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CAD/CAM Technology in Canadian Manufacturing: A Study of Constraints, Incentives and Impacts

by

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CAD/CAM TECHNOLOGY IN CANADIAN MANUFACTURING:

A STUDY OF CONSTRAINTS, INCENTIVES AND IMPACTS

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April, 1985

This survey was prepared for the Department of Regional Industrial Expansion, Government of Canada. The views and opinions expressed are those of the authors and are not necessarily endorsed by the Department of Regional Industrial Expansion.

EXECUTIVE SUMMARY

Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) refers to any use of computer control in the design and manufacture of a product or service. It is part of the information revolution in the factory, and it is an outgrowth of earlier technologies such as automated materials handling, automated assembly, and computerized numerical control of machine tools. While these technologies are an integral part of today's CAD/CAM, other aspects include robotics, automated drafting, engineering computation, and total computer integration of the design and manufacturing operations.

This study investigates the responses of 285 manufacturers from Ontario and Western Canada regarding their perceptions of CAD/CAM constraints, incentives, and impacts. In addition, the constraint and incentive responses are analyzed for 30 CAD/CAM suppliers and 16 educational institutions. The purpose of the study is to provide background information for the formulation of policies.

Of the 285 responding manufacturers, 70 (25 percent) are Present Users of CAD/CAM, 58 (20 percent) are Actively Considering its use, 109 (38 percent) said they Might Consider its use in the next five years, and 47 (17 percent) said they Will Not Consider its use. The users tend to be the larger sized firms, although many small firms also find the technology appropriate. Greater usage occurs in the electrical manufacturing industry, while the apparel, paper, lumber, and miscellaneous manufacturing industries tend to have lower use. In higher-use industries, non-users are more receptive to becoming users themselves. This higher receptivity may be caused by the need to stay competitive or by the existence of role models which a firm can emulate. Probably both forces are causing the higher receptivity.

Those who have adopted CAD/CAM, for the most part, experienced higher productivity, increased sales, moderate to large increases in quality, and shorter lead times. The larger firms tend to decrease employment when adopting CAD/CAM, while the smaller firms expand employment. Amongst non-users, the expectations of impacts are more pessimistic, although still positive. Those Actively Considering CAD/CAM have expectations which are very close to the actual experiences of Present Users.

The most serious constraints seen by Present Users were the unavailability or high cost of capital and an inadequate return on investment. All respondent groups rated these two constraints as being very serious. Those less inclined to use CAD/CAM, particularly the Will Not Consider category, saw the constraints and barriers to be bigger. Important constraints amongst the non-user groups include managerial inexperience in implementation, high financial risk, difficult integration into the present operations, management's lack of knowledge with CAD/CAM technology, and the unavailability of trained staff. The Might Consider and Will Not Consider groups also felt that there was no immediate need for them to change and that the technology was not yet appropriate for their industry.

Tax incentives for capital investment were judged to be the most desirous incentive. Except for a high rating placed on the training of operators and programmers, the importance of the incentives are in line with the severity of the constraints. We would have expected incentives to train managers to have been rated above operator training because management knowledge and experience appeared as a more important constraint.

Small firms reported that they expanded sales and employed more people after adopting CAD/CAM technology. They tend to experience fewer labour problems and achieve easy integration. Larger firms, on the other hand, have more complex manufacturing facilities, more computers, formal personnel systems, and more rigid labour relations. For them, integration is more difficult, but they benefit from higher productivity and increased quality. They generally decrease the size of their workforce.

An analysis of leaders vs. laggards in the use of CAD/CAM revealed that the main difference was in their perception of constraints. Laggards see inadequate return on investment, high financial risk, and unavailable or high cost of capital as enormous barriers. These barriers, however, could be just perceptual. Laggards reported that their managerial team was unknowledgeable about CAD/CAM and inexperienced in its implementation. Their perceptions may be a function of their lack of expertise.

A comparison of suppliers, educational institutions and Present Users reveals that each perceives the constraints and incentives from the perspective of their own special interests. Suppliers place greater emphasis on factors which affect their sales, while educational institutions see knowledge acquisition as an important constraint and requirement for future CAD/CAM development.

Recommendations which evolve from the study are made for manufacturers, suppliers, unions, educational institutions and governments. To promote further use and adoption of CAD/CAM, manufacturers can (1) carry out demonstration programs, (2) provide consulting and CAD/CAM services, (3) rent out their surplus CAD/CAM capacity, (4) merge into larger economic units, (5) strategically specialize in friendly niches, (6) develop their own human resources, and (7) carefully plan their CAD/CAM purchases. Recommendations for suppliers are (1) to cooperate in the standardization of programming and hardware, (2) to provide linking software packages, (3) to improve leasing arrangements, (4) to support training, and (5) to establish CAD/CAM centres. Unions are recommended (1) to recognize the technology, (2) to work with it to achieve wealth redistribution, (3) to argue for safety and good working conditions, and (4) to promote retraining of their members. Educational institutions should (1) train operators and managers, (2) act as diffusion catalysts for the technology, and (3) undertake specific research and development. Recommendations for governments are (1) to establish a stable business environment, (2) to coordinate amongst their various levels, (3) to provide tax incentives for capital investment, and (4) to assist and encourage small business to get on the CAD/CAM bandwagon. Recommendations for government are made last because government should be the agency of last resort.

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Chapter 1

INTRODUCTION

Ever since the Industrial Revolution, machines have allowed man, both male and female, to perform more work with less effort. In the industrialized world, mankind has been able to produce the goods and services it desires with fewer working hours, higher standards of living, and greater leisure. Assembly lines, automation, transport vehicles, communications equipment, and special purpose machines have all contributed to man's advancements. While human toil and effort was removed, human knowledge to run the machines was still present. Man still maintained the information.

With the advent of the computer, a trend started which enabled man to transfer information to a machine. Control of other machines could be given to the computer machine. Information which humans supplied to make the machine operate in a predictable manner could be given to the computer. Thus, working hours could be fed into the computer, and another machine could be directed to automatically print the payroll cheque with all appropriate deductions. In a similar manner, inventory records, airline reservations, funds transfers, statistical calculations, space trajectories, knowledge bases, and simulations can all be handled in seconds as compared to hours, days, and months by a human. The computer's ability to handle complex calculations at enormous speeds has opened up new productivity opportunities. It might occasionally appear that we are drowning in our own proliferation of information, but the computer has kept us afloat.

The first computers were large, slow, and bulky. Such is not the case today. Microprocessors, the latest miniaturized version of the computer, are extremely small, capable of complex calculations in infinitesimal units of time, inexpensive, and extraordinarily reliable. They have the capability of invading all aspects of our lives and jobs -- from monitoring our homes, controlling our cars, transferring our funds, cooking our meals, recording our output, instructing our children, and advising our friends.

Naisbitt (1982), in his best seller book Megatrends, has pointed out that we are undergoing a transformation from an industrial to an information society. We are going through a type of Information Revolution in which electronics, the microprocessor, communications satellites, data bases, and information networks affect all aspects of our lives -- from work, to play, and even sleep. In this new society, information is power; those who react quickly and utilize the requisite information will succeed and prosper.

The Information Revolution in the Workplace

In the workplace, the information revolution has made dramatic inroads. Consider the word processor. In most offices today, the old typewriter is obsolete. Secretaries and specialty typists still use a keyboard, but the information is entered directly to a computer. Gone are the days of direct typing onto paper.

In its computerized format, the typed document can be manipulated in many ways. Corrections can be typed over, new insertions can be made, blocks of information can be moved around, addresses or data can be accessed from other files, titles can be centered, spelling errors can be found by comparing the document to a computerized dictionary, and universal searches and replacements can be made for specified characters. The document can be printed in several different fonts, or it can be sent over communication lines to some other printer or computer at a distant location. In publishing the document, instructions can be given to automatically feed the information into a typesetting machine.

The use of word processors in this manner is part of the electronic office. It is not something of the future -- it is here now. Other aspects of the electronic office include electronic mail, facsimile transmissions, audio and visual conferences, decision support systems, expert systems, and artificial intelligence.

The Information Revolution in the Factory

Just as the office has undergone an electronic transformation, so has the factory and other production systems. The analogy to the word processing in the factory setting is computer aided design.

In the factory, old-style draftsmen, architects and engineers are converting over to computer drawings. Using the graphics and word processing capabilities of the computer, these people are now entering their blueprints, designs, and other information directly into computer memory. Here, they can quickly make corrections, move graphic images around, repetitively insert common designs, and bring figures in from other files. Since the object in computer memory can be represented in three dimensions, it can be easily rotated so that it can be viewed from a different angle. Parts and subparts can be 'exploded', magnified, and analyzed from different perspectives. Kinetic simulations are even possible before the part is produced, and advanced design of jigs and fixtures can be achieved by placing an envelope around the part. Once the design is finished, it can be plotted onto paper, or it can be sent directly in the form of digital instructions to numerically controlled machines or other automated tools. In the same manner that word processing information can be sent directly to a typesetting machine, so too can design information be sent to the production machine.

The use of the computer for design purposes is called computer aided design (CAD). The applications are numerous and probably still not fully discovered. The most obvious applications are any situation where draftsmen prepare two dimensional drawings. Thus, mechanical designs, architectural drawings, electrical schematics, and flow process charts have all been put on the computer. Less common is the use of CAD to undertake various types of mapping such as a three dimensional display of an underground ore body, a plan for town expansion, or a record of the land holdings of a municipality. Once the information is on the computer, various estimating and take-offs of figures can be made.

The use of the computer in the manufacturing process is called computer aided manufacturing (CAM). Its origin springs from the numerical controlled (NC) machine tool developments of the 1960's and subsequent computerized numerical controls (CNC) where programmable computers run the machine tool. When the data from a CAD system is fed directly to the programmable computer, which in turn runs the machine tool, we get an integration of two branches of computer technology called CAD/CAM.

If the computer can be programmed to run a machine tool, then it can also be programmed to aid in other aspects of production and operating processes. Robots, automated materials handling machinery, inventory records, production scheduling, and manufacturing controls can all be instructed without direct human intervention. Unlike CAD, the exact degree and configuration of computer use varies according to the circumstances of each company and industry. The essential point, however, is that both CAD and CAM involve a transfer of traditional production and operating processes to new, electronically controlled processes.

Various other terms have been introduced to describe how the computer is invading the non-office workplace. The merging of CAD/CAM with other activities such as distribution, cost accounting, purchasing, pricing, and inventory conjures ideas of the totally automated factory and what has been called computer integrated manufacturing (CIM). Similarly, the engineer's use of CAD to simulate stress tolerances, test computerized prototypes, and undertake mathematical calculations leads to the term computer aided engineering (CAE). Again, the one thing in common is that new operating processes are based upon electronically controlled information.

The term CAD/CAM has been adopted in this study to imply all computer processes which aid the design and production of a product or service. By including service operations, a very broad definition has been adopted for the concept of production. Thus, a consulting engineering firm may not produce an actual product, but they may perform very valuable services in designing a plant and testing it on a computer before it is actually built. Similarly, McDonald's restaurants may be considered to be in food services, but they may someday take your order with a robot in a similar manner as the automated bank teller serves you money. Just as the computer has aided the exploration of outer space, it also holds out promise for explorations of our production and operating systems. Like exploring the moon, only the surface has been touched.

The Imperatives of CAD/CAM

The benefits of CAD/CAM vary from increased productivity, higher quality, shorter lead times, greater creativity and improved sales. In the use of CAD, the usual reports of productivity ratios are 3:1 to 4:1 for mechanical drawings, 6:1 to 10:1 for electrical drawings, and as high as 10:1 to 30:1 for complex integrated circuit drawings. One study of 33 CAD/CAM users in the United States said "... 90 percent of those surveyed reported improved accuracy, 78 percent reported error reduction, 75 percent reported increased productivity, 76 percent reported shortened cycle time, and 70 percent reported reduced costs." (Datapro Research Corporation, 1984) With such benefits, these CAD/CAM users are undoubtedly happy with their decision to adopt the new technology.

The decision to adopt CAD/CAM, however, is not an easy one. To many who do not understand the new technology, the transition can be scary. The capital and retraining costs can be substantial, and the field is changing so fast that a lower cost and more effective system may soon be available. With such uncertainty, businessmen frequently opt for a delaying strategy. Also, the transition can involve serious social problems if increases in productivity require the company to lay off, transfer, or retrain employees for other jobs.

But to continually resist the change could be economical heresy. Information technology knows no political boundaries. If one nation gets a jump on the others in using CAD/CAM to achieve substantial productivity and quality improvements, then it is likely that that nation will capture markets which will be hard to displace. To wait too long or to lag in the adoption of CAD/CAM may cause an erosion of the international competitiveness of a nation's businesses. It is for this reason that we see numerous articles which say "Automate or Evaporate" (Computer Data, 1984), "Investment in High-tech Must be Made Now to Help West Prosper Later" (Blackwell, 1984), and "Step-by-step Automation Program Urged to Meet Foreign Technical Advances" (The Engineering Times, 1984).

While recognizing that CAD/CAM can have some adverse side effects, this study adopts the stance that the information revolution is upon us and that the computer will affect the way in which we produce goods and services. The problem, then, is to study how the computer will affect us, what difficulties our firms have in adopting it, and what assistance they may welcome to help them make the transition. This report addresses this problem.

Chapter 2

THE SURVEY

The idea for a study into the constraints and incentives for CAD/CAM development in Canada occurred in the spring of 1982. Mr. Ray B. Rebeiro, Senior Associate of the IBI Group of consultants, suggested that the business and government communities should have a better understanding of CAD/CAM developments in Canada and the factors which promoted or inhibited its adoption. Mr. Rebeiro's contention was that Canadian policy makers, both in the public and private sectors, are hampered by the lack of relevant information. If Canadian industry is going to be competitive in the world economy and if sound decisions are going to be made on the use of new CAD/CAM technology, then more information is needed.

The Questionnaire

By the spring of 1983, support for a limited study on CAD/CAM constraints and incentives was supplied by the Department of Regional Industrial Expansion, Government of Canada. A questionnaire was designed for a mail survey which would collect the following type of information:

1. demographic information on Canadian manufacturers, both users and non-users of CAD/CAM technology.
2. actual and expected impacts of using CAD/CAM technology.
3. constraints which have inhibited or would inhibit the use of CAD/CAM technology.
4. incentives which have aided or would aid the use of CAD/CAM technology.

Decisions were made to send the questionnaire to a representative sample of manufacturing establishments in Ontario, the Prairies (Manitoba, Saskatchewan, and Alberta), and British Columbia. The prime unit of analysis was to be the individual plant rather than the total firm. Thus, it is possible for a large multi-divisional firm to have responses to the questionnaire originating from more than one plant.

In order to get an additional perspective, the same questionnaire was sent to other parties interested in the adoption of CAD/CAM. These included manufacturers and suppliers of CAD/CAM equipment, educational and research institutions knowledgeable in CAD/CAM, and trade associations representing CAD/CAM technologists.

In choosing the industries to survey, a conscious attempt was made to get a good cross section from all three regions. Resource and primary manufacturers are more representative in the Prairies and British Columbia while secondary manufacturers are more heavily represented in Ontario. Also, there was an attempt to survey industries which represent a variety of different stages in the adoption of CAD/CAM techniques.

The Sample

Manufacturing establishments listed in Scott's Industrial Directories were used as the population of interest. Table 2-1 lists the industries surveyed, their SIC codes, and the number of establishments in each category. There is about 70 percent duplication across categories, because one plant may be listed as manufacturing products under more than one code. Since these duplications are eliminated when drawing the sample, the actual total population size is about 16,965 establishments. This number represents about 65 percent of all Canadian establishments within the classifications surveyed.

TABLE 2-1

Distribution of Manufacturing Establishments
By Industry and Location

SIC Code	Industry	B.C.	Prairies	Ont.	Total	% of All Industries
2091-92	Canned, cured, fresh or frozen fish and seafoods	96	12	23	131	.4
26	Paper and allied products	122	104	790	1016	3.5
24	Lumber and wood products (except furniture)	907	755	1645	3307	11.5
28	Chemicals and allied products	211	304	1640	2155	7.5
29	Petroleum refining and related products	34	62	157	253	.9
33	Primary metal industries	127	125	681	933	3.2
34	Fabricated metal products (except machinery and transportation equipment	777	501	4143	5421	18.8
35	Machinery (except electrical)	804	1126	4755	6685	23.2
36	Electrical and electronic machinery, equipment and supplies	222	226	1693	2141	7.4
37	Transportation equipment	326	348	761	1435	5.0
38	Measuring, analyzing and control instruments, photographic, medical and optic goods, watches and clocks	90	136	749	975	3.4
39	Miscellaneous manufacturing industries	254	347	1295	1896	6.6
23	Apparel & other finished products made from fabric and similar products	311	647	1534	2492	8.6
Total		4281	4693	19866	28840	100.0
%		14.8	16.3	68.9	100.0	

The sample drawn from the target population consisted of every third establishment employing more than five people. The smallest firms employing five or fewer people represent about 26 percent of the firms in Western

Canada and 16 percent of the firms in Ontario. It was felt that nearly all of these very small firms have neither the knowledge nor interest in CAD/CAM. They were excluded, therefore, in order to lessen the cost of sampling.

The questionnaires were sent to the top corporate officer listed at each manufacturing establishment. A total of 4,651 questionnaires were sent to manufacturers, of which 178 were non-delivered (recipient no longer at address), 14 were spoiled, and 285 were returned and usable (see Table 2-2). Thus, the response rate is 6.4 percent of the delivered questionnaires. This percentage is lower than desired, although not unusually low for a mail questionnaire.

TABLE 2-2

CAD/CAM Questionnaire Mailing Results

	Mailed	Returned	Spoiled	Non-Delivery	Returned/ Delivered
Manufacturers	4651	285	14	178	6.4%
Can. Suppliers	123	21	0	15	19.4%
Associations	8	1	0	2	16.7%
Research Inst.	14	1	0	1	7.7%
Educ. Inst.	41	14	0	0	34.1%
U.S. Suppliers	33	7	0	5	25.0%
U.K. Suppliers	4	0	0	0	0%
TOTAL	4874	329	14	201	70.4%

As also is indicated by Table 2-2, two hundred twenty-three questionnaires were mailed to CAD/CAM suppliers, research and educational institutions, and trade associations. Being more interested in the topic, the response rate from these organizations was much higher.

Questionnaire Design and Distribution

The design of the questionnaire was preceded by an extensive search of the literature and interviews with experts in CAD/CAM usage. The first version of the questionnaire was pretested in the fall of 1983. After revision, additional pretesting, and further investigation, it was sent to the printer in February, 1984. The final version is illustrated in Appendix A.

Preprinted mailing labels were acquired from Scott's Directories. After examining the lists and eliminating duplicate labels, the questionnaires were sent out during the first week of May, 1984. Two months were allowed for their return before the analysis began. Only one questionnaire was received after the cutoff date. It arrived too late for inclusion in the results.

Respondents were assured that the information they supplied would be treated anonymously. As part of the mail-out, they were given a request form for a copy of the survey results. They had the option to mail this request form with their questionnaire or to return it under separate cover. Many respondents (62 percent) enclosed their request forms with their questionnaires. Although these establishments thereby revealed their identity to the researchers, their anonymity is still being respected.

The Analysis

The analysis of the questionnaire data is presented in the remainder of this report. The next section, Chapter 3, presents a profile of CAD/CAM use in Ontario and Western Canada. The main category of analysis is by the degree of receptivity towards CAD/CAM -- whether a Present User of CAD/CAM, a firm Actively Considering its use, one which Might Consider its use, or a firm which Will Not Consider its use. Besides understanding the firms that are already using CAD/CAM, it also is important to evaluate those who may adopt it and those who will not. The profile will give breakdowns by location, size of firm, industry, foreign vs. Canadian control, relative position in the industry, and type of CAD/CAM application.

Chapter 4 looks at the impacts of CAD/CAM, both experienced by Present Users and expected by the various categories of non-users. Data are presented on expectations regarding productivity, employment, sales volume, lead times, and quality of product.

Chapter 5 analyzes the experienced and expected constraints towards the adoption of CAD/CAM. It is a premise of this study that governments, educational institutions, suppliers, and other interested parties can do a good job of promoting and easing the transition to CAD/CAM use only if they first understand the constraints which are operating against Canadian manufacturers. Once the nature of the constraints are understood, incentive plans can be devised. Chapter 6 goes on to document the value manufacturers would place on various types of incentives.

Chapter 7 looks at the special concerns of small firms. It compares small firms with large ones to see if there are any differences in impacts, constraints and incentives. Chapter 8 looks at the differences between leaders and laggards in the adoption of CAD/CAM.

Chapter 9 takes a slightly different focus. It analyzes the constraints and incentives as seen by CAD/CAM suppliers and educational institutions. These perspectives are compared to those of the manufacturers who are currently using CAD/CAM.

Chapter 10 draws upon data from the whole study. In it, recommendations are made for facilitating the adoption of CAD/CAM techniques in Canada. The recommendations are based upon the findings revealed in the earlier chapters.

Chapter 3

A PROFILE OF CAD/CAM USE

The definition of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) used in this survey is a broad one. It includes any use of computer control in the design and manufacture of a product or service. To a certain extent, CAD/CAM is an outgrowth and advancement of earlier technology such as automated materials handling, automated assembly, and computerized numerical control of machine tools. While these technologies are an integral part of the today's CAD/CAM, they are only a portion of the picture.

Present day CAD/CAM goes much farther. It starts with the original design of the product on a computer screen and in a computer's memory. Input to the computer is done in an easy interactive manner once the designer has mastered the technique. The advantages of computer graphics over manual drafting for the same purpose are precise numerical placement of drawings, repeated placements of common templates, different displays from a three dimensional perspective, optional scaling of drawings, kinetic simulations, and very easy editing. These CAD advantages can be used in many industries for drafting, mapping large areas, planning (display and modify designs quickly), and control of operations (offtake of inventory or other specifications).

The computer advantages do not stop there, however. Materials lists may be taken off the computer drawings and inventory requirements calculated. Manufacturing jigs, tools and moulds may be produced ahead of time by taking the product specifications and designing the jig or mould around it. Manufacturing dimensions may be fed directly to numerically controlled machines, and the part can be produced without having to perform a separate input of data. Engineering or managerial data can be requested from the computer, and calculations can be made. All these uses are examples of an integration of CAD with CAM. On top of all this, we have examples of more pure types of CAM such as robotics, computer controlled assembly, computer visual inspection, and automated warehousing.

With such a broad definition of CAD/CAM, it is quite possible that some respondents may mistake the intended meaning. Some may interpret CAD/CAM to be just the computer aided design portion. Others may not perceive robotics as being a part of CAM. Still others may not see their use of numerically controlled machines or automated techniques as part of the computer technology of interest. To alleviate this definitional problem, the first page of the questionnaire contained a CAD/CAM description (see Appendix A).

CAD/CAM by Region and Use

Of the 285 respondents to the questionnaire, 70 said they were already Present Users of CAD/CAM, 58 said they were Actively Considering its use, 109 said they Might Consider its use, 47 said they Would Not Consider it, and one made no response. The 70 users are 25 percent of the respondents. Most of them must be satisfied with CAD/CAM, because 61 of them (87 percent) said they plan to expand its use.

The 167 establishments stating that they were Actively Considering or Might Consider CAD/CAM use represent 59 percent of the sample. Thus, there is ample room for further use and adoption. Moreover, it is likely that the 47 respondents (16 percent) who said they would not consider CAD/CAM's use may have a change of heart in the future.

The regional distribution of the respondents is presented in Table 3-1. As would be expected, 61 percent of the responding users are in Ontario, 24 percent in the Prairie provinces and 14 percent in British Columbia. The larger number of manufacturers in Ontario also applies for the other non-user response categories. More interesting, however, is that as a percent of the respondents for each region, the Prairies and B. C. have just as many users as Ontario. Nevertheless, the other non-user categories paint a different picture. A larger percentage of Ontario establishments are actively considering CAD/CAM use while the Prairies and B. C. have a larger percentage who say they will not consider its use. Perhaps the publicly visible technology centres in Ontario have made the firms of that area more aware of CAD/CAM possibilities.

TABLE 3-1

CAD/CAM Use By Regions

Region	Present Users			Actively Considering Use			Might Consider Use			Will Not Consider Use		
	Number	% of Users	% of Region	Number	% Actively Considering	% of Region	Number	% Might Consider	% of Region	Number	% Will Not Consider	% of Region
Ontario	43	61%	23%	45	78%	24%	71	65%	38%	26	55%	14%
Prairies	17	24%	30%	7	12%	12%	22	20%	39%	11	23%	19%
B.C.	10	14%	24%	6	10%	14%	16	15%	38%	10	21%	24%
Canada	70		25%	58		20%	109		38%	47		17%

Table 3-2 illustrates the respondent categories in terms of average number of employees, average sales, average number of production units per run, and source of control. The table illustrates that it is the largest establishments in terms of both number of employees and sales which have made the greatest use of CAD/CAM. As the average size of the firm drops, the interest in CAD/CAM declines. The typical present user has larger sized production runs, although the effect of this variable on CAD/CAM use is less clear. Perhaps it is the larger firms who are better informed of CAD/CAM capabilities. Consequently, they are the first to adopt it. Also, smaller firms may be waiting for a later stage in the CAD/CAM life cycle when the cost of equipment has declined.

TABLE 3-2

The Typical CAD/CAM Respondent

	Present Users		Actively Considering Use		Might Consider Use		Will Not Consider Use	
	Mean	N	Mean	N	Mean	N	Mean	N
Number of Employees	336	65	225	56	116	106	42	44
SALES	$27,740,300	67	$18,938,200	55	$10,646,800	108	$5,702,200	45
Number of Units Per Run	476	62	365	51	398	99	374	41
CONTROL	Number	%	Number	%	Number	%	Number	%
-Canadian	45	64%	36	62%	78	72%	40	85%
-U.S.	24	34%	18	31%	23	21%	6	13%
-European	1	1%	4	7%	7	6%	1	2%

Sixty-four percent of the Present Users and about the same percentage of those Actively Considering using CAD/CAM are Canadian controlled. The percentage Canadian controlled rises to 85 percent for those firms who Will Not Consider the use of CAD/CAM. While it may appear from these data that foreign controlled firms are more receptive to the use of CAD/CAM, a more probable explanation is the size of firm. Foreign ownership is less in the smaller firms, and it is the smaller firm which does not see the immediate need to adopt the new technology.

Breakdown by Size

Average figures can indicate general tendencies or trends, but they also can hide many important findings. This fact is proven by analyzing Table 3-3 (respondents by number of employees) and Table 3-4 (respondents by size of sales).

TABLE 3-3

Respondents By Number of Employees

Number of Employees		Present Users		Actively Considering Use		Might Consider Use		Will Not Consider Use	
	Total	Number	% of Size Category	Number	% of Size Category	Number	% of Size Category	Number	% of Size Category
1 - 10	37	4	11%	5	13%	14	38%	14	38%
11 - 25	58	8	14%	4	7%	29	50%	17	29%
26 - 50	44	11	25%	10	23%	16	36%	7	16%
51 - 100	34	6	18%	9	26%	16	47%	3	9%
101 - 200	49	13	26%	15	31%	21	43%	0	0%
201 - 500	27	10	37%	7	26%	7	26%	3	11%
501 - 1000	14	8	57%	4	29%	2	14%	0	0%
Over 1000	8	5	62%	2	25%	1	13%	0	0%

TABLE 3-4

Respondents By Size of Sales

Sales	Present Users: Number	Present Users: % in Sales Range	Actively Considering Use: Number	Actively Considering Use: % in Sales Range	Might Consider Use: Number	Might Consider Use: % in Sales Range	Will Not Consider Use: Number	Will Not Consider Use: % in Sales Range	Totals: Number
Less than $200,000	2	11%	1	6%	7	39%	8	44%	18
$ 200,000-$ 1,000,000	6	12%	3	6%	22	45%	18	37%	49
$ 1,000,000-$10,000,000	22	19%	27	24%	50	44%	15	13%	114
$10,000,000-$50,000,000	19	31%	18	29%	23	37%	2	3%	62
Over $50,000,000	18	56%	6	19%	6	19%	2	6%	32

Both tables reaffirm the tendency for larger firms to have adopted CAD/CAM or to be more interested in adopting it. Both tables also affirm, however, that small firms can make use of CAD/CAM technology. Twenty-three (35 percent) of the users have fewer than 50 employees and 30 (45 percent) of the users have sales of less than $10 million per year.

Being smaller does not mean that CAD/CAM is inappropriate. But being smaller may mean that there are special factors inhibiting a firm from making the plunge to new techniques. It may be a lack of awareness, insufficient funds to undertake the plunge, a propensity to avoid risk, or a number of other factors. Since special public policy initiatives are generally set up to help the small firm, it is important to look further into the special interests of them. Such an analysis is presented in Chapter 7.

CAD/CAM Use by Industry

The classification of respondents by industry is presented in Table 3-5. No replies were received from any of the firms in the fish processing industry. Two replies from firms in the measuring, analyzing and control instruments industry were added to the miscellaneous manufacturing industry. All other industries had a sufficient number of replies for analysis.

As Table 3-5 indicates, the fabricated metal products industry has the largest number of respondents (30 percent), followed by miscellaneous manufacturing (14 percent), electrical and electronic machinery, (13 percent), and non-electrical machinery (10 percent). All the other categories have between three and seven percent of the respondents. Compared to Table 2-1, it would appear that there is an above average response rate from the petroleum refining, electrical equipment, and miscellaneous manufacturing industries and a below average response rate form the apparel, fabricated metal products, and non-electrical machinery industries.

How far the respondents are along in the adoption of CAD/CAM can be assessed by the plant receptivity score in the last column of Table 3-5. This score is a weighted average from a 4 point scale, where a weight of 4 is given to a Present User, 3 to a plant considering adoption, 2 to Might Consider and 1 to Will Not Consider.

TABLE 3-5

Use of CAD/CAM By Industries

Industry	Present Users	Actively Considering Use	Might Consider Use	Will Not Consider Use	Plant Receptivity Score
Paper and allied products	2	0	4	3	2.1
Lumber and wood products	3	3	7	4	2.3
Chemicals & allied products	6	2	8	4	2.5
Petroleum refining and related industries	6	0	1	2	3.1
Primary metal industries	3	3	6	2	2.5
Fabricated metal products	21	22	32	9	2.7
Machinery (except electrical)	5	5	13	6	2.3
Electrical and electronic machinery	12	12	12	1	2.9**
Transportation equipment	3	4	5	1	2.7
Miscellaneous manufacturing	7	6	19	9	2.3
Apparel and other finished products	2	1	2	5	2.0

** Significantly larger than the average of all other industries ($p < .01$, two-tailed t-test).

From the scores, one can see that the petroleum refining respondents have been the most receptive towards CAD/CAM (3.1 plant receptivity score), followed closely by the electrical manufacturing respondents (2.9 receptivity score, which is larger than the average receptivity score of all other respondents by a statistically significant amount). The paper products and apparel industries' respondents are much less receptive towards CAD/CAM (receptivity scores of 2.1 and 2.0 respectively), although their receptivity scores are not lower by a statistically significant amount.

Evidence concerning the degree of industry adoption of CAD/CAM is presented in Table 3-6. The scores in the last column represent the degree of CAD/CAM penetration as perceived by the respondents of each industry. Using a scale of 4 to 1, where 4 means used by most firms in the industry, 1 means not used at all, and 2 and 3 mean intermediate use, an industry usage score is calculated. The industry usage scores indicate that the miscellaneous manufacturing industry has the least usage, and that this use is lower than the average of other industries by a statistically significant amount. The apparel, paper, lumber, and primary metal industries are other low users. The highest (and statistically significant) degree of penetration has been in the electrical manufacturing industry. Overall, the average scores indicate that there still is ample room for further penetration.

TABLE 3-6

Perceived Industry Use of CAD/CAM, Classified By Industry

Industries	Used By Most Firms	Used By Some Firms	Used By Few Firms	Not Used At All	Industry Usage Score
Paper and allied products	1	1	4	3	2.0
Lumber and wood products	2	3	6	6	2.1
Chemicals & allied products	1	5	11	3	2.2
Petroleum refining and related industries	0	5	1	2	2.4
Primary metal industries	0	1	13	0	2.1
Fabricated metal products	3	28	38	12	2.3
Machinery (except electrical)	1	10	13	4	2.3
Electrical and electronic machinery	4	21	8	2	2.8**
Transportation equipment	2	3	7	1	2.5
Miscellaneous manufacturing	2	4	18	16	1.8**
Apparel and other finished products	0	1	6	3	1.8

** Significantly higher or lower than the average of all other industries ($p < .01$, two-tailed t-test).

TABLE 3-7

Perceived Industry Use of CAD/CAM, Classified By Degree of Plant Receptivity

	Present Users	Actively Considering Use	Might Consider Use	Will Not Consider Use	Plant Receptivity Score
Used By Most Firms	12	3	1	1	3.5
Used By Some Firms	31	21	24	6	2.9
Used By Few Firms	26	30	56	13	2.6
Not Used At All	0	4	25	24	1.6
Industry Usage Score	2.8	2.4	2.0	1.6	-

Table 3-7 indicates that the competitive effect, or at least the demonstration effect, may have a strong bearing on a firm's behaviour. There appears to be a direct relationship between the degree of plant receptivity and the level of industry usage. Those who have already accepted the new technology perceive that CAD/CAM is being used by a fairly large number of firms in their industry (usage score of 2.8). Those who are compelled to Actively Consider CAD/CAM perceive more than just a few firms using CAD/CAM in their industry (usage score of 2.4), while those who Might Consider perceive just a few firms using it (usage score of 2.0). Those who Will Not Consider the use of CAD/CAM perceive very little usage in their industry (usage score of 1.6). These firms probably are not compelled to adopt CAD/CAM, because they do not see that many firms are using the technology in their industry. Perhaps they have no compulsion to keep up, or perhaps they have no role models to follow.

Another way to look at the same picture is to consider the plant receptivity scores in the last column of Table 3-7. As can be seen, receptivity is much lower if few or no firms in the industry are using the technology.

Next, consider Table 3-8. It demonstrates whether the respondents consider themselves a leader or a laggard in the adoption of CAD/CAM in their industry. Using a five point scale (where 5 means an industry leader and 1 well behind competitors), we can calculate a leadership score for each industry. This score indicates whether we have a representative sample for each industry, since we would expect an equal number of leaders and laggards from each industry and a leadership score which is very close to three, the midpoint on the scale. As Table 3-8 shows, the sample may have a slightly below average number of leaders from the lumber and non-electrical machinery industries.

TABLE 3-8

Perceived Leadership in CAD/CAM, Classified By Industry

Industry	Industry Leader	Ahead of Competitors	On Par With Competitors	Somewhat Behind Competitors	Well Behind Competitors	Leadership Score
Paper and allied products	1	1	5	2	0	3.1
Lumber and wood products	0	2	3	5	3	2.3*
Chemicals & allied products	0	2	11	3	2	2.7
Petroleum refining and related industries	1	2	4	0	0	3.6
Primary metal industries	0	2	6	6	0	2.7
Fabricated metal products	8	16	34	11	7	3.1
Machinery (except electrical)	0	2	14	7	3	2.6*
Electrical and electronic machinery	2	9	11	12	2	2.9
Transportation equipment	2	6	0	4	1	3.3
Miscellaneous manufacturing	4	4	24	3	1	3.2
Apparel and other finished products	0	1	4	4	0	2.7

* = .05

Table 3-9 shows that industry leaders tend to be the Present Users and those Actively Considering CAD/CAM. They are the ones with the higher plant receptivity scores. These would be the findings one would expect. What may be disturbing from Table 3-9, however, are the 61 establishments (21 percent of all establishments) who agree they are behind their competitors but who Will Not Consider or only May Consider CAD/CAM. These firms warrant further investigation. Are they smart laggards, ones who are more profitable and successful because they do not follow the crowd? Alternatively, are they already less successful, and are they only laggards because they cannot afford the transition? Another possibility is that they may be successful, but uninformed about CAD/CAM technology. Chapter 8 will look further into these questions.

TABLE 3-9

Perceived Leadership in CAD/CAM, Classified By Plant Receptivity

Position in Industry	Present Users	Actively Considering Use	Might Consider Use	Will Not Consider Use	Plant Receptivity Score
Industry Leader	10	3	5	0	3.3
Ahead of Competitors	31	12	4	0	3.6
On Par With Competitors	22	31	45	19	2.5
Somewhat Behind Competitors	5	9	32	11	2.1
Well Behind Competitors	1	1	10	8	1.8
Leadership Score	3.6	3.1	2.6	2.3	-

CAD/CAM Applications

The various types of CAD/CAM applications are summarized in Table 3-10, cross-classified by receptivity categories (user, actively considering, might consider) and by whether the respondent is Presently Using, Considering, or Might Consider that particular type of CAD/CAM application. The numbers in the triangular shaped boxes represent incorrect responses. For example, 12 respondents (7 plus 5 in the first row) said that they were already using engineering computation by computer. They also had answered an earlier question saying that they were not present users of CAD/CAM. They said that they were Actively Considering CAD/CAM or Might Consider its use within the next five years. These people have a different meaning of CAD/CAM than intended in the questionnaire. They are confused.

The confusion index in the last column of Table 3-10 gives the percentage of people who answered inappropriately. In many cases, the same respondents are answering inappropriately to different categories of CAD/CAM. Therefore, there is some double counting in the confusion percentages. Irrespective of this fact, notice that the highest degrees of confusion are in the definitions of automation techniques and computerized numerical control of machine tools. In the case of the confusion over automation techniques, it is possible that the respondents' present form of automation is not under computer control. If so, their reply would have been correct, but the questionnaire would not have picked this up. Notwithstanding this possibility, it is more likely that respondents perceive the traditional and older aspects of CAD/CAM (i.e. what they have been doing all along) not to be part of the new CAD/CAM movement.

TABLE 3-10

CAD/CAM Applications

APPLICATION	Present Users	Actively Considering Use	Might Consider Use	Totals	Confusion Percentage
ENGINEERING COMPUTATION BY COMPUTER:					
- Presently Using	30	7	5	42	20%
- Presently Considering	7	9	4	20	20%
- Might Consider	5	2	8	15	-
CAD:					
- Presently Using	20	0	1	21	5%
- Presently Considering	10	13	5	28	18%
- Might Consider	4	2	7	13	-
AUTOMATION TECHNIQUES:					
- Presently Using	28	10	5	43	35%
- Presently Considering	7	6	10	23	43%
- Might Consider	2	4	3	9	-
COMPUTERIZED NUMERICAL CONTROL:					
- Presently Using	30	8	7	45	33%
- Presently Considering	3	5	3	11	27%
- Might Consider	3	6	7	16	-
INTEGRATED CAD/CAM:					
- Presently Using	6	1	0	7	14%
- Presently Considering	11	9	3	23	13%
- Might Consider	11	6	9	26	-
ROBOTICS:					
- Presently Using	8	1	3	12	25%
- Presently Considering	15	6	7	28	25%
- Might Consider	4	5	6	15	-
OTHER:					
- Presently Using	5	1	0	6	17%
- Presently Considering	1	2	0	3	0%
- Might Consider	0	0	0	0	-

The older forms of computer use in manufacturing -- engineering computation by computer, automation techniques, and computerized numerical controlled machinery -- are the most common. Since those older technologies are more mature and in common use, fewer firms are planning to use them. For example, engineering computation by computer, automation techniques, and computerized numerical controlled machinery each have about 43 users, but only about 30 establishments which are or might consider them. Conversely, fewer plants are using the newer aspects of CAD/CAM, although these are the applications which most plants are considering. Computer aided design, integrated CAD/CAM, and robotics have only 21, 7 and 12 users respectively. In spite of the small number of users, each of these application areas have about 45 firms who say they are presently considering or might consider adoption.

Summary

The respondents to this survey are representative of the manufacturing industries selected for analysis. Sixty-five percent of them are from Ontario, 25 percent are already users of CAD/CAM, and 20 percent are actively considering its use. The users tend to be the larger sized firms, although there are many small firms who find the technology appropriate.

Greater receptivity and usage of CAD/CAM has occurred in the electrical manufacturing industry, while the apparel, paper, lumber, and miscellaneous manufacturing industries tend to have lower use. Higher receptivity tends to occur when there is also a high degree of usage in the industry. Whether firms react to competition or need role models to emulate is a matter still to be explored.

The older aspects of CAD/CAM (engineering computation, automation techniques, and computerized numerical control) are the most common forms of CAD/CAM application. Nevertheless, robotics, integrated CAD/CAM and computer aided design are newer applications which are being seriously considered by many firms.

Chapter 4

EXPECTATIONS OF IMPACTS

The questionnaire asked respondents to estimate the effects which CAD/CAM would have on productivity, employment, quality of production, volume of business and lead or set up times getting ready for production. If they were not already a user of CAD/CAM, then respondents were asked to give their best estimates of the potential effects.

These impact data can be analyzed to get an idea of how CAD/CAM affects Canadian firms. Before undertaking the analyses, however, one must recognize that the data are very imprecise -- except for the assessments made by Present Users, the data are largely expectations of what is possible.

Although we may place greater weight on the replies made by Present Users, even here the data may be only approximate. The senior officer of the establishment was asked to fill out the questionnaire, and he or she may not have been the best person to know the exact impact figures. Furthermore, the questionnaire asked to give the impact from CAD/CAM in general, whereas the impact from different types of CAD/CAM application is quite specific. For these reasons, we may use the Present Users' responses as a more reliable benchmark, but we must still consider all the data to be expectations of impacts rather than the actual impacts.

An Overview of Impacts

The overwhelming expectation is that CAD/CAM technology will increase productivity, boost sales volume, and improve quality. Lead times will be lowered and so will employment, but the expectation in these areas is not unanimous. Although they have positive expectations towards CAD/CAM, those less inclined to use it (the Might Consider and Will Not Consider categories) do not see as large a benefit.

In total, 234 respondents said productivity would increase, three said it would decrease and six said there would be no change (Table 4-1). The average increases range from a 62 percent increase as stated by present users to a 29 percent increase as stated by the might consider category. Oddly, 77 percent of those who will not consider its use said productivity would increase by an average of 32 percent. Perhaps a 32 percent gain is not sufficient to cause a shift to CAD/CAM.

TABLE 4-1

Expectations of Impacts by Respondent Groups

PERFORMANCE MEASURE		Present Users		Actively Considering Use		Might Consider Use		Will Not Consider Use	
		Number	Average % Change	Number	Average % Change	Number	Average % Change	Number	Average % Change
PRODUCTIVITY:	- Increase	64	62%	54	52%	95	29%	21	32%
	- Decrease	0	-	0	-	1	-	2	-30%
	- No Change	1	-	0	-	1	-	4	-
SALES VOLUME:	- Increase	48	38%	44	36%	74	24%	17	16%
	- Decrease	0	-	0	-	0	-	0	-
	- No Change	4	-	5	-	11	-	7	-
QUALITY: Decrease ← → Increase -3 -2 -1 0 1 2 3 Changes: 1 = negligible 2 = moderate 3 = large	- Increase	64	2.54	56	2.48	96	2.20	22	2.14
	- Decrease	0	-	0	-	1	-1.00	2	-2.50
	- No Change	0	-	0	-	0	-	3	-
LEAD TIMES:	- Increase	12	95%	2	18%	23	26%	14	74%
	- Decrease	41	-47%	40	-30%	64	-22%	8	-6%
	- No Change	1	-	5	-	3	-	2	-

EMPLOYMENT:		Present Users			Actively Considering Use			Might Consider Use			Will Not Consider Use		
- # Change is the change in the number of people employed at the given plant. - % Change is the change in the affected workforce of the plant.		Number	Average Change #	Average Change %	Number	Average Change #	Average Change %	Number	Average Change #	Average Change %	Number	Average Change #	Average Change %
	- Increase	22	8	18%	20	11	14%	30	4	23%	9	2	72%
	- Decrease	27	-19	-13%	17	-6	-7%	40	-12	-13%	16	-3	-23%
	- No Change	9	-	-	8	-	-	14	-	-	3	-	-

Nobody said that sales volume would decrease, although 13 percent of the respondents said that there would be no change. The average increases range from an increase of 38 percent in the Present Users' category down to a 16 percent increase in the Will Not Consider category. On average, those Actively Considering use felt that sales volume would increase almost exactly what the Present Users indicated that it did increase. Thus, those Actively Considering CAD/CAM have a fairly realistic picture of how the lower costs, higher quality and quicker service from CAD/CAM can be transformed into higher sales.

Three of 244 respondents said that quality would decline, and another three said that there would be no change. All other respondents said that quality would increase. Using a seven point scale, where zero equals no change, 1 equals negligible change, 2 moderate change, 3 large change, and the plus and minus signs the direction of change, we can calculate a quality change score. The scores indicate that the degree of increase averages out to be between moderate and large, although decreasing slightly as we progress from the Present User category to the Will Not Consider category.

One hundred respondents (46 percent) said employment would decrease as a result of using CAD/CAM, 81 (38 percent) said it would increase, and 34 (18 percent) said there would be no change. The 100 who said employment would decrease indicated that the absolute size of the decline would be about 11 people per firm, which is about 14 percent of the affected workforce. The same figures for the 81 who stated employment would increase is 7 people per firm and 25 percent of the affected workforce. The differences indicate that it is the larger firms who decrease employment when going to CAD/CAM. The smaller firms probably have to acquire the expertise to run the CAD/CAM equipment. Consequently, they increase employment. In Chapter 7, these differences between small and large firms are studied in detail.

Impacts by Industries

Of the different types of respondents, the Present Users are the ones with first hand experience with the impacts of CAD/CAM. Undoubtedly, their responses are the most accurate, and we can safely analyze their replies for further insights.

Table 4-2 presents the impact expectations of Present Users by industries. In some industries there are only one or two Present Users, and it is difficult to draw inferences for the industry as a whole. Where there are five or more replies, industry results can be analyzed.

All industries experienced productivity increases. The highest increase was in the petroleum refining industry (104 percent) followed closely by miscellaneous manufacturing (98 percent) and electric and electronic machinery (84 percent). As Table 4-3 illustrates, the petroleum refining industry is a heavy user of engineering computation by computer, CAD, and other techniques such as process fluid control. Miscellaneous manufacturing has benefitted from computerized numerical controls while the electronic industry has made the greatest use of automation techniques and engineering computations.

The average increase in sales volume for all Present Users is 38 percent. In two of the industries, petroleum refining and transportation equipment, only one manager replied to this question. Both of these respondents said that CAD/CAM has no effect on sales (i. e. neither increased nor decreased sales). The effect in all other industries is for sales to increase. The industries with above average increases in their sales volumes are the fabricated metal products and non-electrical machinery. Their primary use of CAD/CAM is computerized numerical control machinery and computer aided design.

TABLE 4-2

Average Impacts on Present Users, Classified by Industry

INDUSTRY	Productivity	Sales Volume	Quality[a]	Lead Times	Employment Number	Employment Percentage
Paper and allied products	50% ↑ (1)	10% ↑ (1)	2.50 ↑ (2)	50% ↑ (1)	-1 ↓ (1)	- (0)
Lumber and wood products	13% ↑ (2)	11% ↑ (2)	2.33 ↑ (6)	1% ↑ (2)	-15 ↓ (2)	-8% ↓ (2)
Chemicals and allied products	55% ↑ (5)	10% ↑ (4)	2.33 ↑ (6)	-15% ↓ (3)	0 (5)	2% ↑ (5)
Petroleum refining and related industries	104% ↑ (6)	0 (1)	2.33 ↑ (6)	250% ↑ (2)	-12 ↓ (5)	-14% ↓ (4)
Primary metal industries	38% ↑ (2)	15% ↑ (1)	2.00 ↑ (3)	-15% ↓ (2)	1 ↑ (2)	3% ↑ (2)
Fabricated metal products	51% ↑ (15)	55% ↑ (15)	2.69 ↑ (16)	-31% ↓ (13)	-4 ↓(12)	10% ↑(13)
Machinery (except electrical)	30% ↑ (4)	55% ↑ (3)	2.75 ↑ (4)	-35% ↓ (2)	-24 ↓ (2)	8% ↑ (2)
Electrical and electronic machinery	84% ↑ (8)	32% ↑ (7)	2.70 ↑ (10)	-93% ↓ (8)	-1 ↓ (7)	1% ↑ (7)
Transportation equipment	38% ↑ (2)	0 (1)	2.33 ↑ (3)	8% ↑ (2)	-22 ↓ (3)	-17% ↓ (3)
Miscellaneous manufacturing	98% ↑ (5)	11% ↑ (4)	2.67 ↑ (6)	-19% ↓ (4)	-8 ↓ (4)	-7% ↓ (4)
Apparel and other finished products	10% ↑ (2)	30% ↑ (1)	2.50 ↑ (2)	100% ↑ (1)	2 ↑ (1)	6% ↑ (1)

n = numbers in brackets

[a] Quality Scale:

-3	-2	-1	0	1	2	3
large decrease	moderate decrease	negligible decrease	no change	negligible increase	moderate increase	large increase

TABLE 4-3

Applications of Present Users, Classified by Industry

INDUSTRY	Engineering Computation By Computer	CAD	Automation Techniques	Computerized CNC	Integrated CAD/CAM	Robotics	Other
Paper and allied products	0	1	1	0	0	0	0
Lumber and wood products	1	1	1	0	0	0	0
Chemicals and allied products	1	0	5	1	0	1	1
Petroleum refining & related industries	4	3	1	0	0	0	3
Primary metal industries	0	0	1	1	0	0	1
Fabricated metal products	9	4	4	12	3	3	0
Machinery (except electrical)	2	1	2	3	0	0	0
Electrical and electronic machinery	7	5	9	5	1	1	0
Transportation equipment	2	1	2	2	0	2	0
Miscellaneous manufacturing	3	2	2	6	1	1	0
Apparel and other finished products	1	2	0	0	1	0	0

It is interesting to note that the fabricated metal products and non-electrical machinery industries, the ones with above average sales increases, also experienced above average increases in the quality of their output but slightly below average increases in productivity. The implication is that quality of output, not necessarily lower prices as a result of productivity improvements, is what leads to higher sales volume. If such is the case, then those adopting CAD/CAM can increase sales at the same profit margin and realize higher profits. The increase in sales probably comes at the expense of those who do not adopt CAD/CAM.

All industries reported increases in quality as a result of using CAD/CAM. As mentioned, above average increases are reported for the fabricated metal products industry and the non-electrical machinery industry. Other industries experiencing above average increases are the electrical and electronic machinery industry and the miscellaneous manufacturing industry. These latter two industries are heavy users of engineering computation by computer, automation techniques, and computerized numerical controls.

The response regarding lead times was mixed. Some firms said lead time would increase dramatically, while others said it would decline. Perhaps the interpretation of lead time caused the differences, or perhaps it was the suitability of the concept of lead time to different industries. For example, the petroleum refining industry tends to have continuous production, and lead times do not make much sense to such firms. Also, some firms may interpret lead time as the period taken to conceive a product, design it, and get it manufactured. Other firms may understand lead time as the period taken to get machines set up and running between batch runs.

The employment impacts by industry are mixed. In most industries, especially those with more than five respondents, the average number of workers declined. Although an increase was recorded for the apparel and primary metals industries, the sample sizes are too small to enable us to say that these industries have a tendency to use more employees. Whether or not CAD/CAM causes an increase or decrease in employment is probably a function of the size of the firm. The overall tendency is to use fewer people, but small firms tend to require more.

Impacts by Applications

Another way to look at impacts is by type of application. It would be very useful to know whether one type of CAD/CAM has a bigger impact than another and whether a particular effect is associated with one type of application. Unfortunately, the questionnaire did not ask for impacts by specific applications. Rather, it requested information on overall impacts of CAD/CAM. Consequently, the impact effects are a composite measure of a number of applications.

We do know, however, the degree of overlap of one application with another. For example, all of the users of robotics also use at least one other type of CAD/CAM. Eighty seven percent of them use three or more other types. Thus, we cannot be sure whether the impact measures for robotics are really attributable to that type of application. On the other hand, from 57 to 66 percent of the respondents to the other types of CAD/CAM used just that type of application or one other. Thus, except for robotics, there is relatively good uniqueness in the impact scores for all applications.

Table 4-4 shows the average impact measures by application. Since the replies for robotics are closely intertwined with the results of other applications (primarily automation techniques, computerized numerical controls, and engineering computations), they will not be analyzed. Similarly, the number of respondents to the integrated CAD/CAM (primarily expansions beyond initial CAD or CAM systems) and other categories are too small to allow reliable analysis. Only the categories of engineering computation, CAD, automation techniques, and computerized CNC have both adequate numbers and sufficient uniqueness to allow more detailed analyses.

TABLE 4-4

Average Impacts on Present Users, Classified by Application

APPLICATION	Average % Productivity Increase	Average % Sales Volume Increase	Average Quality Increase[a]	Average % Lead Times Decrease	Average Employment (Number) Decrease	Average Employment (Percentage) Decrease
Engineering Computation by Computer	78%	22%	2.6	-11%	-10	- 7%
CAD	101%	29%	2.4	- 8%	- 8	-35%
Automation Techniques	80%	18%	2.6	-55%	- 6	- 8%
Computerized CNC	85%	56%	2.8	-49%	- 2	- 6%
Integrated CAD/CAM	17%	22%	2.2	-35%	- 6	- 8%
Robotics	104%	21%	2.8	-23%	-13	-16%
Other	4%	13%	2.2	- 8%	- 1	- 3%

[a] Quality Scale:

-3	-2	-1	0	1	2	3
Large Decrease	Moderate Decrease	Negligible Decrease	No Change	Negligible Increase	Moderate Increase	Large Increase

In terms of productivity improvements, all four techniques generate large increases, especially CAD. Adopting computerized numerical controls seems to produce the largest increase in sales volume and the largest increase in quality. This evidence seems to back up the previously mentioned point that sales increases are greatly enhanced by quality improvements. Regarding lead times, it would appear that all techniques help to lower lead times, but that the effect for CAD is not as great. This finding is somewhat surprising. It could be attributable to differing interpretations of lead time.

For employment, the largest average decrease in the number of employees (10) occurs with engineering computation. Since this number represents only 7 percent of the affected workforce, it means that engineering computation does not cause large displacements. Since an average decrease of 8 with CAD represents 35 percent of the affected workforce, it means that CAD has can cause major displacements in a drafting department.

Summary

For those who have adopted CAD/CAM, the benefits have been major. Productivity has risen markedly, sales have increased, and quality has improved. In most firms, lead times have been lowered and manpower requirements have been lessened, at least for most of the larger establishments. These general impacts are similar in different industries and for different applications.

Why, then, would some firms still be in the non-user categories? The reason has to do with their expectations of impacts. As we look across the user categories, from those actively considering CAD/CAM to those who will not consider it, we witness a decline in expectations. Those less inclined to use CAD/CAM do not perceive the benefits to be as great. To get a better understanding of how these respondents differ from the present users, we turn to an analysis of perceived constraints and incentives.

Chapter 5

PERCEPTIONS OF CONSTRAINTS

Just because CAD/CAM technology can yield some major benefits does not mean that it will be adopted by all firms. Acceptance and implementation of the technology requires many obstacles to be overcome. If these constraints or hurdles are too high, then the benefits will look less desirable and the technology will not be adopted.

The questionnaire asked respondents to rate sixteen different types of constraints. They could say that a mentioned constraint was (1) an unimportant factor when considering CAD/CAM, (2) a not so important factor, (3) an important factor, (4) a very important factor, or (5) a critical factor. The numbers beside these rating can be used to calculate an average constraint score for various classifications. The higher the constraint score, the more severe the constraint.

This chapter analyzes the constraints to CAD/CAM. It pays particular attention to how the different categories of establishments perceive various constraints, and it also analyzes the data for any regional differences.

Constraints by User Categories

The data on constraints are presented in Table 5-1. They are listed in order of severity as perceived by Present Users. As indicated by the statistically significant rank order correlation coefficients at the bottom of the table, Present Users, those Actively Considering the use of CAD/CAM and those who Might Consider its use have similar rankings. Those who Will Not Consider CAD/CAM rank the constraints in a very different manner.

The Present Users are the ones who have already experienced the adoption and use of CAD/CAM. Thus, we may look upon their evaluations as more accurate reflections of what happens when CAD/CAM is actually used. By making statistical comparisons between the average scores of the present users vs. the other categories of respondents, we can get an idea as to whether or not these other categories have different perceptions or misconceptions regarding the technology. We can also look at the absolute value of the scores to see which constraints are more important.

Present Users rated unavailability or high cost of investment capital as the most serious constraint, followed closely by inadequate return on investment. The other respondent groups also placed high ratings on these constraints, although those less inclined to use CAD/CAM, the Might Consider and Will Not Consider categories, rated inadequate return on investment as extremely important. Their average scores (4.03 and 4.32 respectively) are larger than the Present Users' score (3.44) by a statistically significant amount.

TABLE 5-1

Average Constraint Ratings of Respondent Groups

CONSTRAINT	Present User		Considering		Might Consider		Will Not Consider	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Unavailable or high cost of capital	3.52	1	3.53	1	3.77	2	3.95	4
Inadequate return on investment	3.44	2	3.44	3	4.03**	1	4.32**	1
Lack of system software support	3.27	3	3.00	6	3.29	6	3.21	12
System incompatibility in exchanging data	3.23	4	2.90	12	2.49**	15	2.80	15
Management inexperienced in implementation	3.20	5	3.00	8	3.38	5	3.89**	7
Lack of standardization	3.19	6	3.00	7	2.87	13	3.53	10
High financial risk	3.15	7	3.46	2	3.76**	3	3.80*	8
Difficult integration into present operations	3.11	8	2.86	13	3.08	10	3.91**	5
Management unknowledgeable about technology	3.11	9	3.08	5	3.39	4	3.89**	6
Market volatility	3.00	10	2.96	10	3.23	7	3.03	14
Unavailable resources to study CAD/CAM	2.98	11	2.90	11	3.23	8	3.42	11
Fast obsolescence of technology	2.96	12	3.17	4	3.05	11	3.12	13
Trained staff unavailable	2.95	13	3.00	9	3.14	9	3.61**	9
No need for immediate change	2.40	14	2.22	14	3.02**	12	4.05**	3
Potential labour conflict	2.02	15	1.66	16	1.82	16	1.74	16
Not yet appropriate to industry	1.58	16	2.10*	15	2.84**	14	4.13**	2
Range of n	52 ↓ 66		50 ↓ 55		95 ↓ 107		30 ↓ 40	
Spearman's Rank Correlation Coefficient	--		.66**		.60*		.11	

Scale: 1 = Unimportant Factor; 2 = Not So Important; 3 = Important Factor; 4 = Very Important; 5 = Critical Factor

Asterisks indicate a significant difference (correlation) between the average ratings (rankings) of respondent groups: * = $p < .05$; ** = $p < .01$, two tailed, t-test (Spearman's significance test).

At the other end of the scale, Present Users said that questions about the current appropriateness of CAD/CAM was the least important constraint. This constraint, as it turns out, is the best one for distinguishing between the four respondent groups. Its severity and statistical significance steadily rises as the the inclination to use CAD/CAM drops. Present Users say the current inappropriateness is unimportant (1.58), those Actively Considering say it is not so important (2.10), those who Might Consider say it is important (2.84) and those who Will Not Consider CAD/CAM say it is very important (4.13).

Those less inclined to use CAD/CAM (Might Consider and Will Not Consider categories) also place statistically greater weight on high financial risk and no need for immediate change. Both Present Users and those Actively Considering CAD/CAM place about the same weight on financial risk and the need for change, whereas the Might Consider and Will Not Consider categories say that these constraints are significantly more important. The greater risk aversion amongst the latter two groups means that they would require a higher rate of return to adopt the new technology.

Given that all respondent groups had fairly positive expectations about the impacts of CAD/CAM (Chapter 4), we wonder why inadequate return on investment appears as a serious constraint. Is it a true inadequacy of return or is it just an artifact of misperception about no need for immediate change or inappropriateness for the industry? Some credence for the inadequate return on investment argument is indicated by the serious rating which Present Users placed on this constraint. Why would Present Users adopt CAD/CAM if they see an inadequate return on investment as being a serious threat? Since nearly all of them are planning further additions of CAD/CAM, we doubt that they are dissatisfied with their earlier decision. More likely, the inadequate return barrier is related to the unavailability and high cost of capital. At the time the questionnaire was mailed, the economy was just coming out of a serious recession. The tightness and high cost of capital was probably foremost in the minds of all businessmen. Since the CAD/CAM decision is a capital intensive one, a high cost of capital has an adverse effect on the return on investment. When capital costs decline, the return will rise, and more firms will adopt the technology.

Other constraints judged to be serious are lack of software support, data compatibility problems, management team inexperience with implementation, integration difficulties, and management's lack of knowledge about the technology. As compared to Present Users, the Will Not Consider respondents see some constraints to be a much higher barrier. This is the case for management's experience with implementation, integration difficulties, management's lack of knowledge about the CAD/CAM, and unavailability of trained staff -- the scores for these constraints are statistically higher for the Will Not Consider group.

As a general tendency, those less inclined to use CAD/CAM perceive the barriers to be higher. For two constraints, however, this general tendency does not hold. Present Users see data compatibility problems to be more severe than the other groups, and in comparison to the Actively Considering group, they place higher weight on the difficulties of integrating CAD/CAM with present operations. In fact, the data compatibility score for the Might Consider group is smaller by a statistically significant amount. Since Present Users have already experienced the problems of the transition to CAD/CAM, we may conclude that the other respondents are under a slight delusion as to the compatibility and integration difficulties they will encounter if they ever take the big step.

The only constraint which all agree is not very serious is potential labour conflict. For some firms, especially small nonunionized ones which must increase employment, minimal labour conflict can be expected. But as was shown in the last chapter, 46 percent of the establishments said that employment would decline and 18 percent said there would be no change. We would anticipate these firms to experience greater labour strife when moving to CAD/CAM. For them to say otherwise implies that labour change can be managed or else labour's strength in resisting technological change is minimal. The low rating placed by Present Users on labour conflict indicates that it has been managed in the past. Nevertheless, we must remember that poor economic conditions had lessened labour's bargaining power at the time when the questionnaire was distributed.

Constraints by Regions

The average constraint scores for Ontario, the Prairies, and British Columbia are illustrated in Table 5-2. We can test for significant differences between regions by comparing a region's score with the average score of the other two regions. If the difference is large, then the statistical significance will be indicated.

TABLE 5-2

Average Constraint Ratings, Classified by Region

CONSTRAINT	Ontario		Prairies		B.C.	
	Score	Rank	Score	Rank	Score	Rank
Unavailable or high cost of capital	3.64	2	3.79	1	3.74	2
Inadequate return on investment	3.77	1	3.78	2	3.95	1
Lack of system software support	3.20	7	3.10	7	3.43	6
System incompatibility in exchanging data	2.87	14	2.51	13	2.88	14
Management inexperienced in implementation	3.36	4	3.20	4	3.33	8
Lack of standardization	3.15	9	2.62**	12	3.32	9
High financial risk	3.58	3	3.36	3	3.63	3
Difficult integration into present operations	3.30**	6	2.82*	11	2.89	13
Management unknowledgeable about technology	3.34	5	3.18	5	3.44	5
Market volatility	3.09	10	2.96	9	3.26	11
Unavailable resources to study CAD/CAM	3.07	11	3.04	8	3.46	4
Fast obsolescence of technology	2.95*	12	3.16	6	3.41*	7
Trained staff unavailable	3.19	8	2.88	10	3.21	12
No need for immediate change	2.89	13	2.47*	14	3.30*	10
Potential labour conflict	1.81	16	1.85	16	1.84	16
Not yet appropriate to industry	2.68	15	2.33	15	2.77	15
Range of n	159 ↓ 174		45 ↓ 50		34 ↓ 39	
Spearman's Rank Correlation Coefficient	-		.87**		.76**	

Scale: 1 Unimportant Factor — 2 Not So Important — 3 Important Factor — 4 Very Important — 5 Critical Factor

Asterisks indicate a significant difference (correlation) between the average ratings (rankings) of the other two regions (Ontario for the rank order correlation): * = p < .05; ** = p < .01, two tailed t-test (Spearman's significance test).

For the most part, there are only a few differences between the regions. Ontario establishments seem to be less concerned about fast obsolescence, but more concerned with the problems of integrating CAD/CAM with their present operations. Establishments on the Prairies seem to be less concerned with integration problems and the lack of software and equipment standardization. They are also more convinced that there is a need for an immediate change and that CAD/CAM is appropriate for their industries. British Columbian establishments, on the other hand, are more complacent. They do not see an immediate need for change. Perhaps it is because they are more concerned about fast obsolescence. They may be waiting until the technology matures and the possibility of fast obsolescence is lessened.

Summary

As the inclination to use CAD/CAM lessens, the constraints and barriers become bigger. The most serious constraint seen by Present Users was the unavailability or high cost of investment capital. It received an average score of 3.52 which places it between important and very important on the rating scale. In comparison, those respondents who said they Would Not Consider the use of CAD/CAM in the next five years ranked 10 of the 16 constraints higher than 3.52. For the Might Consider category, it was 3 out of 16, and for the Actively Considering category, it was 1 out of 16. As can be seen, the constraints are more severe in the less inclined groups.

We must ask ourselves, however, whether the barriers are real or imagined. The respondents who said they would not consider CAD/CAM were very convinced that CAD/CAM did not provide an adequate return on investment, that it was not yet appropriate to their industry, and that there was no need for immediate change. The same feeling exists amongst the Might Consider group, except to a slightly lesser degree. Both of these groups also feel that there is a high financial risk in going to CAD/CAM technology. With such perceptions, there is good reason for them to have no desire for change.

The Will Not Consider category also felt much stronger about several other constraints. In particular, they said that management's lack of knowledge about CAD/CAM and management's inexperience in system implementation were very serious impediments. If management in these establishments was knowledgeable and experienced, then we would place much greater trust in their perceptions that CAD/CAM provides inadequate returns, is inappropriate and not needed. We feel more knowledge would cause them to shift into one of the other categories which are more receptive to CAD/CAM.

Chapter 6

PERCEPTIONS OF INCENTIVES

The previous chapter documented the various types of constraints which deter manufacturers from adopting CAD/CAM technology. This chapter looks at the other side, at the incentives which may encourage more firms to take the plunge. It considers various incentives which may be provided by federal or provincial agencies, suppliers of equipment, educational institutions, and other manufacturers.

Incentives by Types of Respondent

Table 6-1 illustrates the average incentive scores for the four categories of respondents. The incentives are ranked in order of perceived importance by Present Users. Except for the incentive ranked lowest by Present Users, all incentive scores are larger than three, meaning that they are all judged to have some desirable impact.

TABLE 6-1

Average Incentive Ratings of Respondent Groups

INCENTIVE	Present User		Considering		Might Consider		Will Not Consider	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Tax incentives for capital investment	4.36	1	4.30	1	4.34	1	3.88**	2
Suppliers train operators and programmers	4.07	2	4.23	2	4.24	2	3.91	1
Suppliers standardize software and hardware	3.88	3	3.78	6	3.93	4	3.68*	6
Educational institutions train operators	3.85	4	3.79	5		5	3.58	8
Educational institutions train management	3.76	5	3.75	8	3.76	9	3.81	3
Government funding for feasibility studies	3.72	6	3.88	3	3.94	3	3.70	4
Government funding for innovative programs	3.68	7	3.82	4	3.70	11	3.61	7
Manufacturers share information and insights	3.64	8	3.74	9	3.81	6	3.70	5
Industry collaboration in R&D	3.62	9	3.40	12	3.71	10	3.42	12
Change CAD/CAM tariff arrangements	3.45	10	3.33	13	3.54	13	3.28	13
Government funding for on-the-job training	3.43	11	3.76	7	3.77*	8	3.53	10
Suppliers train management	3.38	12	3.46	11	3.79**	7	3.45	11
Educational institutions research CAD/CAM	3.34	13	3.09	16	3.45	14	3.23	14
Practical sessions on others' equipment	3.21	14	3.53*	10	3.68**	12	3.56	9
More regional CAD/CAM centres	3.08	15	3.11	15	3.20	15	3.16	15
Government seminars and conferences	2.98	16	3.17	14	3.19	16	3.00	16
Range of n	60 ↓ 69		49 ↓ 57		93 ↓ 105		29 ↓ 33	
Spearman's Rank Correlation Coefficient	-		.85**		.86**		.87**	

Scale:

1	2	3	4	5
Undesirable Impact	Little Impact	Some Desirable Impact	Very Beneficial Impact	Essential For Increasing CAD/CAM Use

Asterisks indicate a significant difference (correlation) between the average ratings (rankings) of respondent groups: * = p < .05; ** = p < .01, two tailed, t-test (Spearman's significance test).

As compared to perceptions of constraints, much greater concordance exists amongst the respondent categories regarding the importance of incentives. The high and statistically significant rank order correlation coefficients at the bottom of Table 6-1 illustrate this fact. As a general rule, the Will Not Consider group placed slightly less importance on the incentives. This is opposite to how they rated the constraints.

The highest rated incentive is increased tax incentives for capital investment. It, along with assistance from suppliers for operator and programmer training, is judged to be somewhere between very beneficial to essential for CAD/CAM implementation. Other incentives which receive very high ratings are standardized software from suppliers, increased training programs offered by educational institutions for operators and programmers, CAD/CAM management education offered by educational institutions, funding assistance from governments for feasibility studies, government funding for innovative application programs, shared information about CAD/CAM successes and failures, and industry collaboration in research and development. Everyone ranked development of regional CAD/CAM centres and government seminars as very minimal incentives for the development of CAD/CAM.

Within Table 6-1, there are some comparisons between Present Users and other respondent groups which are statistically significant. The group which said they would not consider CAD/CAM over the next five years placed significantly less emphasis on tax incentives for capital investment and standardized programming languages and hardware from suppliers. This finding is in keeping with the lower ratings which this group placed on most of the incentives.

The other significant differences associated with the Actively Considering and Might Consider groups indicate a stronger desire for certain incentives. The Might Consider respondents place greater emphasis on government funding for on-the-job training, supplier-sponsored management training seminars, and practical experience sessions on other people's equipment. The Actively Considering group also evaluated practical experience sessions on other people's equipment as being significantly more important. Since two groups judge this latter incentive to be significantly more important, it should be thoroughly investigated as a measure to promote further use.

Incentives by Regions

A breakdown of incentives by regions is given in Table 6-2. Except for three incentives, no significant differences are indicated between the regions.

Ontario establishments place significantly more emphasis on government funding for feasibility studies and innovative application programs. British Columbia establishments, on the other hand, place significantly less emphasis on tax incentives for capital investment, government funding of feasibility studies, and government funding of innovative application programs.

TABLE 6-2

Average Incentive Ratings, Classified by Region

INCENTIVE	Ontario		Prairies		B.C.	
	Score	Rank	Score	Rank	Score	Rank
Tax incentives for capital investment	4.34	1	4.29	1	3.97*	2
Suppliers train operators and programmers	4.20	2	4.04	3	4.11	1
Suppliers standardize software and hardware	3.82	4	4.07	2	3.77	6
Educational institutions train operators	3.80	6	3.65	7	3.89	3
Educational institutions train management	3.75	8	3.73	5	3.86	4
Government funding for feasibility studies	3.94*	3	3.74	4	3.49*	9
Government funding for innovative programs	3.82*	5	3.58	10	3.32*	13
Manufacturers share information and insights	3.77	7	3.67	6	3.67	7
Industry collaboration in R&D	3.57	12	3.47	11	3.81	5
Change CAD/CAM tariff arrangements	3.46	13	3.47	12	3.28	14
Government funding for on-the-job training	3.69	9	3.64	8	3.53	8
Suppliers train management	3.60	10	3.62	9	3.37	12
Educational institutions research CAD/CAM	3.28	14	3.38	13	3.40	10
Practical sessions on others' equipment	3.58	11	3.34	14	3.39	11
More regional CAD/CAM centres	3.14	16	3.13	15	3.17	15
Government seminars and conferences	3.17	15	2.93	16	3.03	16
Range of n	159 ↓ 177		43 ↓ 48		29 ↓ 37	
Spearman's Rank Correlation Coefficient	-		.91**		.70**	

Scale: 1 = Undesirable Impact; 2 = Little Impact; 3 = Some Desirable Impact; 4 = Very Beneficial Impact; 5 = Essential For Increasing CAD/CAM Use

Asterisks indicate a significant difference (correlation) between the average ratings (rankings) of the other two regions (Ontario for the rank order correlation): * = $p < .05$; ** = $p < .01$, two tailed t-test (Spearman's significance test).

The reason why B. C. businessmen want less government involvement and assistance in their affairs warrants further investigation. The first point to note is that respondents from British Columbia stated that the need to immediately change to CAD/CAM was not high on their priority list (Table 5-2). Secondly, B. C. respondents may be suspicious of government programs. Many of them feel that most government programs are a waste of their tax dollars and that federal government expenditures are misallocated to other parts of the country. Finally, B. C. businessmen, being far away from Ottawa, are not attuned to various programs offered by the federal government. It is as though the mountains create a psychological barrier between the west coast and the rest of Canada.

Summary

The sixteen different types of incentives analyzed in this study all were rated as having a desirable or very beneficial impact on the implementation of CAD/CAM. Only the Will Not Consider group and British Columbia respondents rated some of the incentives lower than average. Their ratings, although lower by a statistically significant amount, were still in the desirable to very beneficial range.

Tax incentives for capital investment were judged to be the most desirous incentive. Given that the unavailability or high cost of investment capital is the most serious constraint, this desire is logical and consistent.

Except for the high rating placed on the training of operators and programmers, the importance of the incentives are in line with the severity of the constraints. Respondents said that the availability of trained staff was an important constraint, but that incentives to train such people were much more important. We would have expected incentives to train managers to have come out above operator training, because management knowledge and experience appeared as a more serious constraint. Perhaps the questionnaire did not ask for opinions on the correct incentives.

Chapter 7

SMALL VS. LARGE FIRMS

The profile presented in Chapter 3 demonstrated that CAD/CAM use is more prevalent in large firms, but not solely the domain of large firms. Thirty-five percent of the CAD/CAM users in this survey have fewer than 50 employees and thirty percent have less than $10 million in sales per year. This chapter makes special analysis of these small firms and compares them to their larger counterparts.

The definition of small adopted for this study is any firm with sales less than $10 million per year. Those respondents reporting sales over this amount were automatically classified as large firms. Those reporting less than this amount could still be large firms, because the survey requested replies from establishments rather than firms. It is possible for a small plant (establishment) to be part of a large firm.

To separate the small establishments of large firms into the large category, the researchers analyzed the request forms enclosed with the questionnaires. Sixty-two percent of the total sample (178 respondents) enclosed their request forms. One hundred six of these firms had annual sales less than $10 million, and a thorough examination of them revealed that 16 (15 percent) were actually subsidiaries or branch plants of large firms. These sixteen were moved to the large category. If the same misclassification rate is applied to the small plants which did not include their request forms, then it is possible for 7 percent (11 firms) of the total small firm sample actually to be large. It is unlikely that this potential misclassification is substantial enough to distort the results.

Constraints by Small vs. Large Firms

Table 7-1 shows the average constraint ratings for large and small firms, ranked in order of perceived importance to small firms which are Present Users. The Spearman correlation coefficients at the bottom of the table test the overall correlation between how the small and large firms rank the constraints. Statistically significant correlations are found for three of the four user categories, implying that perceptions of constraints are very similar for small and large firms in the Actively Considering, Might Consider, and Will Not Consider categories. The insignificant rank correlation between small and large Present Users suggests that more substantial differences in perceptions exist between them .

Between small and large sized Present Users, only two constraints have statistically significant differences. Small firms found it much less difficult to integrate CAD/CAM into their operations and had much less labour conflict. By comparing these two constraints with the responses of non-users, it would appear that large firms underestimate the labour conflicts and integration problems they will have when introducing CAD/CAM technology. Small firms who are non-users tend to overestimate the integration problems.

TABLE 7-1

Average Constraint Ratings of Small and Large Firms

CONSTRAINT	Present User		Considering		Might Consider		Will Not Consider	
	S	L	S	L	S	L	S	L
Unavailable or high cost of capital	3.52	3.44	3.92	3.09*	3.81	3.68	4.16	2.67**
Lack of system software support	3.38	3.03	3.20	2.71	3.42	3.08	3.22	3.17
Management inexperienced in implementation	3.26	3.10	2.92	3.08	3.43	3.28	4.03	3.17
Market volatility	3.24	2.88	3.12	2.61	3.29	3.11	3.14	2.50
High financial risk	3.19	3.11	3.63	3.12	3.90	3.47	2.89	3.17
Inadequate return on investment	3.19	3.52	3.30	3.44	3.90	4.27	4.33	4.17
Management unknowledgeable about technology	3.15	3.00	3.12	3.00	3.48	3.19	3.97	3.50
System incompatability in exchanging data	3.13	3.23	2.72	2.91	2.25	2.83*	2.75	3.00
Lack of standardization	3.08	3.14	3.24	2.78	2.84	2.94	3.53	3.50
Fast obsolescence of technology	2.84	2.91	3.40	2.74*	3.13	2.86	3.17	2.83
Unavailable resources to study CAD/CAM	2.83	2.97	3.32	2.46*	3.33	3.00	3.44	3.33
Trained staff unavailable	2.72	3.00	2.96	3.04	3.15	3.08	3.63	3.50
Difficult integration into present operations	2.57	3.44**	2.85	2.84	3.00	3.24	3.90	4.00
No need for immediate change	2.05	2.53	2.20	2.26	3.05	2.97	4.14	3.50
Potential labour conflict	1.65	2.27*	1.50	1.70	1.77	1.91	1.69	2.00
Not yet appropriate to industry	1.58	1.50	2.12	2.17	2.77	2.95	4.09	4.17
Range of n	19 ↓ 26	30 ↓ 37	24 ↓ 27	23 ↓ 25	58 ↓ 67	34 ↓ 38	24 ↓ 33	6
Spearman's Rank Correlation Coefficient	.28		.53*		.86**		.65**	

Scale: 1 Unimportant Factor — 2 Not So Important — 3 Important Factor — 4 Very Important — 5 Critical Factor

Asterisks indicate a significant difference (correlation) between the average ratings (rankings) of small vs. large firms: * = $p < .05$; ** = $p < .01$, two tailed t-test (Spearman's significance test)

Although not statistically significant, small firms using CAD/CAM tend to place different weights on certain constraints. While high cost of capital, lack of software support and management inexperienced in implementation are the most important constraints for both small and large firms, small companies find market volatility and unknowledgeable management to be more important and an inadequate return on investment, untrained staff, and no need for an immediate change to be less important.

In the non-user categories, there are some statistically significant differences, although the overall pattern of differences between small and large firms is not as distinct. Smaller firms perceive the high cost of capital to be a greater impediment to their adoption of CAD/CAM. Similarly, they are more concerned with the potential fast obsolescence of the technology and the unavailability of resources to study and evaluate CAD/CAM systems. They are less concerned than large firms with the compatibility of the technology with other computer systems which the firm already has. With worries of high capital cost and fast obsolescence, small firms are likely to be sitting on the sidelines until the technology matures and the price declines.

Incentives by Small vs. Large Firms

If small firms have peculiar differences which inhibit them from adopting CAD/CAM, are there any special incentives which they desire? Data which help to answer this question are presented in Table 7-2. Again, the incentives are listed in order of their importance to Present Users of small firms.

TABLE 7-2

Average Incentive Ratings of Small and Large Firms

INCENTIVE	Present User		Considering		Might Consider		Will Not Consider	
	S	L	S	L	S	L	S	L
Tax incentives for capital investment	4.50	4.24	4.36	4.19	4.38	4.27	4.00	3.20
Suppliers train operators and programmers	3.92	4.13	4.11	4.38	4.27	4.18	3.96	3.60
Government funding for feasibility studies	3.80	3.61	3.96	3.73	3.94	3.95	3.74	3.50
Manufacturers share information and insights	3.73	3.48	3.62	3.92	3.90	3.65	3.67	3.83
Government funding for innovative programs	3.72	3.62	4.00	3.62	3.66	3.76	3.77	2.80
Suppliers standardize software and hardware	3.72	3.92	3.96	3.58	4.00	3.81	3.69	3.60
Educational institutions train operators	3.60	3.97	3.78	3.85	3.88	3.65	3.65	3.20
Industry collaboration in R&D	3.60	3.59	3.32	3.56	3.74	3.65	3.28	4.00
Educational institutions train management	3.56	3.81	3.63	3.92	3.73	3.78	3.85	3.60
Government funding for on-the-job training	3.56	3.32	3.96	3.60	3.75	3.81	3.62	3.17
Change CAD/CAM tariff arrangements	3.54	3.33	3.31	3.32	3.54	3.53	3.28	3.25
Educational institutions research CAD/CAM	3.52	3.16	3.12	3.16	3.50	3.35	3.19	3.40
More regional CAD/CAM centres	3.26	2.95	3.07	3.15	3.25	3.11	3.23	2.80
Suppliers train management	3.23	3.47	3.31	3.56	3.86	3.65	3.50	3.20
Practical sessions on others' equipment	3.13	3.30	3.58	3.50	3.75	3.54	3.54	3.67
Government seminars and conferences	2.79	3.05	3.31	3.08	3.23	3.14	3.04	2.80
Range of n	23 ↓ 28	33 ↓ 38	25 ↓ 28	22 ↓ 26	59 ↓ 68	34 ↓ 37	25 ↓ 27	5 ↓ 6
Spearman's Rank Correlation Coefficient	.82**		.81**		.82**		.22	

Scale: 1 = Undesirable Impact; 2 = Little Impact; 3 = Some Desirable Impact; 4 = Very Beneficial Impact; 5 = Essential For Increasing CAD/CAM Use

** Significant correlation between the rankings of small and large firms: ** = $p < .01$, Spearman's significance test.

As Table 7-2 illustrates, small and large firms evaluate the incentives in a very similar manner. There is a statistically significant correlation between how small and large firms rank the incentives for all categories of users except those who Will Not Consider CAD/CAM. For the latter category, the small sample of Will-Not-Consider large firms may account for the lack of significant correlation. Within the table, there are no statistically significant differences between the individual ratings of incentives by small and large firms.

Tax incentives for the investment of capital are at the top of the list for both small and large firms, with small firms placing slightly greater weight on them. Given that the high cost of capital is a greater concern to small firms, it is understandable that they are looking for a tax break.

All of the incentives were judged to be desirable to very beneficial in promoting the use of CAD/CAM. After tax incentives, the higher ranked ones were suppliers training operators and programmers, provincial or federal governments funding feasibility studies, manufacturers sharing information on their successes and failures, the suppliers standardizing programming languages and hardware, and educational institutions training operators and programmers. Obviously, firms see the standardization of software and hardware compatibility as a means for overcoming their perceived problems with lack of software support. Given that the unavailability of trained staff was not a high rated constraint, it is somewhat surprising that firms place so much attention on outside training of operators and programmers. It also is somewhat surprising that training programs for managers is not ranked higher when management being inexperienced in implementation is one of the major problems.

Impacts by Small vs. Large Firms

CAD/CAM tends to affect small and large firms in a very different manner. Although there is an overall tendency for increased productivity, quality, and sales and decreased lead times, the degree of the effect is very different (Table 7-3). Statistically significant differences are found amongst the employment and sales impacts. The most noticeable difference is in how CAD/CAM affects employment -- small firms increase the number employed, while large firms decrease employment.

TABLE 7-3

Expectations of Impacts by Small and Large Firms

	Present User		Considering		Might Consider		Will Not Consider	
	S	L	S	L	S	L	S	L
Average % Change in Productivity	61.3	63.1	58.8	45.8	28.1	30.0	21.1	5.0
Average % Change in Sales Volume	51.8	15.1	37.8	22.2	24.7	9.8**	10.7	0.0
Average Amount of Change in Quality[a]	2.54	2.53	2.38	2.58	2.14	2.24	1.48	2.50
Average % Change in Lead Times	-42.2	4.1	-19.6	-30.4	-9.8	-10.5	45.1	-8.0
Average % Change in Number of Employees	11.7	-8.4**	4.2	-0.7	5.4	-6.7**	2.7	-6.0
Range of n	18 ↓ 24	19 ↓ 34	19 ↓ 29	13 ↓ 24	47 ↓ 69	17 ↓ 25	18 ↓ 25	1 ↓ 2

[a] Quality Scale:

-3	-2	-1	0	1	2	3
Large Decrease	Moderate Decrease	Negligible Decrease	No Change	Negligible Increase	Moderate Increase	Large Increase

Asterisks indicate a significant difference between the average scores of small and large firms: ** = $p < .01$, two tailed t-test.

Small firms employ a significantly larger number of people, achieve higher sales, but do not get as much increase in quality. The reason they employ more people is a combination of two factors. The first is that they do not have the experienced personnel. When they adopt CAD/CAM, they have to hire the expertise. Secondly, adopting CAD/CAM increases their volume of business. Smaller firms have to hire more people to meet the increase in sales. For policymakers who want to increase employment, the inference is that small business should be promoted.

By using CAD/CAM, large firms achieve significantly larger increases in quality, lower increases in sales, and smaller numbers employed. Although not statistically significant, large firms tend to get greater increases in productivity. Probably this larger increase in productivity enables them to employ fewer people and, in the process, experience greater labour problems.

Summary

Small firms who use CAD/CAM reported that they experienced few labour problems and achieved relatively easy integration. Being smaller, they are more flexible to adapt, they probably have fewer union restrictions, and they have fewer computer systems which have to be integrated. Going to CAD/CAM technology allowed them to expand sales and employ more people. This expansion of their labour force meant that they had fewer labour problems.

Large firms, on the other hand, have more complex manufacturing systems, more computers, formal personnel systems and more rigid labour relations. For them, adopting CAD/CAM does not have as great an impact on their volume of sales. They benefit from increased quality and productivity. They generally are able to decrease the size of their workforce, and this process causes labour problems. To large firms, CAD/CAM allows them to maintain their position in the competitive marketplace.

From the perspective of the policymaker who is trying to devise differential policies for the small and large business sectors, removing constraints is more important than providing incentives. Since system incompatibility is more of a concern to large firms, endeavors should be made for suppliers to standardize software and to work on integration procedures. For small firms which have not yet adopted CAD/CAM, fast obsolescence, high cost of capital and the unavailability of resources to study CAD/CAM are of much greater concern. Specific programs directed towards small firms could help to overcome these constraints.

Chapter 8

LEADERS VS. LAGGARDS

Another way to look at the adoption of CAD/CAM is from the perspective of leader and laggard establishments. Whenever a new technology is being introduced, some firms are faster to respond than others. They pioneer the introduction and adoption of new techniques and take greater risks by venturing into the new technology before it has become commonplace. They are leaders.

Others sit back and wait until the technology is more mature. They may watch the development of the technology and wait until the cost of equipment has declined. Alternatively, they may not be aware of what is happening to their industry. One way or another, they lag behind.

In the use of the names leader and laggard in this chapter, we do not want to imply that one is necessarily more preferable to another. It is possible to be a very wise laggard -- a firm which waits and adopts the new technology at an opportune time when it is proven and lower in cost. Alternatively, it is possible to be a foolhardy leader who adopts the technology when equipment costs are high and integration problems abound. Nevertheless, we do recognize that some laggards will miss the boat if they wait too long.

The Definition of Leaders and Laggards

In this analysis, a combination of two variables has been used to define leaders and laggards. The first variable is plant use or receptivity which is measured on a four point scale from Will Not Consider (1) to Present User (4). The second variable is the reported industry leadership which is measured on a five point scale from well behind competitors (1) to an industry leader (5). A cross-tabulation of these two variables is displayed in Table 3-9. By adding the two variables together, we can get a combined variable which varies from 2 (establishment which is well behind competitors and will not consider) to 9 (an establishment which is an industry leader and a present user of CAD/CAM).

Laggards are defined as those establishments in the shaded area in the bottom, right-hand side of Table 3-9. They are respondents who Will Not or only Might Consider CAD/CAM and are somewhat or well behind competitors in its use. These firms have a score of 4 or less on the combined receptivity-leadership variable.

Leaders are those establishments in the top left corner of Table 3-9. They are either Present Users or those Actively Considering CAD/CAM who also admit that they are industry leaders or firms who are well ahead of their competitors. They have a score of 7 or more on the combined receptivity-leadership scale.

The most desired incentive is tax incentives for capital investment. Also ranked high are assistance from suppliers to train operators and standardize software, training from educational institutions for operators and managers, and government funding for feasibility studies and innovative programs. Assistance from suppliers to train managers has above average benefit, although it is not ranked as high as training of managers by educational institutions. Presumably management knowledge, which is more important to the purchase decision, is judged to be better supplied by educational institutions which are unbiased and have an arms length relationship.

Impacts by Leaders and Laggards

Differences in how leaders and laggards perceive the impacts of CAD/CAM are presented in Table 8-3. In general, leaders, most of whom have already experienced CAD/CAM, perceive greater benefits from using the new technology. Statistically better impacts are received by leaders for productivity and quality improvements.

TABLE 8-3

Expectations of Impacts by Leaders and Laggards

PERFORMANCE MEASURES	Leaders	Laggards
Average % Change in Productivity	61.0	29.1**
Average % Change in Sales Volume	33.8	21.5
Average Amount of Change in Quality[a]	2.56	2.00**
Average % Change in Lead Times	-19.6	8.9
Average % Change in Number of Employees	1.1	5.7
Range of n	51 ↓ 75	48 ↓ 63

[a] Quality Scale:

-3	-2	-1	0	1	2	3
Large Decrease	Moderate Decrease	Negligible Decrease	No Change	Negligible Increase	Moderate Increase	Large Increase

Asterisks indicate a significant difference between the average scores of leaders and laggards: ** = $p < .01$, two tailed t-test.

Although laggards perceive positive benefits, they are not as large as for leaders and possibly not large enough to generate adequate returns on investment. As a consequence, laggards do not perceive the technology as yet being appropriate for their industry. They see no need for immediate change. Nevertheless, we must remember that the managers who responded said that their management, and possibly themselves, were unknowledgeable and inexperienced in CAD/CAM. They may be underestimating the benefits and overestimating the constraints.

Summary

The major differences between leaders and laggards are in the ratings of constraints. Laggards see many more barriers to their adoption of CAD/CAM, and they do not see as many beneficial impacts. The biggest barriers are an inadequate return on investment, high financial risk, and unavailable or high cost of capital.

But these could be just perceptual barriers. Laggards reported that their managerial team was unknowledgeable about CAD/CAM and inexperienced in its implementation. Their perceptions of high barriers and low benefits may be a function of their lack of expertise.

Chapter 9

PERCEPTIONS OF SUPPLIERS AND EDUCATIONAL INSTITUTIONS

Besides information from different types of manufacturers, data were gathered from suppliers, CAD/CAM associations, research institutions, and educational institutions. These respondents were asked only for their perceptions on the constraints and incentives. The idea behind questioning them was to see if their perceptions were congruent with those who actually had to use their products or services.

As is indicated in Table 2-2, thirty suppliers responded, seven of them from the United States. Replies were also received from fourteen educational institutions, one CAD/CAM association, and one research institution. For the purposes of this chapter, the single replies from the CAD/CAM association and the research institution are combined with those of the educational institutions.

Perceptions of Constraints

Average constraint scores for present users, suppliers and educational institutions are listed in Table 9-1 in order of importance to Present Users. As indicated by the significant rank order correlation coefficient at the bottom of the table, there are fairly similar perceptions between Present Users and suppliers. The non-significant correlation between Present Users and educational institutions indicates greater differences in perceptions for these two groups.

To suppliers, the most serious constraints are the unavailability or high cost of investment capital, managements' lack of knowledge about the technology, high financial risk, and the lack of system software support. For the suppliers to admit that software support is a weak link is surprising, but encouraging. Their awareness of the problem should help in its resolution.

The suppliers see two ratings to be statistically more important than do Present Users. These are managements' knowledge of the technology and CAD/CAM's appropriateness to a particular industry. These differences are probably attributable to the nature of the suppliers' job. They are continually going out and selling their wares to firms and industries which have not yet adopted the technology. As a consequence, they are usually talking to the unconverted. No wonder, then, that they have stronger perceptions that management is unknowledgeable and the technology can be inappropriate. These findings are not startling. What is noteworthy is that suppliers, like Present Users, rate the inappropriateness problem as being the least severe of all the constraints.

The perceptions of educational respondents, like suppliers, are tainted by their occupation. To them, unknowledgeable management, management inexperienced in implementation, the lack of trained staff, high financial risk, and inappropriateness to an industry are all judged to be more serious by a statistically significant amount. But like Present Users and suppliers, they do not judge the inappropriateness constraint to be a very strong one. They probably see a large market for their services in many industries.

TABLE 9-1

Average Constraint Ratings of Present Users, Suppliers and Educational Institutions

CONSTRAINT	Present Users		Suppliers		Educational Institutions	
	Score	Rank	Score	Rank	Score	Rank
Unavailable or high cost of capital	3.52	1	3.89	1	3.93	4
Inadequate return on investment	3.44	2	3.18	7	3.46	7
Lack of system software support	3.27	3	3.42	4	3.71	6
System incompatibility in exchanging data	3.23	4	2.93	11	3.00	12
Management inexperienced in implementation	3.20	5	3.29	5	4.00*	2
Lack of standardization	3.19	6	3.00	10	2.93	13
High financial risk	3.15	7	3.61	3	4.08**	1
Difficult integration into present operations	3.11	8	3.11	9	3.23	10
Management unknowledgeable about technology	3.11	9	3.64*	2	4.00*	3
Market volatility	3.00	10	3.18	8	3.29	9
Unavailable resources to study CAD/CAM	2.98	11	2.67	13	2.69	15
Fast obsolescence of technology	2.96	12	2.89	12	3.36	8
Trained staff unavailable	2.95	13	3.26	6	3.79*	5
No need for immediate change	2.40	14	2.36	15	3.08	11
Potential labour conflict	2.02	15	2.44	14	2.64	16
Not yet appropriate to industry	1.58	16	2.26*	16	2.70**	14
Range of n	52 ↓ 66		25 ↓ 28		10 ↓ 15	
Spearman's Rank Correlation Coefficient	-		.68*		.48	

Scale: 1 = Unimportant Factor; 2 = Not So Important Factor; 3 = Important Factor; 4 = Very Important Factor; 5 = Critical Factor

Asterisks indicate a significant difference (correlation) between the average ratings (rankings) of Present Users, Suppliers and Educational Institutions: * = $p < .05$; ** = $p < .01$, two tailed t-test (Spearman's significance test).

As a generalization, educational institutions see all the constraints to be more severe. Other non-significant ones which they rated as being very important are the unavailability or high cost of investment capital, lack of software support, inadequate return on investment, fast obsolescence of the technology, market volatility, and difficulty of integrating CAD/CAM into present operations.

From the perspective of both suppliers and educational institutions, it is interesting to note that they judge lack of system software support to be quite a bit more important than integration, standardization and compatibility problems. As one educationalist said in some written comments, the standardization problem is only critical for the final integration of one CAD/CAM system with another. A firm can easily adopt a stand-alone CAD/CAM system without being very concerned about standardization, integration and compatibility. It is only at a later date when they start to realize the full potential of CAD/CAM that manufacturers become concerned with compatibility and integration. The same educationalist, however, felt that the compatibility problem was being licked. The more difficult problem was to bring the software solutions, (i.e. the software support) to the factory floor.

Perceptions of Incentives

As indicated by the statistically significant rank order correlation coefficients at the bottom of Table 9-2, the perceptions of incentives by both suppliers and educational institutions are similar to those of Present Users. Nevertheless, there are some statistically significant differences within the table for a few specific incentives.

Suppliers were not as inclined as Present Users to say that software standardization would be a strong incentive. Although suppliers rated this incentive as important, they placed it towards the bottom of their list. This is not to say that suppliers are disinterested in providing software support. They recognize software support as a major constraint and rate supplier assistant to overcome it as very important. But when it comes to standardizing their software with that of others, suppliers are less enthused. By keeping their software distinct, suppliers put pressures on purchasers to return when they buy additional equipment. If the suppliers are unwilling to voluntarily move to standardization, then a market niche probably exists which could be filled by the software industry.

A second significant difference between suppliers and Present Users is their attitude towards tariffs. Suppliers believe that tariff changes would have a very beneficial impact, and this remains strong even when the seven U.S. suppliers are removed from the comparison. The most favoured nation tariff (i.e. Japan and the U.S.) on imports of robots and numerical control equipment is 11.4 percent, although this amount is eligible for duty remission if such goods are not available from production in Canada. For electronic data processing machines, plotters, and operational software, the most favoured nation tariff is 3.9 percent. For disk drives and application software (except for a nominal charge on the value of the disk), there is no duty. A nine percent federal sales tax is charged on top of the landed cost, although a supplier can reclaim this amount if the equipment is sold to a manufacturer.

In most cases, the effective duty is not great and over the years has been declining. The main problem is in the hassles to get remission of duty or rebates of sales tax. Suppliers would be passing these administrative costs along to manufacturers as well as the effective tariff. Removing the tariff or streamlining the procedures would help lower the sales price of CAD/CAM equipment and get more firms using it.

TABLE 9-2

Average Incentive Ratings of Present Users, Suppliers and Educational Institutions

INCENTIVE	Present Users		Suppliers		Educational Institutions	
	Score	Rank	Score	Rank	Score	Rank
Tax incentives for capital investment	4.36	1	4.27	1	4.21	2
Suppliers train operators and programmers	4.07	2	3.93	3	3.57	8
Suppliers standardize software and hardware	3.88	3	3.00**	13	3.36	14
Educational institutions train operators	3.85	4	3.44	10	4.14	4
Educational institutions train management	3.76	5	3.70	5	4.29	1
Government funding for feasibility studies	3.72	6	3.67	7	4.21	3
Government funding for innovative programs	3.68	7	3.89	4	4.14	5
Manufacturers share information and insights	3.64	8	3.44	11	3.43	10
Industry collaboration in R&D	3.62	9	3.59	9	3.71	7
Change CAD/CAM tariff arrangements	3.45	10	4.08*	2	3.38	13
Government funding for on-the-job training	3.43	11	3.70	6	3.43	11
Suppliers train management	3.38	12	3.67	8	3.50	9
Educational institutions research CAD/CAM	3.34	13	2.96	14	4.00*	6
Practical sessions on others' equipment	3.21	14	3.30	12	3.36	15
More regional CAD/CAM centres	3.08	15	2.78	16	3.43	12
Government seminars and conferences	2.98	16	2.89	15	3.07	16
Range of n	60 ↓ 69		26 ↓ 27		13 ↓ 14	
Spearman's Rank Correlation Coefficient	-		.61*		.60*	

Scale: 1 = Undesirable Impact; 2 = Little Impact; 3 = Some Desirable Impact; 4 = Very Beneficial Impact; 5 = Essential For Increasing CAD/CAM Use

Asterisks indicate a significant difference (correlation) between the average ratings (rankings) of Present Users, Suppliers and Educational Institutions: * = $p < .05$; ** = $p < .01$, two tailed t-test (Spearman's significance test).

In the comparisons between educational institutions and Present Users, only one incentive, that educational institutions should undertake CAD/CAM research, has a statistically significant difference. While Present Users (and suppliers) believe that educational institutions should be active in educating managers and training operators, they are not so sure that the educational institutions should be undertaking research. Perhaps they think that the research undertaken by educational institutions is too esoteric, or else they do not understand the research function of educational institutions. Either way, the educational institutions must prove themselves if they want to get their research adopted.

Summary

Present Users, suppliers, and educational institutions each perceive the constraints and incentives from their own special interest. The manufacturers presently using CAD/CAM are pragmatists. They are the ones who must ultimately make the equipment work. They are concerned about the bottom line, and they want things like tax incentives to improve the return, help in analyzing the technology, and assistance to get it quickly into operation.

Suppliers also are concerned with the bottom line, although they achieve it by selling lots of equipment. They wish CAD/CAM was applicable everywhere and they wish all managers were knowledgeable about what CAD/CAM can do.

Chapter 10

RECOMMENDATIONS

We have now looked at the impacts, constraints, and incentives associated with the use and adoption of CAD/CAM. Perceptions of manufacturers have been analyzed in terms of their regional location, size, use, and receptivity to accept and implement CAD/CAM. We have also looked at the constraints and incentives from the perspectives of suppliers and educational institutions. In this chapter, we turn our attention to the various actions which can be taken to promote further use and adoption.

When making recommendations, we must remember that the process is not the same as analyzing survey data. In previous chapters when we analyzed data and drew inferences, the data were factual and the interpretations we made from them were open to debate. When we deal with recommendations, the arguments become more subjective. To the extent possible, the authors attempt to utilize interpretations of the factual data to support the recommendations; nevertheless, we recognize that some of our subjective biases will creep into the analysis. Moreover, the recommendations (and our views) have been affected by the interviews we have had with manufacturers, suppliers, and others who are interested in CAD/CAM applications.

We present the recommendations first for manufacturers, second for suppliers, third for unions, fourth for educational institutions, and finally for governments. We leave the recommendations for governments to the end since we believe that private enterprise too frequently looks to government for a "quick fix" of their problems. We believe that industry should first look within itself before turning to government for assistance.

Recommendations for Manufacturers

1. Demonstration Programs

A business opportunity exists for companies who already possess CAD/CAM facilities to provide experiential sessions and demonstration programs for other firms. Those firms who are not yet using CAD/CAM indicated that such an opportunity would be very desirable. These firms also indicated that they have less expertise amongst management and staff in CAD/CAM techniques and concepts. Presumably, they would be willing to spend time, effort, and money to acquire some experience.

A firm which has already gone through the process of acquiring and implementing CAD/CAM has valuable information which others would desire. They could take the experience of their implementation team, treat it as a profit centre, and sell the knowledge to others. Insofar as such firms are not using all their CAD/CAM capacity, they could use it to allow others to get some hands-on experience during evenings and other non-peak hours. Monies recovered from the operation of such a profit centre will increase the return to the CAD/CAM investment while at the same time helping other firms (presumably non-competitive ones) to improve their productivity, profitability, and decision making.

2. Service Firm

Another possibility is to form a separate firm to provide CAD/CAM consulting and services. Such a firm could be a demonstration profit centre which is spun off on its own, or it could be a new venture capital enterprise which is started from scratch. Either way, a market need would be fulfilled.

The need for a service firm or a demonstration profit centre is more acute in British Columbia and, to a lesser extent, the Prairies. There, firms are less inclined to make the move to CAD/CAM and they have a distrust of government support. A well-run private endeavor is needed to bring Western firms up-to-date on what is possible. Various universities, technological institutes, suppliers, and government-sponsored programs are providing information and assistance, but not very much in the way of direct services.

In Ontario, the provincially initiated technology centers are creating publicity and assisting firms in the adoption process. But even here, there is an opportunity for a private firm to provide services. For example, the two branches of the Ontario Centre for Advanced Manufacturing -- the CAD/CAM Centre in Cambridge and the Robotics Centre in Peterborough -- are both set up to provide preliminary advice, consulting, education, technical information, feasibility studies, and various demonstrations which help companies determine what type of technology they need. But since these institutions are funded in part by government money, they do not get into services such as actually performing computer aided design, cutting a tape for numerically controlled machines, and programming a firm's robot. These tasks could be performed by an outside service and consulting firm, or a service firm could be made an appendage of the technology centres.

3. Sell Surplus CAD/CAM Capacity

If extra capacity is available for some firms to provide demonstration programs, then there is probably room for other firms to actually sell such capacity. For example, a CAD firm which has surplus capacity could allow access to its system via the telephone lines. In this way, non-users who perceive high financial risk, unavailability of capital, and inadequate returns from self-ownership will be able to use CAD/CAM without actually purchasing it. They will get the benefits of CAD/CAM with low risk, and the owner of the system will get an even higher rate of return than would otherwise be possible.

4. Mergers, Joint Ventures and Consortia

The cost of acquiring CAD/CAM technology can be large, and the development costs of making major breakthroughs are even larger. To spread costs, avoid duplications, and diffuse technological breakthroughs, several countries have formed a consortium which cooperates on the development of new ideas. The consortium members either form a joint venture company to market the ideas or take the concept back to their parent firms to market the concepts themselves. Japan's ambitious Fifth Generation Computer Project (Feigenbaum and McCorduck, 1983) sparked this trend, and other industrial nations have evolved their own structures to meet the challenge.

In the United States, twelve major electronics companies formed the Microelectronics and Computer Technology Corporation to research and design CAD/CAM systems, productivity software, and architecture design (Zeidenberg, 1984).

The implication for Canada is that a group of firms could form a similar consortium or joint venture. Alternatively, some growth-minded person could initiate mergers of firms with complementary talents and resources. The crucial point is that such endeavors generate the critical mass and interchange which is conducive to technological breakthroughs. While it is true that many individual firms can be creative and innovative, it is also true that the development of individual competing systems causes incompatibility of software, integration difficulties, and interchangeability problems. Present users are well aware of these problems. They realize that a small amount of cooperation amongst CAD/CAM manufacturers may have resulted in standardized software and protocols. In a similar manner, Canadian users and designers of CAD/CAM applications should pool their resources, avoid duplications, and produce synergistic results.

5. Specialization in Friendly Niches

If cooperative endeavors are to be tried, in what areas should they be attempted? Most certainly, it should not be in the same areas that other nations have already initiated. Canadian manufacturers should develop their own specialized market niches. As Calvin Gotlieb of the University of Toronto recognizes (Computing Canada, September 6, 1984), such niches will unlikely be in colour televisions, hi-fi equipment or other products for mass markets. He suggests that we should develop computer systems for areas in which we already have expertise, such as modern paper mills. Such mills could be sold in Canada and abroad, and it is unlikely that lower cost nations would want to compete with us in such limited, but profitable, markets. Other expertise niches which warrant investigation are petroleum and minerals development, health care, fisheries management, telecommunications, municipal governance, forestry, and agriculture.

In the new information society, success will be less a function of survival of the fittest and more the survival of the smartest. Picking the correct market and product niche will require astute and wise decisions on the part of our business leaders. And it has generally become recognized that governments are not the smartest ones at picking "winners". They will probably take a back role and leave the choice of the correct niche to the marketplace. This places great onus on our industrial leaders to plan wisely and make decisive choices. It also means that smart nichemanship can occur outside the resource-type sectors indicated above. Friendly niches for smart enterprises can exist in all industries, including mass production ones.

6. Training and Development

Survival of the smartest means that the quality of human resources is going to be very crucial to a firm's success. Yet, those firms who were less inclined to use CAD/CAM were the ones who saw inexperienced and unknowledgeable management as being major barriers. They have a responsibility to learn about CAD/CAM and then decide whether or not it is appropriate.

Since computer technology in industry is still at the early stages of development, many new uses are still to be found and applied. If a non-user investigates, digs into the literature, and learns about CAD/CAM, then it is quite likely that new applications will be unearthed. If the management team is knowledgeable about CAD/CAM and still comes to the conclusion that it is inappropriate, then that is a legitimate choice. But to dismiss CAD/CAM with no or limited information is an avoidance of the businessman's responsibility. The benefits from CAD/CAM can be major, and smart businessmen will find out what it is all about.

7. Planning of Purchases

Manufacturers are frequently the cause of their own subsequent problems. For example, the usual procedure for the introduction of CAD/CAM equipment is for an individual department to make a project proposal to top management. Such proposals generally reflect the interest of that department and are supported by discounted cash flow or other financial calculations. As Senker (1984) has pointed out, such perspectives bring suboptimal results. Discounted cash flow, although useful, does not measure all benefits which can accrue from adopting a radically new technology. Moreover, the perspectives of the submitting department do not reflect the interests of the larger corporation. As a consequence, we see purchases of CAD systems which are very cost effective for the design department, but which are totally inappropriate for later expansion into an integrated CAD/CAM system. To overcome such departmental and temporal suboptimization, CAD/CAM decisions should be analyzed as a strategy decision and not as a regular equipment replacement decision. This means that top management must be both more knowledgeable and more involved.

Recommendations for Suppliers

1. Standards

To assist manufacturers in their use of CAD/CAM, suppliers should get together in their own interest or consortia groups to set standards. One of the top-rated incentives which manufacturers desire is standardized programming and hardware. Furthermore, they identified the lack of system software support as being one of the most serious constraints. The standardization of operating systems and graphics protocols increases programming productivity by releasing the programmer from the concerns of hardware peculiarities and makes applications programs easier to write, maintain, and distribute.

One promising trend is the increasing use of Unix as a standard operating system and the Graphical Kernal System (GKS) as the standard graphics language (Franson and Associates, 1984). GKS, a software standard for two-dimensional computer graphics, was first promoted by DIN, the West German standards authority, and later adopted by the International Standards Organization. In the United States, the American National Standards Association (ANSA) has endorsed GKS and many software companies now use GKS and sell graphics software in Europe. Such standardization illustrates that cooperation amongst companies and countries can facilitate easier use of new computer technology.

2. Linking Packages

Insofar as there are compatibility problems between the software and hardware of different suppliers, there is also the opportunity for a software supplier to provide a solution. Some supplier could step into the void and provide a computer program which links together dissimilar systems. Such a solution would be cheaper than scrapping an existing system, it could be undertaken for profit, and it would satisfy many manufacturers.

3. Leasing Packages

The most restrictive constraint holding manufacturers back from purchasing CAD/CAM equipment is the unavailability or high cost of capital. Suppliers could help manufacturers overcome this barrier by either selling their equipment at a lower price or by providing assistance for the financing. Assuming that their equipment is already priced competitively, the quickest way suppliers can provide assistance is to alter the financing package. One solution would be to provide extended payment terms while another would be to put together innovative lease packages. Since some potential purchasers, particularly smaller firms, are less sophisticated in searching out capital, well informed suppliers would be helpful. Suppliers have a vested interest in providing assistance at getting financing because it means more sales for them.

4. Training and Support

The survey data indicated that suppliers agreed with manufacturers that the lack of software support is a serious problem and that suppliers' assistance in operator and programmers' training would be very beneficial. Since suppliers recognize the problem and the solution, there should be no hesitation on their part to provide continuing services. The one difficulty is that these services cost money. Although they may be desirable, they lower the suppliers' bottom line.

It appears that suppliers are using the old motto of caveat emptor. They are selling the equipment and then consciously failing to give good after-purchase support. Their profits are higher, but it may just be a short-term and illusory thing. The CAD/CAM industry is still in its infancy, and manufacturers will be making substantial purchases in the future. Those suppliers who give good training and follow-up support will be the ones who are likely to get the repeat business. Furthermore, manufacturers, as they begin to gain experience with the new technology, will become more astute purchasers. They will realize that the purchase price is only part of the total cost of getting a new system introduced and operating. They will evaluate the more intangible start-up costs and give preference to a supplier who provides better training and support.

5. CAD/CAM Centres

Included in the category of the suppliers would be the various CAD/CAM centres. Although they do not supply equipment, they do sell information, feasibility studies, hands-on workshops, and consulting services. They are set up to help manufacturers overcome some of the difficulties encountered when adopting CAD/CAM.

In Ontario, these centres are eventually supposed to generate sufficient revenues to become self supporting. At present, their operating budget is subsidized by the provincial government. While they advertise their services as being available to Ontario industry, there is no reason, so long as they are covering full costs, that these centres could not extend their services to other provinces. Similarly, there is no reason why other provincial CAD/CAM centres could not venture outside their provincial boundaries to generate revenues and provide services.

Recommendations for Unions

Although the role of unions was not a central focus of this study, they are affected by CAD/CAM, and there are some recommendations which they may like to heed.

1. Recognize the Technology

Canada's manufacturers operate in an internationally competitive market, and technology knows no national boundaries. As negotiations proceed to reduce duties and non-tariff barriers, international competitiveness will become more severe. Canadian manufacturers will have to be more adept at adopting to new conditions, and their unions will have to accommodate the change.

This does not mean that unions must acquiesce to management's every whim and that working conditions will revert to a slave labour situation. What it does mean is that computer technology is inevitable and that greater output will be possible with less toil and effort. As we have seen, jobs, particularly in the larger firms, will be fewer, but the total pie of output should be larger. Realizing that change is inevitable and the pie is larger, unions should work to guide the change in a positive manner. Like management, unions must become knowledgeable about computer technology, and they should only resist it if it is being introduced in an inhumane manner.

2. Wealth Redistribution

If the pie is larger, but fewer people may be working, then wealth distribution becomes a problem. At the present time in our society, employment is the prime mechanism for distributing wealth. If you have a job, then you receive a paycheck and have the means to acquire products. If you are unemployed, then you have to rely on savings, credit, unemployment insurance or welfare to make ends meet. The result is that those who have jobs have greater wealth, while whose without live close to subsistence. The irony of the situation is that some people whose talents are in very high demand are overworked while others remain unemployed or underemployed.

The main method for supporting those without jobs is to impose ever higher taxes on corporations and those citizens with jobs. But there is a limit to how far we can increase direct and indirect taxes. Governments try to solve the problem by creating and encouraging more jobs. But if the future scenario is for more production with fewer people, then there is a limit to how many new jobs can be created. Alternative approaches must be developed to redistribute wealth, and unions can play a major role. In particular, unions can agitate for shorter work weeks for their members, thereby spreading the available work hours over more people. Moreover, greater flexibility in how unions define working hours would enable two or more workers to share a single job.

3. Working Conditions

The introduction of CAD/CAM technology to the workplace means that working conditions will be changed. One of the most noteworthy changes is the degree of information which is collected about the production process. Managers will be able to obtain detailed and instantaneous information about how both workers and machines are performing. This is of concern to unions, because excessive controls could be interpreted by workers as an invasion of privacy. In a prison setting, instantaneous feedback of peoples' activities and locations is necessary and desirable. We do not, however, want our workplaces to be like prisons. Organizations must be allowed to get the benefits of online information, yet workers must be assured that the information will not be abused. Unions have a role to play here to assure that a fair balance is achieved between the productivity from information and the privacy of workers.

Another area of concern is the reliability and safety of the equipment. We have heard much about possible bad effects of working too long in front of video display terminals in office settings. But we have not heard very much about the dangers of working with computers, robots, and digitally controlled machines in factory settings. In the case of CAD, a system failure generally causes nothing more serious than frustration with having to recreate information from backed-up files. But the failure of a microchip or a bug in the software are much more dangerous in CAM systems. Workers can get maimed and lives even lost.

The usual procedure to attain adequate reliability is to build sufficient redundancy into the machines, systems, and software. In space and military programs, the redundancy requirements are well recognized. But in private industry, especially at the leading edge of technology, redundancy takes second place to getting a system operating. Much of the debugging and experimentation takes place in the workplace, and many of the redundant components are left out because designers assume that computers are infallible. In this manner, suppliers and manufacturers keep the cost of their systems competitive.

Part of the redundancy problem will be alleviated by the exponentially decreasing costs of hardware. Nevertheless, there is still a major problem associated with the lack of recognized standards for the degree of redundancy which should be included. This is an area where unions can and should take leadership -- to argue for adequate safety features being built into both the software and hardware. To do so, unions must become more familiar with the new technology which they are encountering.

4. Retraining

Unions, if they wished, could take an obstructionist role towards CAD/CAM technology. Such a tactic, however, could only be used in the short run. Over the longer time horizon, new technology, if viable, will win out. As shown in Chapter 4, CAD/CAM can have beneficial impacts -- it is viable and it will make inroads. This means that unions and their members will have to adapt, make adjustments, and accommodations.

If change is inevitable, then unions, like businesses, should become involved in the change process. Two areas stand out as being important. The first is the retraining of their own members. Union members should be encouraged to take retraining programs so that their skills do not become obsolete. Similarly, unions should be lobbying both the public and governments to support retraining and the transition to a new job. They could even become involved themselves in the retraining function.

The second area of importance is training and knowledge acquisition amongst union management. If union leaders are going to influence CAD/CAM changes, then they had better become knowledgeable about what is possible. They had better realize that job preservation and income maximization for their members is inextricably tied up with the long run well-being of the industries whose workers they represent. Just as managers of these industries must become more knowledgeable about CAD/CAM and its strategic implications, so too must union leaders. Both parties should become involved in and be concerned with the identification of viable industries.

Recommendations for Educational Institutions

1. Training and Education

The most obvious role which educational institutions can play is to train operators and managers in the use of CAD/CAM. The lack of knowledge amongst managers and the availability of trained operators and programmers was judged by the survey respondents to be a serious constraint to further CAD/CAM use, especially amongst those firms less likely to adopt it. We suspect that the resistance amongst many firms is their lack of knowledge about what CAD/CAM is capable of doing for them. The few educational institutions who responded to this survey indicated that they recognized these constraints, and all classifications of respondents indicated that the educational institutions could be a major incentive for overcoming the deficiency.

Besides the manufacturing establishments themselves, the responsibility for the training of operators and computer programmers should be left primarily to the regional colleges and technical institutes. Since these colleges and technical institutes cannot afford to purchase the equipment of all suppliers, they must be careful to acquire equipment which is representative of what is available in the marketplace and what manufacturers already have. They should also be careful to assess the demand for their students and assure that their graduates have enough flexibility to switch from the peculiarities of one system to another. Since CAD/CAM techniques are changing rapidly, training programs must incorporate the understanding and flexibility which will enable graduates to learn the methods of their employers and adopt new techniques as they evolve.

Universities, especially in their engineering faculties, should also provide training, but it should be at a more general level. The more specific vocational training should be left to the regional colleges and technical institutes. In the managerial education, however, universities should take a more dominant role. Their business schools, in particular, should provide educational programs on how technological change is managed and implemented. Unfortunately, most business schools are weak on providing the technical skills. To overcome this deficiency, they should design their programs in cooperation with engineering faculties and technical institutes. In addition, university business schools, who are training our future managers, should pay more attention to providing goods and services in a productive and efficient manner.

2. Diffusion Catalysts

Universities, and to a lesser extent regional colleges and technical institutes, can act as a catalyst to bring various parties together for short courses or conferences. For example, bankers are traditional risk avoiders, and they possibly turn down loans for CAD/CAM because they do not adequately understand the technology. Similarly, unions are being forced to react to CAD/CAM changes, but they are unsure of whether their reaction should be combative or cooperative. Universities are neutral bodies, with no axe to grind. They can provide neutral territory where managers, unions, suppliers, bankers, government officials and other interested parties can explore their different perceptions. With better understanding amongst the various parties, barriers should be easier to overcome and the technology will be diffused.

3. Research and Development

In the area of research and development, universities can play an active role of remaining at the cutting edge of the technology. Matters such as machine vision and its use with robots, optical scanning, audio sensing, and the integration of CAD and CAM with other systems all deserve greater efforts at our universities. This does not mean that every university develops capabilities in each of these areas. Like our corporations, universities should carve out their special market niches for research and pursue policies of world product excellence.

Recommendations for Governments

1. Stable Environment

Perhaps the most valuable contribution which can be made by governments is to provide a stable business environment which is in harmony with the competitive situation in the world. This need for a stable environment is the most often heard complaint. Businessmen contend that the ground rules change too often. And with such frequent changes, it is difficult and risky to undertake the long range planning associated with capital investment decisions.

More than elsewhere, owners and managers of small businesses express frustration with the environmental conditions. They feel that the tax act is against entrepreneurship and that there are too many impediments in front of those who want to accomplish something. Too many reports are required, too many hoops must be jumped through in order to acquire funds, and too many bodies are looking over their shoulders. While some hoops and reports are necessary, businessmen feel that the demanders of the reports have little regard for the person filling them out. Small businessmen are so busy keeping up with the numerous activities of their firms that they have little time for becoming intimate with the requirements of some report or regulation. They would rather have a stable environment where they are not required to continuously learn new rules and procedures.

2. Coordination

The second most frequent complaint is the lack of coordination and the degree of duplication. The federal government, in particular, should not duplicate what has already been established in the provinces. Rather, the federal government should coordinate various CAD/CAM activities across the nation and act as a clearing house for ideas and approaches. Since some provinces are ahead of others, the advanced experiences of one area can be transferred to another.

Another aspect of the coordination requirement is the benefit which will occur from regional or product specialization. Ontario already has a jump on most other areas through the establishment of its CAD/CAM centres. Yet this advanced edge primarily benefits secondary manufacturing industries. Canada has many resource and primary processing industries, and we seldom think of them as candidates for CAD/CAM. We are more familiar with CAD/CAM in secondary manufacturing. Yet CAD/CAM, particularly CAM, is appropriate in lumber manufacturing, pulp and paper products, fish processing, smelting, and agriculture. In addition, there are applications in our consulting engineering firms, hospitals, municipal governments, and other service industries. Expertise and technical assistance has not been adequately developed in these other areas. They are important. The federal government could play a valuable role in encouraging such endeavors and assuring that unnecessary duplications do not occur.

In order to allow the federal government to carry out its coordinating role, cooperation must be forthcoming from provincial bodies. To a certain extent this cooperation is already present. Yet, it could still be carried further. For example, Ontario's Centres for Advanced Manufacturing, which operate under a sunset provision, have built up a large body of experience for disseminating CAD/CAM. They have no bureaucracy and they operate with the vigor which should make them self sufficient. As their provincial support drops, they could easily expand their activities to help other parts of Canada, and federal government support, either morally or monetarily, should be forthcoming. If the federal government funds such endeavors, or any other endeavors, the assistance should be temporary and with a sunset provision. The energy in such bodies is usually the highest during the initial years before a bureaucracy has set in.

3. Tax and Other Incentives

The most desired incentive by manufacturers is increased tax incentives for capital equipment. Although we believe that a general incentive for capital investment would be worthwhile, we are not recommending a special incentive just for CAD/CAM investment. Such a specialized program would require too much paperwork and just complicate the business environment even further. Rather, we believe that a stable regime takes first priority, and only later should other universal provisions be introduced.

Some non-tax provisions, however, should be introduced. The first is greater government assistance in carrying out a feasibility study. Such studies could be carried out by CAD/CAM centres or private consultants. Either way, the proven benefits will probably encourage and hasten the recipient firm to adopt CAD/CAM. If such studies demonstrate a strong positive benefit, then possibly the consultant or some government agency could help the firm approach a bank for funding. The government could even undertake to guarantee such loans so long as they were backed up by sound feasibility studies. Finally, if governments do provide assistance such as funding new, innovative applications of CAD/CAM, they should make sure that knowledge from such endeavors becomes publicly available.

4. Assistance for Small Businesses

Small businesses have particular problems, and particular benefits. In particular, small businesses are the ones which are increasing employment when they adopt CAD/CAM. One of governments' main objectives during these periods of high unemployment is to create more jobs. Thus it is in their special interest to encourage small business.

On the other hand, small businesses have particular problem in adopting CAD/CAM. They are short of capital, fearful of fast obsolescence, and unable to carry out their own feasibility studies. A body which understands and emphasizes CAD/CAM for small business would be beneficial. Possibly the Federal Business Development Bank or some other agency could play this role.

<u>Summary</u>

CAD/CAM is a new technology which presents opportunities for Canadian manufacturers to increase their operating effectiveness and competitive positions. In an international world which is becoming increasingly open, it is important for Canadian firms to compete and adapt if they wish to remain in existence. Healthy adoption will enable some firms to prosper; failure to adapt will result in tough economic conditions and probably the eventual demise of the firm. Both situations are bound to occur.

All parties concerned with CAD/CAM have a role to play in helping Canadian manufacturers achieve healthy adaptation. The largest role, however, must be played by the manufacturers themselves. Those manufacturers which have already gone through the process of acquiring

CAD/CAM systems should consider the possibility of taking that expertise, treating it as a profit centre, and selling hands-on demonstration programs to other companies. Alternatively, they could sell surplus CAD/CAM capacity if they have any, or they could consider setting up a separate firm to provide CAD/CAM consulting and services. Those firms which are considering new ventures in the technology may want to consider larger economic units (mergers, joint ventures, or consortia) which can spread costs, avoid duplications, and diffuse technological breakthroughs. Whichever tact is taken, it is important for firms to undertake strategic planning which identifies friendly niches in which they can compete and survive. To identify the appropriate niches and to assure that correct CAD/CAM purchases are made, management must take on the responsibility of learning what CAD/CAM is all about. In the process of acquiring CAD/CAM, they must also assure that their employees are properly prepared and trained.

Suppliers also have a role to play. One of the most beneficial steps they could undertake would be the setting of software standards and protocols. Insofar as existing standardization is inadequate, there is an opportunity for software suppliers to provide linking programs between different systems. Suppliers could also help by assembling better leasing packages and supporting the training function. In the area of supplier services, there is room for an CAD/CAM centres to provide a fuller range of activities on a broader geographic scale.

Although the reactions of unions was not specifically covered in this survey, unions, too, have an important role to play. They should recognize that technological change such as CAD/CAM is inevitable, and they should work towards its adoption in a humane manner. In particular, unions should play a very active role to assure equitable distribution of both wealth and jobs. Similarly, they should lobby and assure that CAD/CAM working conditions are safe. This means that union management, like company management, must become more knowledgeable in CAD/CAM.

The educational institutions, of course, can train operators, managers, and union leaders in the use of CAD/CAM. They can also act as diffusion catalysts to bring various parties together on neutral ground. In research and development, they can help keep Canada at the cutting edge of technology. But like our manufacturers, it is important for our research and development establishments to direct their attention to friendly niches.

Finally, there is the role to be played by government. Most important is the need for government to establish a stable business environment. It is only through a stable environment, reasonably free of red tape, that businessmen feel comfortable with making long range decisions If government wants to become more actively involved, then such involvement is recommended in only three areas. The first is to achieve greater coordination amongst the various programs to promote CAD/CAM. Such coordination also implies greater cooperation amongst the various levels of government. Secondly, tax incentives for capital investment and feasibility study assistance would result in greater utilization of new technologies such as CAD/CAM. Third, governments should seriously consider the specialized CAD/CAM needs of small manufacturers. They are the ones who are less knowledgeable about CAD/CAM; they are also the ones, however, who employ more people after they adopt the new technology.

APPENDIX A

Survey Questionnaire

QUESTIONNAIRE

CONSTRAINTS TO AUTOMATING CANADIAN MANUFACTURING INDUSTRY

The Meaning of CAD/CAM

CAD/CAM stands for Computer Aided Design/Computer Aided Manufacturing. It can be defined as any integrated design or manufacturing system which is under the control of a computer. This brief definition, however, does not begin to illustrate CAD/CAM's potential and its impact.

As a design tool (CAD), flexible graphics on a computer enables quick definition of drawings, blueprints and plans. Parts and subparts can be "exploded", magnified, and analyzed from different perspectives. Modifications can be easily made before the design is plotted on paper; and for moving parts, a kinetic simulation is even possible before a part is produced. To get these benefits of CAD, we must acquire computer hardware, software, and expertise; and alter our approach to the design and construction of a new product or process.

But the benefits do not stop there. The computer can also aid the manufacturing process (CAM). Since our CAD data is already in a digital computer format, it can be passed along to one or more numerically controlled machines which carry out the actual manufacturing operations. A system which totally integrates both CAD and CAM would involve design, numerically controlled machine tools, robotics, automated materials handling, inventory control, production scheduling, and manufacturing control. Although the exact degree and configuration of CAD/CAM varies according to the circumstances of each company and industry, the essential point is that CAD/CAM involves a transfer of technology from traditional production processes to new, electronically controlled processes.

CAD/CAM technology is capable of improving a company's quality, productivity, and profitability. Many observers claim that its benefits are so strong that its adoption is inevitable. Firms or nations which fail to keep up will lose out to competitors.

With this background of CAD/CAM in mind, please turn the page and answer the questionnaire.

Please be sure that this questionnaire is filled out by the General Manager or the most senior officer responsible for CAD/CAM at the Establishment to which this questionnaire has been forwarded.

CONSTRAINTS TO AUTOMATING CANADIAN MANUFACTURING INDUSTRY

We will greatly appreciate your assistance in this major study. Your answers are of particular importance since you have been selected as part of a "sample", representative of manufacturers, suppliers of Computer Aided Manufacturing (CAD/CAM) equipment and institutions. Under no circumstance will your individual answers be divulged. They will be used only in combination with those of other companies responding to the study. For most of the questions your answers can be given simply by checking (✓) the appropriate box or boxes.

If you would like a free summary report of the study simply forward a separate request on your company letterhead. This will further ensure confidentiality of your response.

IF YOU ARE A CAD/CAM SUPPLIER, TECHNICAL SOCIETY OR TRADE ASSOCIATION PLEASE GO DIRECTLY TO QUESTION 10 AND INDICATE YOUR ASSESSMENT OF THE CONSTRAINTS THAT MANUFACTURERS PRESENTLY FACE AND WHAT YOU BELIEVE ARE THE INCENTIVES THAT MIGHT ENCOURAGE INCREASED USE OF CAD/CAM SYSTEMS.

DO NOT WRITE IN THIS COLUMN

(1) WHAT IS YOUR KNOWLEDGE OF CAD/CAM? — 7

1 ☐ Expert 2 ☐ Major Knowledge 3 ☐ Average Knowledge 4 ☐ Minor Knowledge 5 ☐ No Knowledge

(2) WHAT CLASS OF CAD/CAM USER IS THIS ESTABLISHMENT? (Question 3 provides some indication as to what is included in a CAD/CAM System.) — 8

1 ☐ Present User Considering increased use of CAD/CAM
2 ☐ Present User Not considering increased use of CAD/CAM
3 ☐ Not a User But actively considering CAD/CAM systems
4 ☐ Not a User But intend to consider CAD/CAM in next 5 years
5 ☐ No intention to use CAD/CAM systems in the next 5 years

(3) WHAT APPLICATION OF CAD/CAM DO YOU PRESENTLY USE, ARE CONSIDERING USING OR MIGHT CONSIDER USING IN THE NEXT 5 YEARS. — 9-10, 11-12, 13-14, 15-16, 17-18, 19-20, 21-22, 23-24, 25-26

	Presently Using	Presently Considering Use	Might Consider	
1	☐	15 ☐	29 ☐	Engineering Computation by Computer
2	☐	16 ☐	30 ☐	Automated Drafting/Design
3	☐	17 ☐	31 ☐	Automated Production and Parts Scheduling
4	☐	18 ☐	32 ☐	Direct wired link from CAD to machine tool and/or process
5	☐	19 ☐	33 ☐	Computerized Numerical Control (CNC) Machine Tooling
6	☐	20 ☐	34 ☐	Automated Assembly by special purpose equipment
7	☐	21 ☐	35 ☐	Robotic Units for parts handling
8	☐	22 ☐	36 ☐	Automatic assembly by Robots
9	☐	23 ☐	37 ☐	Other applications of Robots
10	☐	24 ☐	38 ☐	Automated testing
11	☐	25 ☐	39 ☐	Automated warehousing, work in progress parts movement and finished goods
12	☐	26 ☐	40 ☐	Integrated total CAD/CAM Systems
13	☐	27 ☐	41 ☐	(other)____________
14	☐	28 ☐	42 ☐	(other)____________

(4) WHAT ARE YOUR ESTIMATES OF THE EFFECTS OF CAD/CAM? IF YOU ARE NOT PRESENTLY A USER, GIVE YOUR ESTIMATES.

a) on productivity -- will ☐ increase ☐ decrease productivity by _____ percent — 27, 28-29

b) on employment -- will ☐ increase ☐ decrease employment by _____ people which is _____ percent of the affected workforce. — 30, 31 - 34, 35-36

c) on quality -- will ☐ increase ☐ decrease reliability, consistency and quality by a ☐ negligible ☐ moderate ☐ large amount. — 37, 38

d) on volume of present and new business -- will ☐ increase ☐ decrease sales by _______ percent — 39, 40-41

e) lead times or set up times are ☐ increased ☐ decreased by _______ percent — 42, 43-44

(5) TOTAL NUMBER OF EMPLOYEES AT THIS PLANT OR DIVISION (INCLUDE ALL EMPLOYEES -- BLUE COLLAR, SECRETARIAL, ADMINISTRATIVE, ETC.). — 45 - 48

NUMBER: ____________

(6) ESTIMATED MANUFACTURING FACILITY SALES FOR 1983 OF THIS PLANT OR DIVISION — 49

1 ☐ Up to $99,999
2 ☐ $100,000-$199,999
3 ☐ $200,000-$499,999
4 ☐ $500,000-$999,999
5 ☐ $1,000,000-$2,999,999
6 ☐ $3,000,000-$9,999,999
7 ☐ $10,000,000-$24,999,999
8 ☐ $25,000,000-$49,999,999
9 ☐ $50,000,000 and over

(7) ESTIMATE THE AVERAGE NUMBER OF UNITS PER JOB RUN IN THIS MANUFACTURING FACILITY — 50

1 ☐ 1-5 units
2 ☐ 6-24 units
3 ☐ 25-50 units
4 ☐ 51-100 units
5 ☐ 101-500 units
6 ☐ over 500 units

(8) WHICH CLASSIFICATION BEST DESCRIBES THIS MANUFACTURING FACILITY

1 ☐ Paper and allied products
2 ☐ Lumber and Wood Products (except Furniture)
3 ☐ Fish Processing
4 ☐ Chemicals and allied products
5 ☐ Petroleum Refining and related industries
6 ☐ Primary Metal Industries
7 ☐ Fabricated Metal Products(except Machinery and Transport Equipment)
8 ☐ Machinery - except Electrical
9 ☐ Electrical and Electronic Machinery equipment and supplies
10 ☐ Transportation equipment
11 ☐ Measuring, Analyzing and Control Instruments, photographic, medical and optic goods, watches and clocks
12 ☐ Miscellaneous Manufacturing Industries
13 ☐ Apparel and other finished products made from fabric and similar materials

51-52

(9) LOCATION OF THIS PLANT OR MANUFACTURING FACILITY

1 ☐ Newfoundland
2 ☐ P.E.I.
3 ☐ Nova Scotia
4 ☐ New Brunswick
5 ☐ Quebec
6 ☐ Ontario
7 ☐ Manitoba
8 ☐ Saskatchewan
9 ☐ Alberta
10 ☐ B.C.
11 ☐ Y.T.
12 ☐ N.W.T.

53-54

(10) PRESENTLY THERE ARE A NUMBER OF FACTORS THAT DISCOURAGE THE INCREASED USE OR IMPLEMENTATION OF CAD/-CAM SYSEMS. THESE FACTORS MIGHT BE CONSIDERED CONSTRAINTS. PLEASE INDICATE WHICH CONSTRAINTS APPLY TO YOUR COMPANY TODAY AND HOW IMPORTANT THESE CONSTRAINTS ARE. PLACE A CHECK MARK (✓) UNDER THE APPROPRIATE POINT ON THE SPACE.

	A Critical or fundimental factor when considering CAD/CAM systems 1	Very Important But not critical factor when considering CAD/CAM systems 2	An Important factor when considering CAD/CAM systems 3	A Not so Important factor when considering CAD/CAM systems 4	An Unimportant factor when considering CAD /CAM systems 5	
1 Potential labour conflict						7
2 Lack of system software support						8
3 High financial risk						9
4 Market volatility						10
5 Management team not knowledgeable about the technology						11
6 management team not experienced in system implementation						12
7 Trained staff not available						13
8 Technology not mature - fast obsolescence possible						14
9 Difficulty of integrating into present operations						15
10 Lack of standardization						16
11 Inadequate return on investment						17
12 Unavailability of resources to study and evaluate CAD/CAM systems						18
13 Unavailability or high cost of investment capital						19
14 No need for immediate change						20
15 Compatability problems of exchanging data with other systems						21
16 Not yet appropriate to my industry						22
17 Other (specify)						23

(11) WHICH OF THE ABOVE FACTORS ARE PRESENTLY CAUSING YOU TO SERIOUSLY QUESTION OR HOLD BACK ON THE IMPLEMENTATION OR EXPANSION OF A CAD/CAM SYSTEM. PLEASE RESPOND BY RECORDING THE APPROPRIATE NUMBER IN THE FOLLOWING BOXES.

☐☐ Most Important
☐☐ 2nd Most Important
☐☐ 3rd Most Important
☐☐ 4th Most Important

24-25
26-27
28-29
30-31

(12) THE FOLLOWING IS A LIST OF POSSIBLE INCENTIVES FOR INCREASING THE USE OF CAD/CAM SYSTEMS. PLEASE INDICATE HOW EFFECTIVE YOU THINK EACH OF THE INCENTIVES MIGHT BE. PLACE A CHECK MARK (✓) UNDER THE APPROPRIATE POINT ON THE SCALE.

	Essential for rapid increase of CAD/CAM systems 1	Can have a Very Beneficial Impact - but not essential to CAD/CAM implementation 2	Can have Some Desirable Impact on CAD/CAM implementation 3	Can have Little or no Impact on CAD/CAM implementation 4	Can have Undesirable Impacts on CAD/CAM system implementation 5	
1 Suppliers standardize programming languages and hardware						32
2 Suppliers assist in operator/programmer training						33
3 Suppliers conduct more frequent Management Training Seminars						34
4 Federal/Provincial agencies provide increased tax incentives for capital investment						35
5 Federal/Provincial agencies provide funding assistance for feasibility studies						36
6 Federal/Provincial agencies provide funding assistance for innovative application programs						37
7 Federal/Provincial agencies change CAD/CAM Trade/Torriff arrangements						38
8 Federal/Provincial agencies provide increased funding assistance for on-job training						39
9 Federal/Povincial agencies increase responsibility for CAD/CAM seminars, conferences, etc.						40
10 Education institutions increase and improve training programs for operators, programmers, etc.						41
11 Education institutions develop programs to educate management Re: CAD/CAM concepts, evaluation and implementation						42
12 Education institutions assume greater responsibilities for CAD/CAM research and development						43
13 Develop more Regional Centres for Information Collection and dissemination Re: CAD/CAM						44
14 Develop practical experience sessions on other people's equipment						45
15 Create and encourage industry collaboration in R & D						46
16 Present Manufacturers share information and insights into success and failure of CAD/CAM systems						47

(13) DO YOU HAVE ANY ADDITIONAL COMMENTS REGARDING CONSTRAINTS OR INCENTIVES FOR CAD/CAM

48-49

(14) IN YOUR INDUSTRY, IS CAD/CAM:

1 ☐ Used by most firms
2 ☐ Used by some firms
3 ☐ Used by few firms
4 ☐ Not used at all

(15) IN THE USE OF CAD/CAM IN YOUR INDUSTRY, ARE YOU:

1 ☐ An industry leader
2 ☐ Somewhat ahead of competitors
3 ☐ On par with other firms
4 ☐ Somewhat behind competitors
5 ☐ Well behind competitors

50-51

(16) IS THE OWNERSHIP OF THIS ESTABLISHMENT:

1 ☐ Canadian controlled
2 ☐ U.S. controlled
3 ☐ U.K. controlled
4 ☐ Other European controlled
5 ☐ Asian controlled
6 ☐ Other ________

52

THANK YOU -- PLEASE RETURN THIS QUESTIONNAIRE IN THE PREPAID SELF-ADDRESSED ENVELOPE

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TECHNOLOGICAL INNOVATION STUDIES PROGRAM

PROGRAMME DES ÉTUDES SUR LES INNOVATIONS TECHNIQUES

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