorter time of development of supporting software	15.5	11.7	11.0	10.7
Ease of communication	15.1	10.6	10.9	18.2
Faster delivery time	11.9	17.0	9.5	9.2
Higher risk in dealing with unfamiliar sources	4.6	7.4	9.8	5.6
Special arrangements	2.4	4.3	9.3	2.8
Other	5.5	8.5	4.7	8.1
Non-response	30.8	32.2	34.8	41.8

Appendix D - 1993 Survey Questionnaire

Advanced Technology Sections

Question 6 : Advanced Technology Use

6.1 For EACH item or class of software listed below, and currently used in your operations, please enter the approximate number of years in use; if NOT currently used, please indicate (✓) which description best reflects plans for use.

TECHNOLOGY	Used in Operations	Not currently used		
	Approximate Number of Years in Use	Plan to use within next 2 years ✓	No plans to use	
			No Application ✓	Not Cost effective ✓
FUNCTION: DESIGN AND ENGINEERING				
Computer aided design (CAD) and/or computer aided engineering (CAE)				
CAD output used to control manufacturing machines (CAD/CAM)				
Digital representation of CAD output used in procurement activities				
FUNCTION: FABRICATION AND ASSEMBLY				
Flexible manufacturing cell(s) (FMC) or systems (FMS)				
Numerically controlled and computer numerically controlled (NC/CNC) machine(s)				
Materials working laser(s)				
Pick and place robot(s)				
Other robots				
FUNCTION: AUTOMATED MATERIAL HANDLING				
Automated storage and retrieval system (AS/RS)				
Automated guided vehicle systems (AGVS)				
FUNCTION: INSPECTION AND COMMUNICATIONS				
Automated sensor-based equipment used for inspection/testing of:				
• incoming or in-process materials				
• final product				
Local area network for technical data				
Local area network for factory use				
Inter-company computer network linking plant to subcontractors, suppliers and/or customers				
Programmable controller(s)				
Computer(s) used for control on the factory floor				

6.2 For EACH item or class of software listed below, and currently used in your operations, please enter the approximate number of years in use; if NOT currently used, please indicate (✓) which description best reflects plans for use.

TECHNOLOGY	Used in Operations	Not Currently Used		
			No Plans to Use	
	Approximate Number of Years in Use	Plan to use within next 2 years ✓	No Application ✓	Not Cost Effective ✓
MANUFACTURING INFORMATION SYSTEMS				
Materials Requirement Planning (MRP)				
Manufacturing Resource Planning (MRP II)				
INTEGRATION AND CONTROL				
Computer integrated manufacturing (CIM)				
Supervisory control and data acquisition (SCADA)				
Artificial intelligence and/or expert systems				

Question 7 : Acquisition of Advanced Technology

For the purposes of this section of the questionnaire please refer to the functional grouping of technologies in Q.6.1. You are asked to answer for each such functional group. If none of the technologies listed in Q.6.1 are in current use in your operations, please answer only questions 7.14, 8.1, 8.2, and 8.3.

7.1 Please indicate (✓) the range that best reflects this plant's total investment in technologically advanced equipment and software for the period 1989-1991. Please EXCLUDE education and training but INCLUDE plant modifications, construction, integration, and equipment and software purchased or developed.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

COST CATEGORY	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Less than $100,000				
$100,000 to less than $1 million				
$1 million to less than $5 million				
$5 million to less than $10 million				
$10 million or more				
Not applicable				

7.2 For each functional technology group, please specify the percentage of total investment made up of technologically advanced equipment and software.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Percentage of total investment				

7.3 Please indicate (✓) any factors that had particular significance over the last three years (1989-1991) in HAMPERING or DELAYING your acquisition of technologically advanced equipment and software from CANADIAN sources.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

FACTORS	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Overall cost				
Cost of technology acquisition				
Cost of education and training				
Worker uncertainty				
Time to develop software				
Cost to develop software				
Increased maintenance expense				
Need for market expansion				
Lack of financial justification				
Lack of technical support from vendors				
Other				
Not applicable				

7.4 Please indicate (✓) any factors that had particular significance over the last three years (1989-1991) in HAMPERING or DELAYING your acquisition of technologically advanced equipment and software from FOREIGN sources.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

FACTORS	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Overall cost				
Cost of technology acquisition				
Cost of education and training				
Worker uncertainty				
Time to develop software				
Cost to develop software				
Increased maintenance expense				
Need for market expansion				
Lack of financial justification				
Lack of technical support from vendors				
Other				
Not applicable				

7.5 Please indicate (✓) any factors that had particular significance over the last three years (1989-1991) in HAMPERING or DELAYING your acquisition of technologically advanced equipment and software.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

FACTORS	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Overall cost				
Cost of technology acquisition				
Cost of education and training				
Worker uncertainty				
Time to develop software				
Cost to develop software				
Increased maintenance expense				
Need for market expansion				
Lack of financial justification				
Lack of technical support from vendors				
Other				
Not applicable				

7.6 Please indicate (✓) any factors that have particular significance for your acquisition of technologically advanced equipment and software.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

FACTORS	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Lower price				
Internal familiarity with the technology				
Better technical support				
Lower maintenance expense				
Lower costs and shorter time of development of supporting software				
Ease of communication				
Faster delivery time				
Higher risk in dealing with unfamiliar sources				
Special arrangements				
Other				

7.7 How would you compare* your production technology with that of your most significant competitors in Canada and outside of Canada?

* *1: Much less advanced; 2: Less advanced; 3: About the same; 4: More advanced; 5: Much more advanced*

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

COMPETITORS	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Other Canadian producers				
Producers abroad				

7.8 Please indicate (✓) your principal INTERNAL sources of ideas for the adoption of technologically advanced equipment and software.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

INTERNAL SOURCE	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Research				
Experimental development				
Design work				
Production engineering				
Operating staff				
Management				
Corporate Head Office				
Other				

7.9 Please indicate (✓) your principal EXTERNAL sources of ideas for the adoption of technologically advanced equipment and software.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

EXTERNAL SOURCE	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
A related firm (with same parent firm)				
An unrelated firm				
Government laboratories				
University laboratories				
Provincial research organization				
Industrial research firms				
Research consortia				
Consultants and service firms				
Joint ventures and strategic alliances				
Publications				
Trade fairs, conferences				
Customer firms				
Supplier firms				
There was no significant external input				
Other				

7.10 Please indicate (✓) the principal REGIONAL sources of your present technologically advanced equipment and software.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

REGIONAL SOURCE	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Canada				
United States				
Europe				
Pacific Rim*				
Other (please specify)				

* *Pacific Rim is defined here as : Hong Kong, Indonesia, Japan, Malaysia, Singapore, South Korea, Taiwan, Thailand.*

7.11 Please indicate (✓) the average length of time between your becoming aware of the technologically advanced equipment and software that you eventually acquired and its implementation.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

TIME PERIOD	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Less than 1 year				
1 - 3 years				
3 - 5 years				
5 - 10 years				
More than 10 years				

7.12 Please indicate (✓) whether the adoption of technologically advanced equipment and software led to any of the following results.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

RESULTS	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
An improvement in productivity				
LOWER PRODUCTION COSTS BY REDUCING:				
. Labour requirements				
. Material consumption				
. Energy consumption				
. Product rejection rate				
OTHER IMPROVEMENTS:				
Improvement in product quality				
Reduced set-up time				
Greater product flexibility				
Improved working conditions				
Reduced environmental damage				
Reduced skill requirements				
Reduced capital investments				
Increased skill requirements				
Increased capital requirements				
Increased equipment utilization rate				
Lower inventory				
Other				

7.13 Please indicate (✓) any plans to acquire technologically advanced equipment and software for this plant over the next three years.

PLEASE ANSWER SEPARATELY FOR EACH FUNCTIONAL GROUP.

EXTENT OF PLANNED TECHNOLOGY ACQUISITION	Design and Engineering	Fabrication and Assembly	Automated Material Handling	Inspection and Communications
Total replacement (75% or more)				
Major upgrade (25% to less than 75%)				
Minor upgrade (less than 25%)				
Under consideration, but no firm plans				
None				

Question 8 : Acquisition of Advanced Technology : Impediments

8.1 Please indicate (✓) which of the following factors have particular significance to your firm as IMPEDIMENTS to technology acquisition.

IMPEDIMENT	Source of Technology	
	CANADIAN	FOREIGN
COST-RELATED PROBLEMS		
Cost of capital		
High cost of equipment		
Costs to develop software		
Increased maintenance expenses		
Cost of technology acquisition		
Lack of financial justification		
Tax regime: R&D investment tax credits		
Tax regime: capital cost allowances		
Government regulations/standards		
LABOUR-RELATED PROBLEMS		
Shortage of skills		
Training difficulties		
Labour contracts		
ORGANIZATION/STRATEGIC PROBLEMS		
Difficulties in introducing important changes to the organization		
Management attitude		
Worker resistance		
OTHER PROBLEMS		
Lack of scientific and technical information		
Lack of technological services (e.g. technical and scientific consulting, tests, standards)		
Lack of technical support from vendors		
Other		

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Notes

[1] The Business Register maintains a listing of all establishments in the Canadian manufacturing sector.

[2] For the purpose of this survey, large firms are defined as those coming from the "Integrated Portion" of Statistics Canada's Business Register. Most businesses in Canadian manufacturing have a simple structure. Usually they are small businesses consisting of one legal entity controlling one operating entity. Some businesses, however, have a more complex structure and tend to be larger in size. Statistics Canada's Business Register includes in its integrated portion those firms which are large or more complex and which are the major contributors to the economic activity of the industry. For more information, see "The Statistics Canada Business Register (1990)".

[3] Despite the fact that only users of the 22 technologies listed in the survey were directed to answer the second section, some establishments not meeting these requirements nevertheless completed it. They may well be users of other advanced technologies not listed in the survey; however, they are excluded from the calculations reported here and treated as non-users.

[4] As evidenced by a number of surveys of manufacturing technologies (SMT) carried out by different countries. They include the U.S. Bureau of the Census (1989), Australia Bureau of Statistics (1989) and Statistics Canada (1991).

[5] For the purposes of this study, only the first four of the six functional groups are included. They are seen to represent different stages of the production process and are used to investigate the extent to which the benefits and problems associated with technology adoption vary across the different stages of production.

[6] For further industry detail, see Baldwin and Sabourin (1995).

[7] This is not to be confused with investment as a percentage of sales. The latter measures capital intensity. Thus a plant may be technologically intensive by the definition used here even though its capital intensity may be low. The intensity measure used here captures how progressive a plant is, that is, whether its investment makes maximum use of advanced technologies.

[8] Pacific Rim includes Hong Kong, Indonesia, Japan, Malaysia, Singapore, South Korea, Taiwan, and Thailand.

[9] The discount rate that equates the acquisition cost with the present value of expected future net revenues from its use is called the internal rate of return.

[10] See Zaltman, Duncan, and Holbeck (1973) for the sequence of decisions that organizations use in innovating and adopting new technologies.

[11] The nature of user-producer interaction as one of the major sources of innovation has been also stressed by Imai (1992) and Malerba (1992).

[12] While the amount of labour per unit of output declines, total demand for labour increases if the amount of output increases in response to the introduction of new advanced technologies. For more on this see *Innovation in Canadian Manufacturing Enterprises,* catalogue no. 88-513.

[13] *Cost-related* differences are statistically significant for all but fabrication and assembly, while *non-specific cost* differences are statistically significant across all functional groups. *Lack of financial justification* results are statistically significant only for fabrication and assembly, and automated material handling.

[14] *Software development time* differences are statistically significant for all but design and engineering; *training cost* and *technical support* differences are statistically significant for design and engineering only; *maintenance costs* differences are statistically significant for fabrication and assembly, and inspection and communications.

[15] Price is a proxy for equipment costs.

[16] Recall that these percentages are based on establishments using a particular functional technology. As such the base varies across functional groups.

[17] Moreover, the Canadian/United States comparisons are, by necessity, only partial since the United States survey covers only five 2-digit industries.

[18] Included in the tabulations are only those establishments that rated themselves against <u>both</u> domestic and foreign competitors.

[19] Questions about technology characteristics other than use were asked only of design and engineering, fabrication and assembly, automated material handling and inspection and communications. Automated material handling has not been included due to small numbers of responses.

[20] Results are statistically significant at the 5% level.

[21] Results for this group were generated but were not included in the table.

[22] The difference in these distributions are significantly different.

[23] Ibid.

[24] The 91% is calculated as the ratio of Canadian sources to American sources, converted to percentages.

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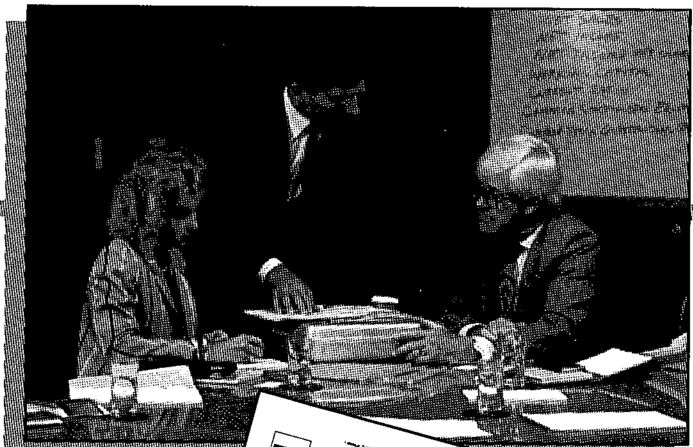

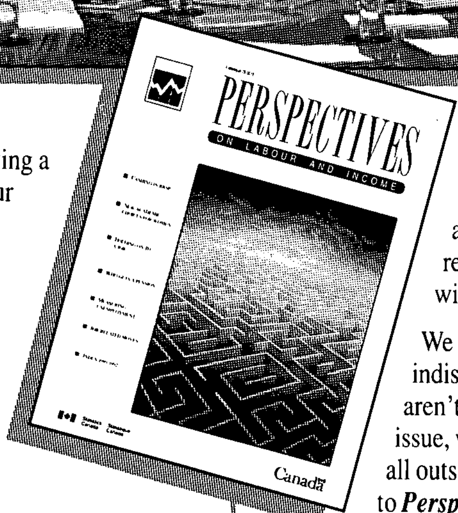

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