A SURVEY ON THE IMPACT OF INFORMATION TECHNOLOGY ON THE CANADIAN ARCHITECTURE, ENGINEERING AND CONSTRUCTION INDUSTRY

SUBMITTED: February 2000
PUBLISHED: May 2000 at http://itcon.org/2000/3/
EDITOR: Bo-Christer Björk

Hugues Rivard, Assistant Professor,
Concordia University, Canada
email:rivard@alcor.concordia.ca, http://alcor.concordia.ca/~rivard/

SUMMARY: A survey about the current and planned use of information technology (IT) and its impact on the architecture, engineering, and construction (AEC) industry in Canada has been conducted at the end of 1998 and beginning of 1999. It was found that many business processes are now almost completely computerised and the tendency is toward a greater computerisation of the remaining processes. Although the Internet has been adopted by most firms surveyed, design information is still exchanged in its traditional form. These firms have increased and will increase further their investment in IT, which has raised productivity in most business processes and has resulted in an increase in the quality of documents and in the speed of work, better financial controls and communications, and simpler access to common data. However, the benefits of IT come at a cost since the complexity of work, the administrative needs and the costs of doing business have all increased. The continual demand for upgrading and the greater know-how required are considered important obstacles. The two most important areas of future research is the implementation of computer-integrated design and construction as well as the development of new tools to support concurrent design and to assist designers in the conceptual stages.

KEYWORDS: Information technology; Architecture, engineering, and construction industry; Survey; Canada.

1. INTRODUCTION

Computers have revolutionised the way documents are generated. Similarly, information technology is bound to revolutionise the way people exchange information and documents. Information technology (IT) is defined as "the use of electronic machines and programs for the processing, storage, transfer and presentation of information" (Bjork, 1999). IT encompasses many technologies such as computers, software, networks and even telephones and fax machines. The purpose of IT is to facilitate the exchange and management of information and has a lot of potentials for the information process component of the construction industry. These recent technologies will undoubtedly have a profound impact on how organisations operate on a daily basis. This paper presents selected results from a survey, which was conducted at the end of 1998 and beginning of 1999, in order to determine this impact on the architecture, engineering and construction (AEC) industry in Canada.

Several surveys have been conducted in the past couple of years to determine the impact of information technology in the construction industries of various countries. Such surveys were conducted in New Zealand (Doherty, 1997); Sweden, Denmark and Finland (Howard and Samuelsson, 1998, Howard et al., 1998); Hong Kong (Futcher and Rowlinson, 1998, Futcher and Rowlinson, 1999); and Saudi Arabia (O'Brien and Al-Biqami, 1999). In Canada, two government agencies have conducted similar studies: Industry Canada and the Canada Mortgage and Housing Corporation. An extensive survey of technology diffusion in service industries was conducted by Statistics Canada on behalf of Industry Canada between October and December 1996 (Industry Canada, 1997). The purpose of that survey was to provide a portrait of the use of electronic technologies in the Canadian industry. It provides an interesting comparison between the construction industry and other service industries, but is already two years old and focuses on the use of various technologies only. The Canada Mortgage and Housing Corporation (CMHC) conducted a survey in 1997 to determine the level of penetration of the Internet in the housing sector (CMHC, 1999). This survey focused on associations, organisations and government agencies involved in the housing sector. Only 17% of the respondents were from the private sector.

Hence, this survey provides a clear picture of the use of the Internet within non-profit associations and governmental agencies but not within consulting firms and contractors.

The purpose of the survey presented here is to reveal the current and planned use of computer-based and telecommunication technologies as well as to determine their impact on architectural firms, engineering firms, and contractors in Canada. To achieve this purpose, the survey looked at the availability and usage of computers, computer-aided drafting software, networks, and information technology among AEC firms. The results will provide directions in research, development, training, and strategies that will respond to the needs of this industry. The paper commences with a description of the survey and methodology used followed by the profiles of the respondents, the findings of the survey, and some concluding remarks.

2. SURVEY'S ORIGIN AND METHODOLOGY

The questionnaire used in this survey is a slightly modified and improved version of the "IT barometer survey" which was created at the Royal Institute of Technology (Kungl Tekniska Högskolan) of Sweden, in 1997, by Olle Samuelsson (Samuelsson, 1998). This survey has since been used in different countries, and thus makes comparison among countries possible. Such results have already been published for Scandinavia in (Howard et al., 1998) and (Howard and Samuelsson, 1998). The following changes were introduced: instructions were provided on the first page; a new layout was produced to clarify questions; options were added or modified to account for the Canadian perspective; a question was added on areas of research; and the questionnaire was translated in French for the French-speaking respondents. The twelve-page questionnaire was printed in the form of a letter-size booklet.

The survey was sent by mail to a statistical sample of 1000 firms in the AEC industry across Canada. This sample of firms was split in three equal categories: architectural firms, engineering firms, and construction contractors. The mailing list was assembled with registers obtained from associations of architects, associations of consulting engineers, and construction associations from each of the ten provinces. The sample was made proportionate to the number of firms in each province. The sample was selected at random in order to ascertain reliability about the population.

A package was sent to every executive in the sample. Packages were prepared in either English or French depending on the province of the recipient. Participation to the survey was voluntary. The only incentive was the option to receive the findings of the survey. The survey was sent at the end of November 1998 and answers were collected between the months of December 1998 and March 1999. The answers provided were kept confidential and used for statistical purposes and released in aggregate form only. The returned questionnaires were destroyed once the analysis was completed.

3. RESPONDENT PROFILES

The return rates for mail surveys in the construction industry oscillate often around 10%; 7% for the general survey in New Zealand (Doherty, 1997); 10% in Denmark and 16% in Sweden (Howard et al., 1998); 9% in Saudi Arabia (O'Brien and Al-Biqami, 1999). The findings presented here are based on an overall 22% return rate. In general, a mail survey cannot be considered statistically significant under a 50% return rate (Erdos, 1983). Even though a low-response was obtained, the findings of the survey still present useful information about the respondents and show tendencies within the industry. The distribution of responses with respect to the three categories of firms surveyed is shown in Figure 1. The category "Other" consists of manufacturers and distributors. The position of 85% of the respondents were in senior management while 7% were information technology managers.

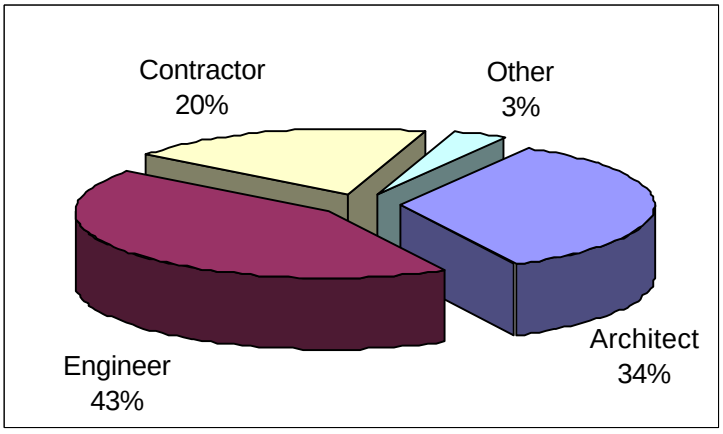


FIG. 1: Distribution of responses among the three categories of firms surveyed.

The distribution of responses with respect to the five regions of Canada (i.e., British Columbia, the Prairies, Ontario, Quebec and the Maritimes) is shown in Fig. 2. This distribution correlates well with the population distribution of Canada in 1998 except for the Maritimes and Ontario (Statistics Canada, 1999). The proportion of the responses from the Maritimes is actually twice that of its contribution to the overall population of Canada, while the proportion of the responses from Ontario is 8% less than its contribution to Canada's population.

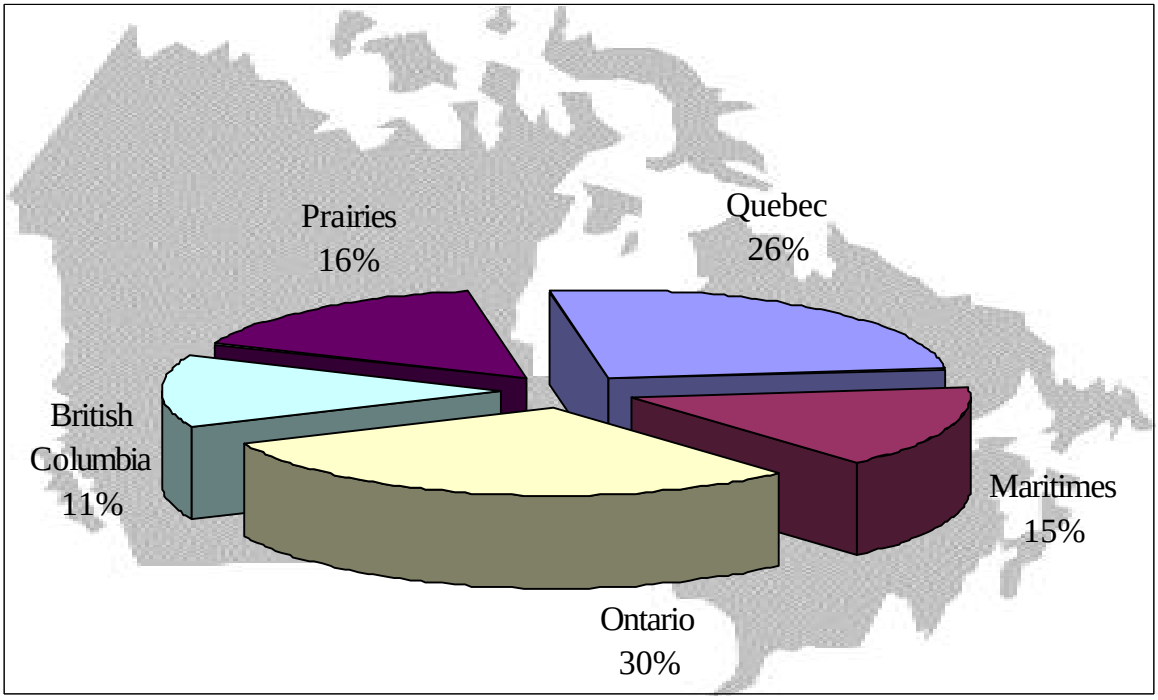


FIG. 2: Distribution of responses within Canada.

The firms represented in the survey had a work force that varied from one employee to over 2000 employees on average. Fig. 3 shows the size distribution for all three categories of firms surveyed. It is interesting to note that the majority of architectural firms surveyed are very small firms since 56% of them have less than 5 employees on average. Engineering firms, on the other hand, were more evenly distributed over the four categories of size defined. Actually, the biggest firms surveyed were engineering firms with a couple of them over 2000 employees. Contractors were more middle-size range with almost 80% of the contractors who responded had between 5 and 100 employees.

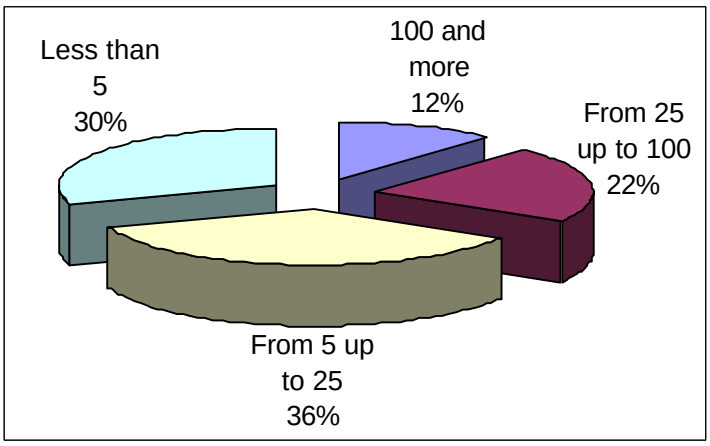


FIG. 3: Size distribution of all the firms surveyed in terms of number of employees.

Another important characteristic of a company is its gross annual revenue. Most of the respondent provided the category which best represented their company's gross annual revenue. Only 4% did not answer this question. Fig. 4 shows that the annual revenues of the firms surveyed varied from less than $100,000 to more than $100 million. The largest category was between $1 million and $10 million.

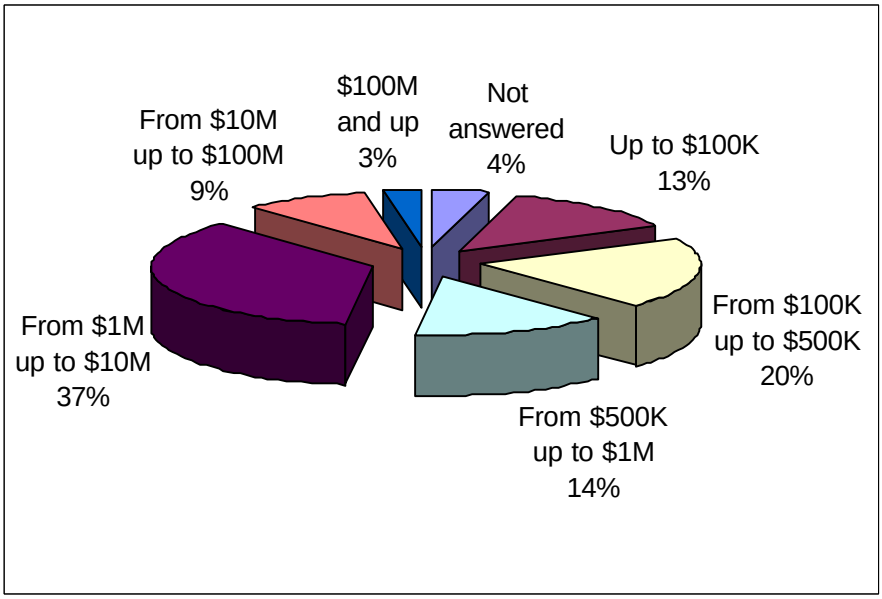


FIG. 4: Distribution of gross annual revenue among the firms surveyed.

4. SURVEY FINDINGS

The selected results of the survey are presented within the following four topics: computer availability; computer usage; computer-aided drafting; networks and communications; information technology; and research directions.

4.1 Computer Availability

Almost all respondents have computers. Only 1% indicated that they did not have computers. This kind of survey has the deficiency of appealing to people who are already using IT while it rebuffs those who are not. Although the survey most probably overestimates the computer use within the industry, it still indicates a greater use of computers than two years ago. The survey published by Industry Canada shows that at the end of 1996 65% of the construction industry were using personal computers while another 5% were either implementing or considering using PCs (Industry Canada, 1997). Hence, the drastic reduction in computer prices over the last

few years and the increased power, usefulness and popularity of computers have made this tool more ubiquitous within the industry.

There is an average of 0.8 desktop computer per employee among the companies surveyed that have computers. Table 1 shows the average number of desktop and portable computers per employee for the three categories of firms surveyed. Architectural firms have more than one desktop computer per employee probably because they keep old computers longer to prepare renderings and walk-through animations. It is clear from table 1 that the main workhorse is the desktop computer since there is only one portable computer per five employees in engineering firms and one per ten employees in architectural firms. In another question, it was found that architectural and engineering firms have the same high proportions of staff that use computer and that have a computer assigned to them. Nine out of ten employees use computers in their work and eight out of ten employees have their own computer on which to do their work. These percentages are very similar to what exists in Scandinavia (Howard et al., 1998). These findings clearly indicate that architects and engineers have come to rely heavily on computers in their work. Contractors, on the other hand, have only half these proportions because of the proportion of staff working on site.

TABLE 1: Number of computers per employee.

Categories of Firms	Desktop Computers	Portable Computers
Architects	1.2	0.10
Engineers	0.9	0.18
Contractors	0.3	0.06

4.2 Computer Usage

Computers are versatile and can be used for many purposes. This section considers the type of operating systems and office software used among the surveyed firms as well as their usage of computers in specific business processes.

The operating system on a computer is the software responsible for controlling the allocation and usage of hardware resources such as memory, central processing unit (CPU) time, disk space, and peripheral devices. The operating system is the first software installed on a computer and is the foundation on which applications run. Microsoft is the dominant brand of operating systems used in the construction industry since it sold almost 90% of all operating systems installed. The next contender is the Mac OS with a meagre 8%.

Office software consists of general-purpose applications such as word processors and spreadsheets. The survey also looked at the types of office software used in the industry. Figure 5 shows that almost all companies surveyed that have computers use word processors and spreadsheets. On the other hand, database systems and project planning packages are not as prevalent but their use is increasing.

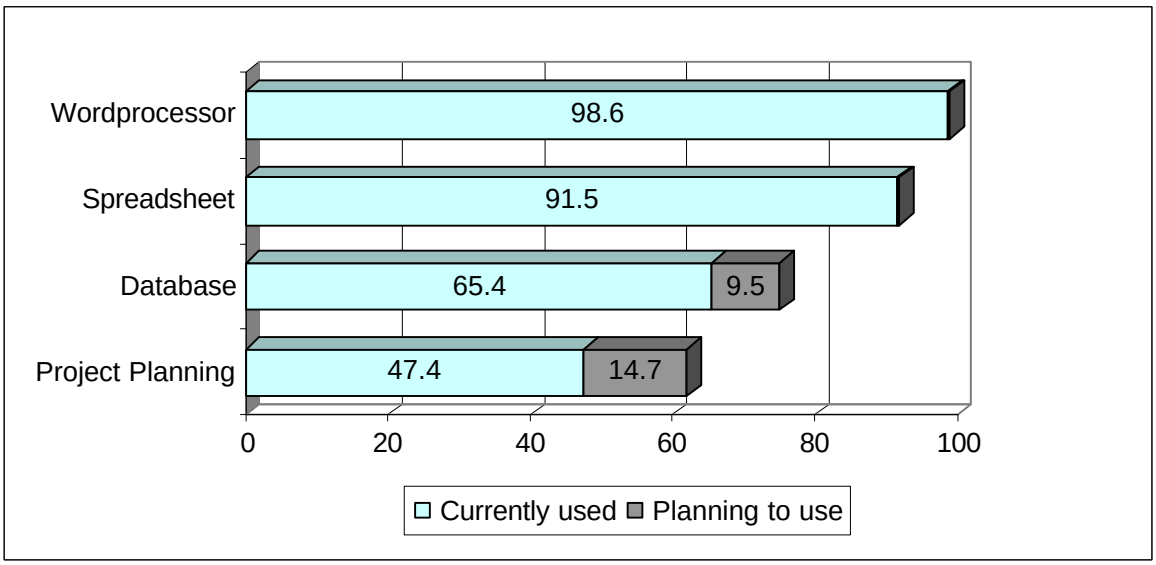


FIG. 5: Percentage use of office software in the construction industry.

The survey evaluated the extent of computerisation of some business processes and the results are shown on Fig. 6. The answers provided by the respondents were classified into three distinct categories: highly computerised means that from 60% up to 100% of the process is computerised; partially computerised means that from 20% up to 59% of the process is computerised; and mostly manual means that either no computer is used or up to 19% of the process is computerised. Fig. 6 shows that, on one hand, bookkeeping, invoicing and specification writing are almost completely computerised, while, on the other hand, 47% of materials control and purchasing are mostly manual. The lack of computerisation of some processes could be due to a lack of good and efficient software tools and/or a lack of training of the staff. It is surprising to see that 30% of the scheduling process is still mostly done manually even though there are cheap and efficient software applications available for this task (e.g., Microsoft Project 98, Time Line Solutions, and Scitor Project Scheduler 7). In any events, it is clear that the tendency is toward a greater computerisation of the processes shown in Fig. 6 since the "highly computerised" category is extensive in most of them.

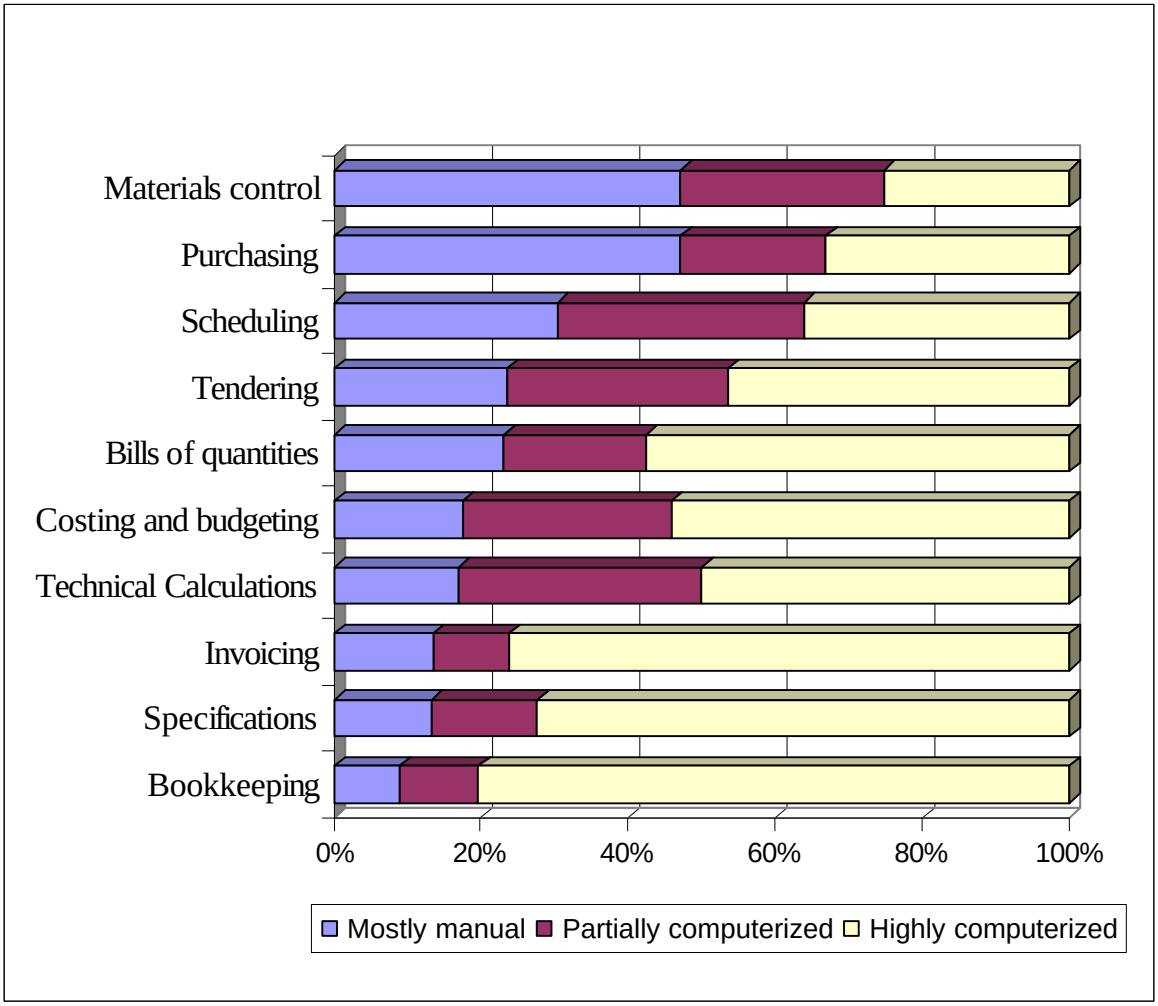


FIG. 6: Extent to which processes are computerised.

4.3 Computer-Aided Drafting

The main output of any architectural and engineering firms is drawings and these drawings are now mostly generated on computers. Computer-aided drafting (CAD) is used in 76% of the firms surveyed that have computers. Figure 7 shows that almost every architectural and engineering firm surveyed use CAD. On the other hand, only one out of four contractors uses CAD.

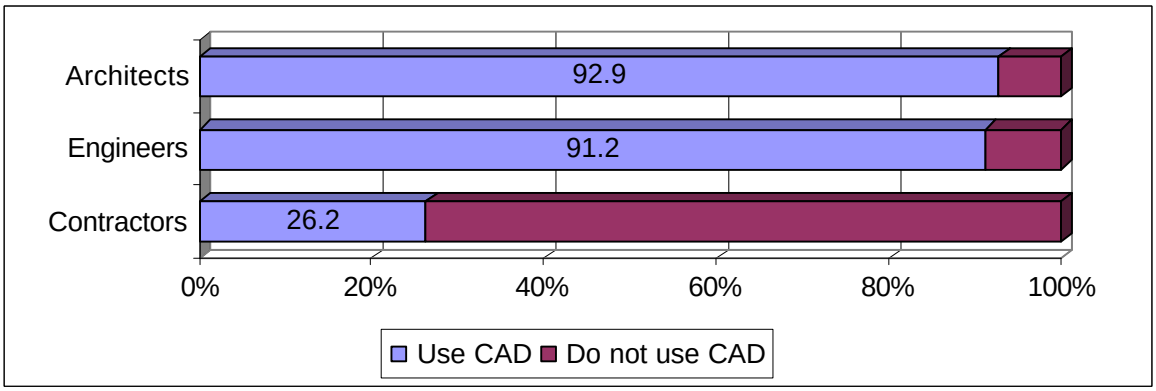


FIG. 7: Percentage of firms that use CAD.

Autodesk is the dominant brand of CAD software used in the industry. Figure 8 shows that 65% of all packages used in the firms surveyed were sold by Autodesk (i.e., AutoCAD and AutoCAD LT). The next most popular brands are Microstation from Bentley with 16% and Visio Technical from Visio Corp. with 11%.

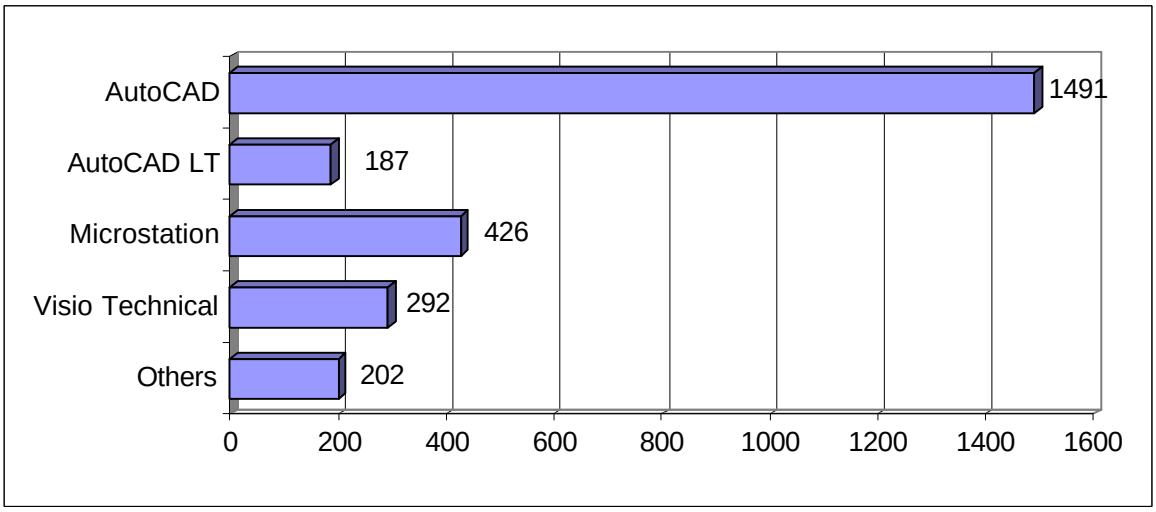


FIG. 8: Number of licenses per CAD software.

CAD has several related technologies, two of which are GIS and rendering packages. GIS stands for geographic information systems. A GIS is an integrated software application devised to capture, store, edit, analyze and display geographic information and is typically used in land use planning, infrastructure management, environmental engineering, natural resources planning and management. 20% of engineering firms use GIS while only 5% of architectural firms surveyed use GIS. A rendering package is a software application used to create, edit and render a realistic 3-D image of an architectural or engineered effort and typically includes lighting effects, camera setup and the application of materials on surfaces. Half of the architectural firms surveyed used rendering packages while 23% of the engineering firms use such packages.

Most of the drawing design work is now done using CAD. Figure 9 shows that 71% of the firms surveyed use CAD to prepare 80% to 100% of all drawings. The numbers between brackets indicate that, for instance, from 40 to 59% of the drawing design work is done with CAD in 7% of the firms surveyed that use CAD. This diagram clearly shows how necessary and ubiquitous CAD software has become in the industry.

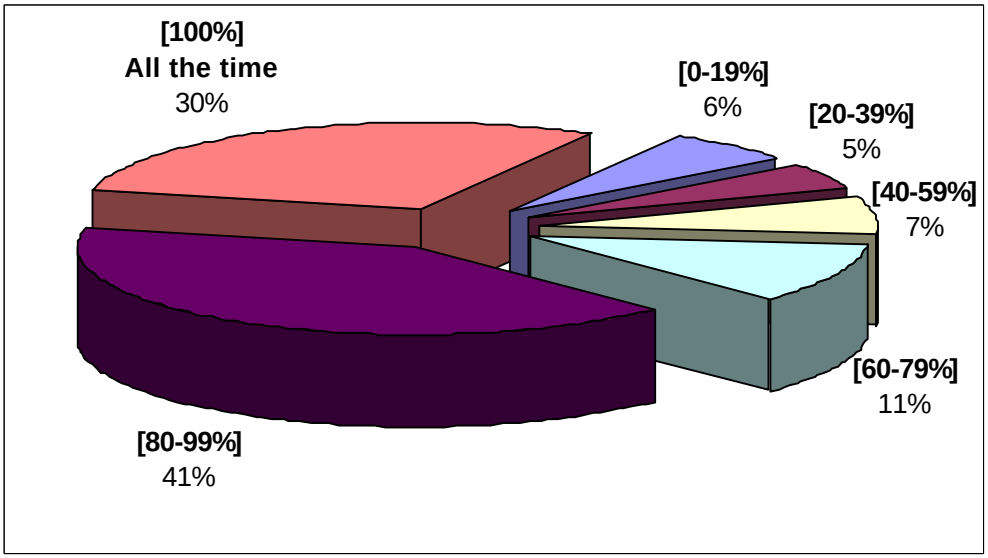


FIG. 9: Percentage of the amount of the drawing design work done with CAD.

There are several ways to represent drawing information within CAD software. Figure 10 shows that most of the drawings are two-dimensional drawings (i.e., 94% of all drawings). The majority of drawings are structured drawings with standardized layers and attributes. A quarter of all drawings generated integrate databases or external reference files with two-dimensional drawings. Only 5% of all drawings are done in three-dimensions with building objects. A product model is a digital representation of the objects making up a building or an engineering facility, capturing the form, behavior and relations of the parts and assemblies within the building or the facility (Eastman, 1999). Even though product models hold the promise of standardized information exchange and richer design information, its use in Canada in generating drawings is negligible. Canada lags behind Scandinavian countries in the adoption of product models and structured 3D CAD. As a comparison, in Finland, drawings are prepared 13% of the time with product models and 22% of the time with 3D CAD (Howard et al., 1998).

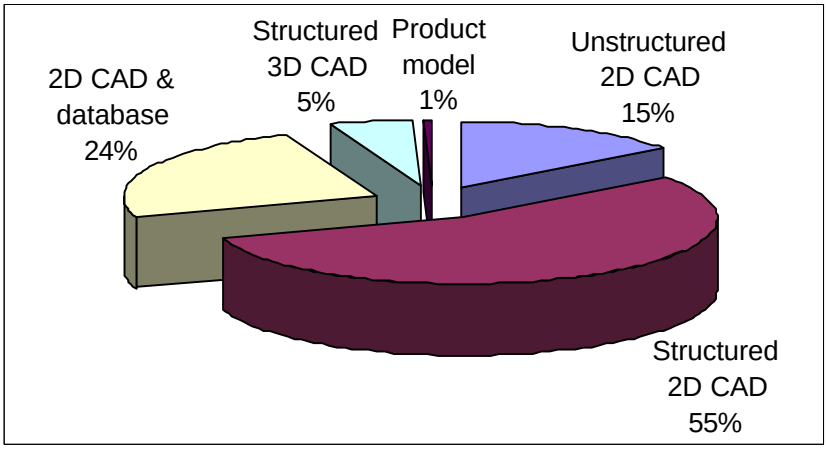


FIG. 10: Percentage of design time with five CAD approaches.

With the advent of ISO 9000, the quality management and quality assurance standard, more and more firms are adopting quality assurance in their processes. Quality assurance aims at ensuring that a firm can time and time again deliver the product or services that satisfy given requirements for quality. Quality assurance implies the use of documented procedures that are known, understood and operated by all personnel. The results from the survey show that 66% of the engineering firms and 44% of the architectural firms surveyed have a CAD handbook for internal procedures, but only 47% of these engineering firms and 34% of these architectural firms have this handbook as part of the certified quality system.

4.4 Networks and Communications

The advent of networks in general and the Internet in particular provides phenomenal opportunities for communication and data exchange among and within firms. This section examines the use of networks among firms, the use of and access to the Internet, as well as the exchange of document in an electronic fashion.

Computers in a firm may be connected by a local area network (LAN). A LAN is an association of computers connected by less than 1,000 feet of cable (Doherty, 1997). It was found in the survey that 62% of the respondents have computers connected through a LAN. In terms of categories of firms, it was found that only 44% of the architectural firms have a LAN while 75% of the engineering firms have a LAN. This wide discrepancy is due to the large difference in sizes between architectural and engineering firms. Half of the architectural firms surveyed have four computers or less, hence they do not need a network. The same explanation applies to the contractors surveyed since 61% of them have a LAN (half of the contractors surveyed have four computers or less).

The Internet is a global network of networks that uses a standard protocol for communication (called TCP/IP) and that allows computers to be connectected throughout the world. The Internet has become ubiquitous in the industry as 90% of the company surveyed are connected to the Internet. In terms of categories of firms, 86% of the architectural firms, 97% of the engineering firms, and 83% of the contractors surveyed are connected to the Internet. Hence, the industry has quickly jumped in the Internet bandwagon since it became popular in 1995.

Figure 11 shows what types of connections to the Internet the firms surveyed use. The most pervading type of connections used is the modem which has speed varying from 14.4 Kbps up to 56 Kbps (i.e., 56,000 bits per second). 79% of the firms surveyed that are connected to the Internet use modem connections. This is bound to change with the recent deregulation, since cable companies are now competing with telephone companies in the domain of Internet connection and are offering an attractive and cheap alternative to modems. Cable modems are faster than modems with a speeds ranging from 500 Kbps to 10 Mbps. 7% of the firms surveyed connected to the Internet have already adopted cable modems. The other two popular types of connections are ISDN and T1/T3. 7% of the firms surveyed used ISDN while 6% used T1/T3. ISDN stands for Integrated Services Digital Network and is a digital communications service for voice and data transmission that runs over regular lines (Doherty, 1997). ISDN has speeds ranging between 56 Kbps and 128 Kbps. T1/T3 are dedicated leased lines for businesses that need fast Internet access and can afford it. A T1 line comprises 24 ISDN circuits and has a data rate of 1.5 Mbps while a T3 line comprises 30 T1 line and has a data rate of 45 Mbps. Because of their associated high costs, ISDN and T1/T3 are mostly used in large firms.

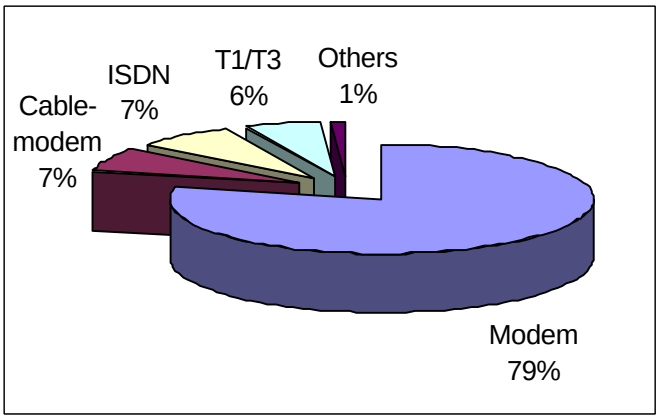


FIG. 11: Types of Internet connection used.

E-mail has reached an 87% penetration with an additional 8% implementing it. This is in sharp contrast with the results obtained by Industry Canada at the end of 1996 when only 15% of the construction industry were using e-mail (in comparison with 28% across all industries) and 17% were either implementing or considering it (Industry Canada, 1997). A similar penetration was achieved with the World-Wide Web where now 82% of the industry are using web browsers while only 15% had access to the Web in 1996.

Fig. 12 and Fig. 13 show the adoption of e-mail and World-Wide Web browsers in the three different categories of firms surveyed. The use of the Internet seems ubiquitous in engineering firms. A large proportion of the architectural firms have also adopted the Internet, but at a lesser extent than engineering firms. On the other hand, a large proportion of the contractors surveyed has adopted the Internet but there are still many that have not. Three-quarters of the contractors surveyed use e-mail and two-thirds use web browsers. This is bound to change because more and more calls for project tenders are published on the web. In Canada, there are two important sources of project opportunities on the Internet. MERX provides access to thousands of project opportunities (with an estimated worth of $6 billion annually) from the federal, provincial, and municipal governments as well as from other institutions (can be accessed at www.merx.cebra.com). The Construction Opportunity On-Line Network (COOLnet) is another important source of project opportunities whose objective is to provide an economical method of disseminating project opportunity information (can be accessed at www.coolnet.ca). Therefore, it is only a question of time before the remaining firms inevitably adopt this new technology.

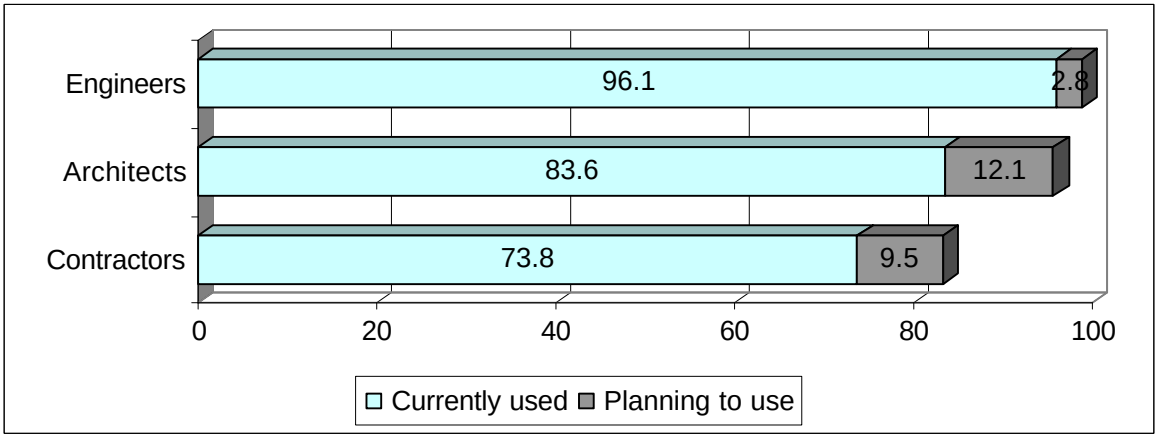


FIG. 12: Percentage use of e-mail with respect to the three types of firms surveyed.

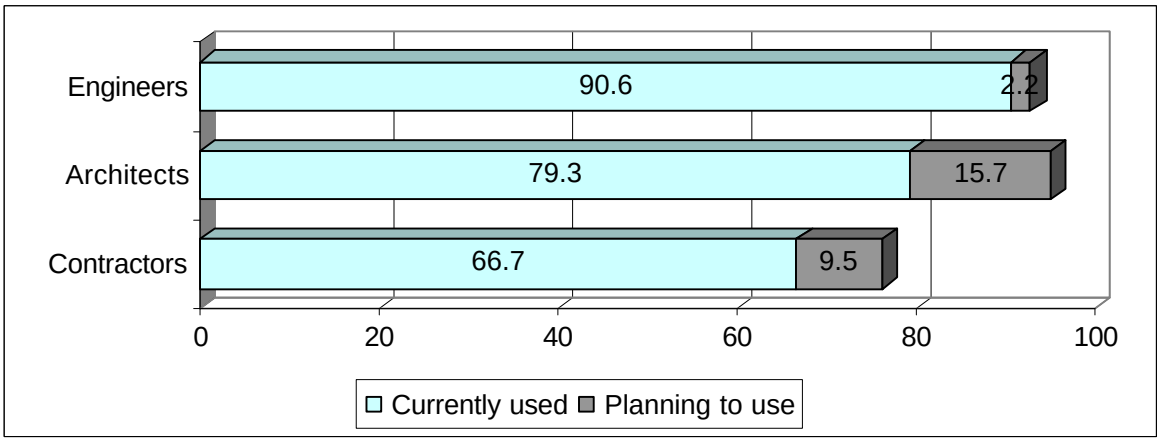


FIG. 13: Percentage use of Web browsers with respect to the three types of firms surveyed.

The World-Wide Web has become an efficient medium to advertise services and products offered. For instance, many organisations surveyed by CMHC in the housing sector are involved in publishing and in distributing free information and 55% of these were found to have a web site (CMHC, 1999). The AEC industry is also adopting this mean of communication for advertisement as well since 38% of the firms surveyed have a home page on the World Wide Web. With respect to the categories of firms, 43% of the engineering firms, 27% of the architectural firms, and 27% of the contractors surveyed have a home page. Although many firms still do not have a presence on the Web, this situation will change in the coming years since 51% of the firms which do not currently have a web page plan to have one in the near future (these results do not vary across company types).

An important capability provided by information technology is the instant transfer of documents in electronic forms. Fig. 14 shows that most documents in the industry are still exchanged by traditional means. Based on these results, design documents are the type of documents with the highest probability (only 28%) to be exchanged often or always in an electronic form. Similar results were obtained in Sweden with 28% of the design documents being exchanged digitally (Howard et al., 1998). The differences are greater, on the other hand, with respect to textual documents since 25% of the minutes of meetings and 22% of the specifications are often or always exchanged digitally among the Canadian respondents versus 44% and 40% respectively in Sweden. The main barriers to the widespread digital exchange of documents are: the slow Internet connections (the large majority of the respondents use modems); the lack of common standards that would permit the exchange of data among software applications; and the fact that this new mode of communication has still not been integrated in the business culture of the AEC industry. These proportions are bound to augment as more companies are switching to better connections and as more players in the AEC industry get accustomed to this mode of information exchange.

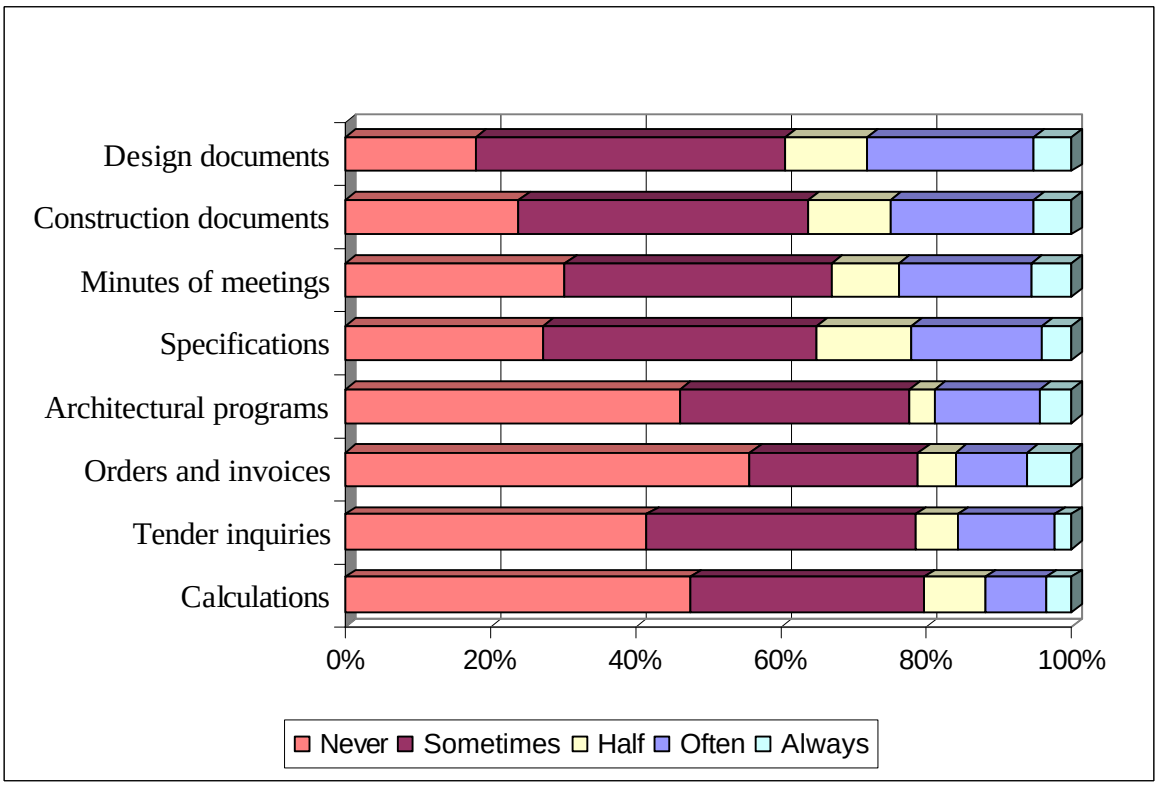


FIG. 14: Digital exchange of documents.

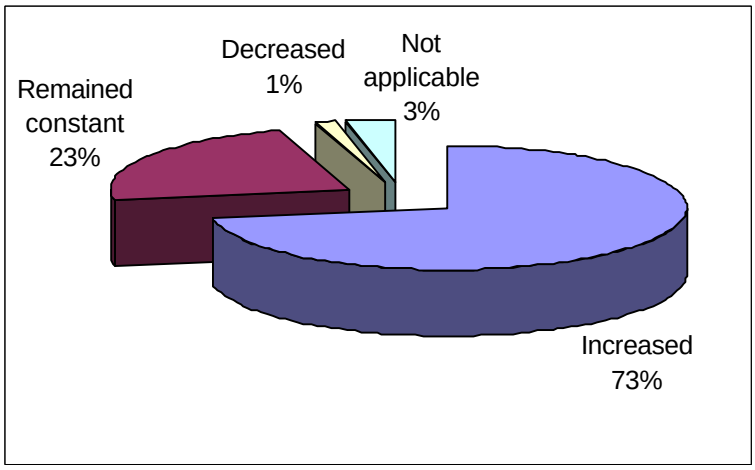
Even though most firms are connected to the Internet, not everyone within a given firm has access to the Internet. For those firms that are connected to the Internet, an average of 65% of the employees have an e-mail address, 42% of the employees have access to the World Wide Web from their own computer; and 42% of the employees have access to the World Wide Web from other computers. Table 2 provides the same results but with respect to the three categories of firms surveyed. Only a few employees working for contractors do have access to the Internet while a majority does in architectural and engineering firms.

TABLE 2: Percentage of employees that has access to these Internet capabilities.

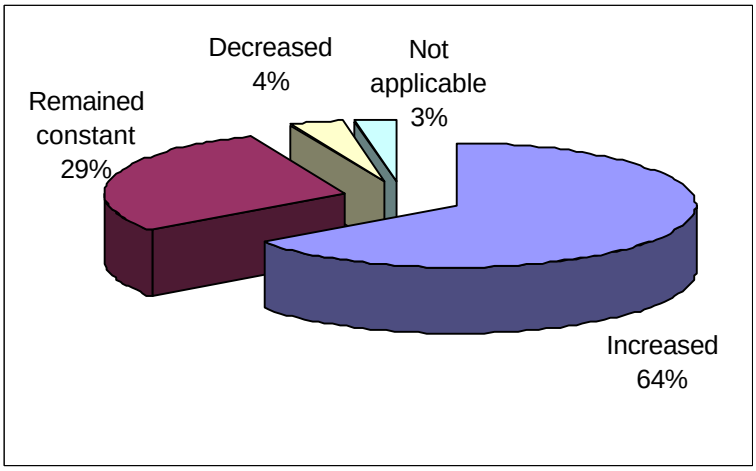
Categories of Firms	E-mail Address	WWW-access from own computer	WWW-access from other computer
Architects	70%	49%	50%
Engineers	78%	48%	46%
Contractors	28%	23%	15%

4.5 Information Technology

IT has come about very recently and has required significant investments from companies. Fig. 15 shows that the large majority of the respondents' companies have increased the information technology investment in the past two years and will increase the IT investment in the next two years.



In the PAST two years



In the NEXT two years

FIG. 15: Estimate of how the IT investment has changed and will change.

What motivates firms to make new investments in information technologies? According to the survey, many factors were found to be important in motivating firms to do such investments. Fig. 16 shows that five of the six motivations proposed were considered important or very important by more than 85% of the respondents. Only the desire to be in the vanguard of technical development did not fare as high as the others with 60% of the respondents considering it important or very important. Hence, many factors regarding efficiency, demands and competition are all considered important in initiating investments in information technologies.

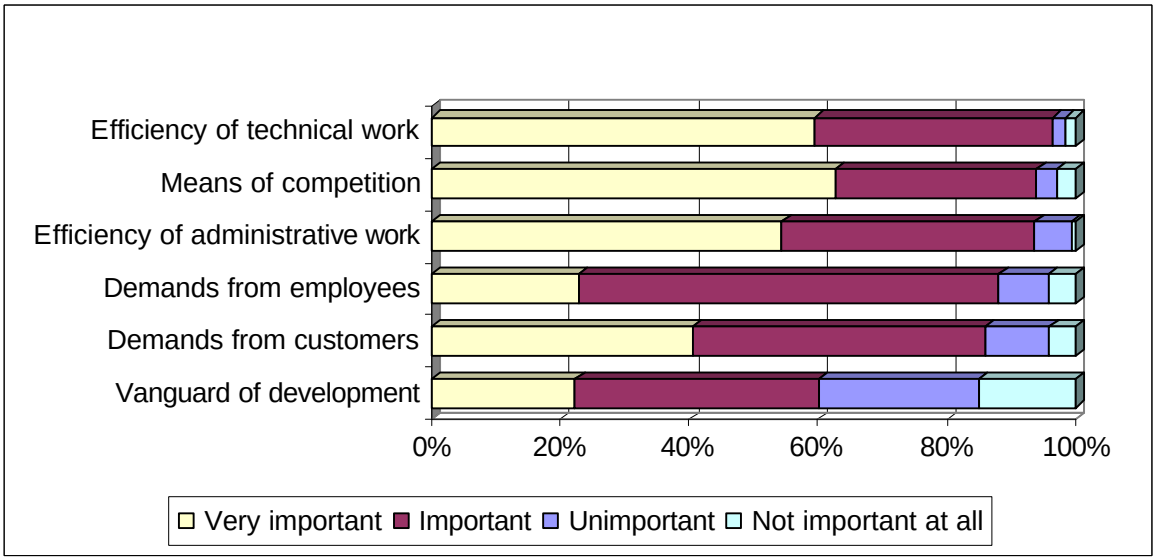


FIG. 16: Motivations for new IT investments.

The successful introduction of a new information technology depends very much on the receptivity of the staff. The firms of the respondents shine on that front since the staff of 82% of engineering firms, 70% of architectural firms, and 62% of contractors quickly accept or is actively involved in a greater use of IT as is shown in Fig. 17.

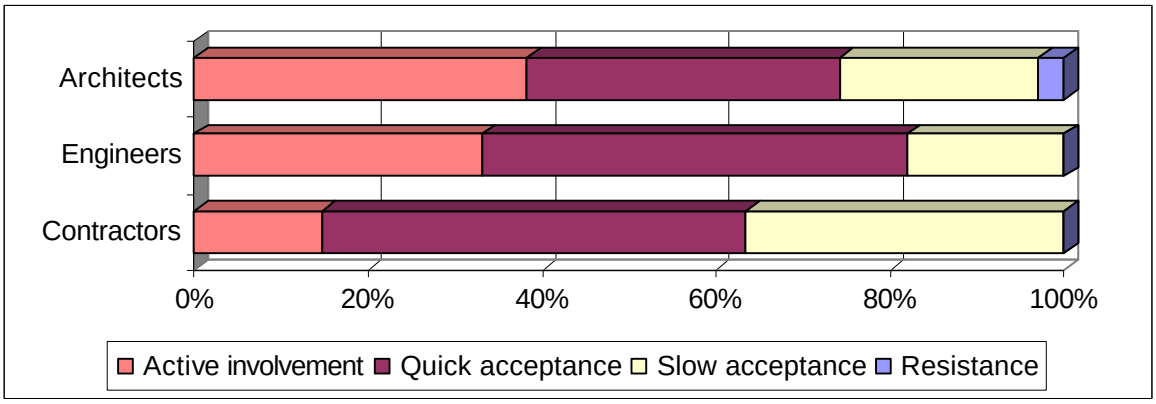


FIG. 17: Attitude of the staff to a greater use of IT with respect to the three categories of firms.

The introduction of information technologies is considered to have raised productivity in most areas as is shown in Fig. 18. General administration, design and project management are the areas for which productivity has increased the most while materials administration has largely remained unchanged according to the respondents.

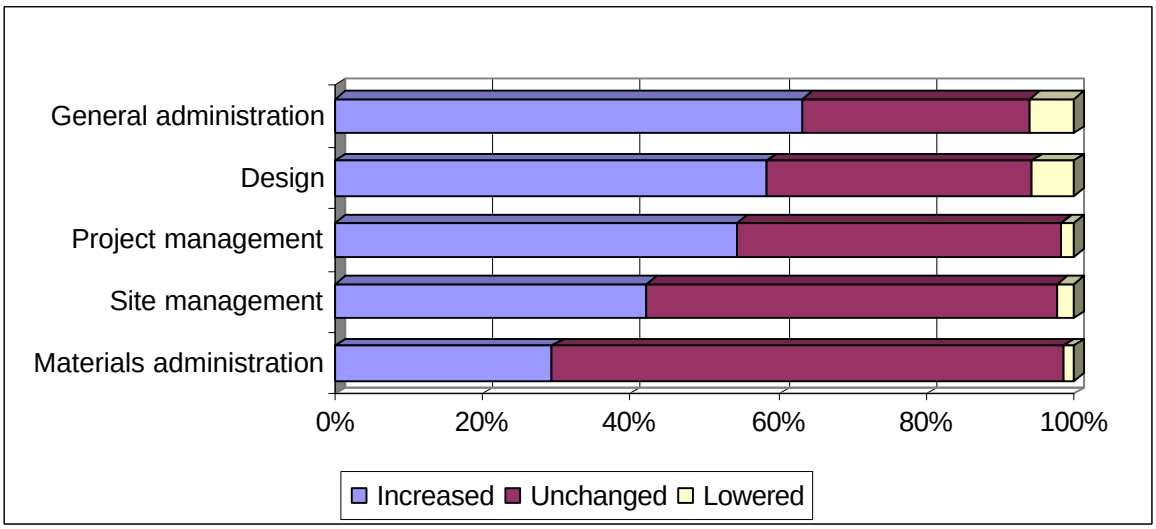


FIG. 18: Perception of the impact of IT on the productivity of business activities.

One of the objectives of the survey is to find how information technology has changed the design and construction process. According to the results shown in Fig. 19, these changes have been both beneficial and detrimental. On one hand, the number of mistakes in documentation has decreased, the number of construction errors has not changed or has lowered, and the quality of documents and the speed of work have both increased. On the other hand, the complexity of work, the administrative needs, the proportion of new operations and the costs of doing business have all increased. The benefits of information technology come at a cost.

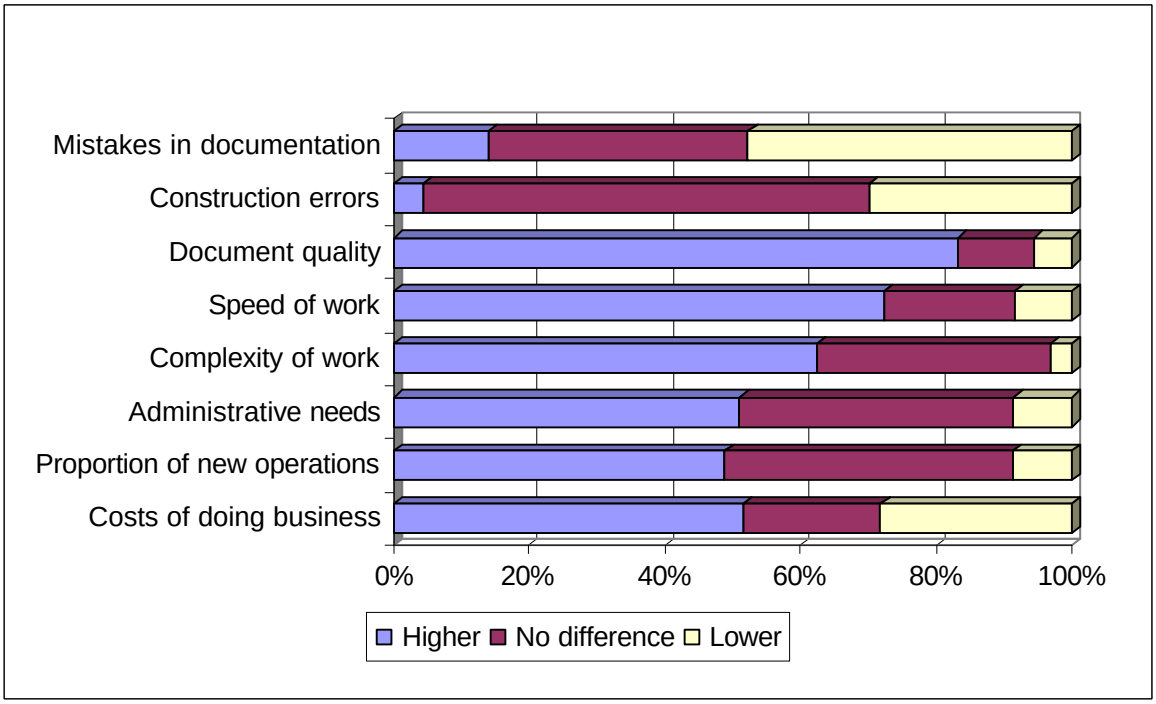


FIG. 19: Changes caused by the introduction of information technology.

The questionnaire had four questions where the respondents were asked to select the three most important statements for their firms among a set of statements and rank them. Their first option was given three points, their second one was given two points, and their third one was given one point. These cumulative ranking provide a good idea of what the respondents considered to be the most important statements. Fig. 20 shows the results of these cumulative ranking with respect to their plans for investing in and using information technologies

in the next two years. It is clear from these findings that the main area, by far, for future investments is computer-aided design (CAD). This is a major investment cost since almost every architectural and engineering firms surveyed depend on CAD to do their work. The next areas are the Internet, accounts systems, cost control systems and project management. Very little investments are planned in the areas of product models and virtual reality.

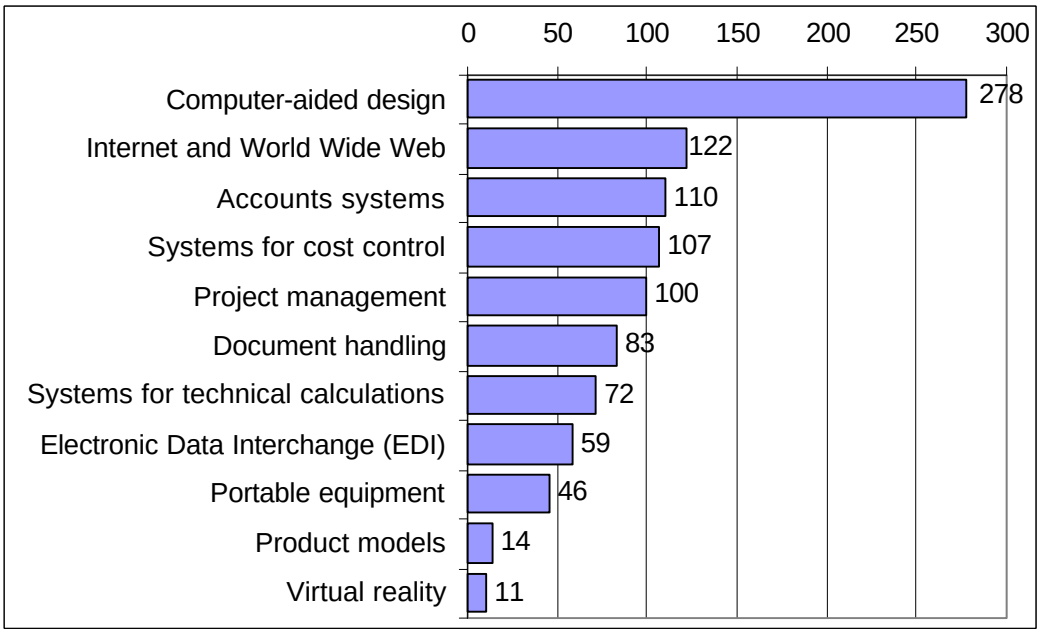


FIG. 20: Future plans regarding investments in information technology.

Fig. 21 displays the main benefits achieved by the adoption of IT. The main advantages provided by a greater use of IT are better quality work, work done more quickly, better financial control, better communications and simpler and faster access to common data according to the respondents. These results correlate well with the findings shown in Fig. 19. Paper-less office which was advertise with the advent of IT seems to be a myth since almost no respondent selected that potential benefits. Telecommuting and staff contentment are also not considered as important benefits by most respondents.

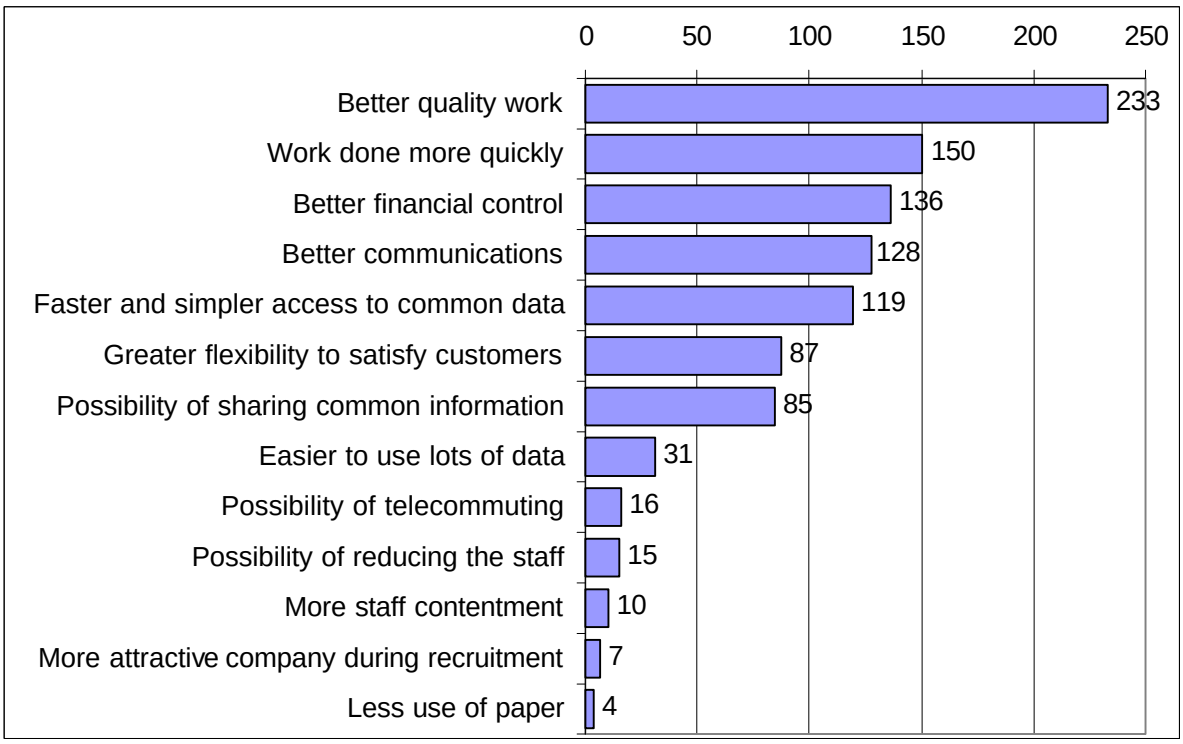


FIG. 21: Benefits of information technology.

The three main obstacles to greater use of IT in the firms surveyed are the continual demand for upgrading hardware and software, high investment costs and a greater know-how required from the staff. The lack of standards and co-ordination problems is not considered an important obstacle to the use of IT. Fig. 22 shows the ranking of the set of obstacles proposed.

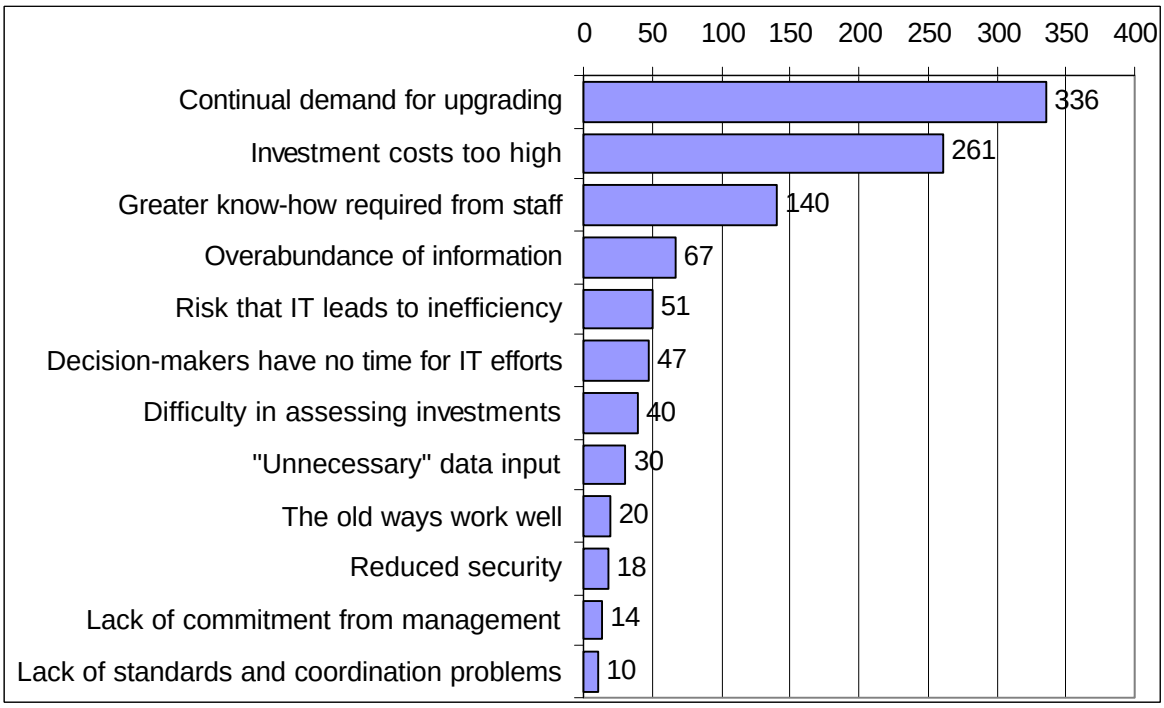


FIG. 22: Obstacles to a greater use of information technology.

4.6 Research Directions

The respondents were asked to select the research topics they considered the most important for their firms. Fig. 23 shows the set of topics proposed along with their respective score. The results show clearly that the firms surveyed need a way to integrate their operations using computers since the two related topics computer-integrated construction and standard format for the electronic exchange of product data have both scored high. Two other topics that have scored high are concerned with design support. Design tools that would allow concurrent design and support conceptual design are deemed necessary. On the other hand, most of the firms surveyed do not see the needs for robot-construction and virtual reality applications. There are some variations with respect to the categories of firms surveyed. The three most important topics selected by architectural firms are "Computer-integrated design and construction", "Preliminary conceptual design support", and "Concurrent design support" in that order; while engineering firms selected "Concurrent design support", "Computer-integrated design and construction" and "Standard format for data exchange"; and contractors selected "Computer-integrated design and construction", "Internet-based tendering", and "Standard format for data exchange".

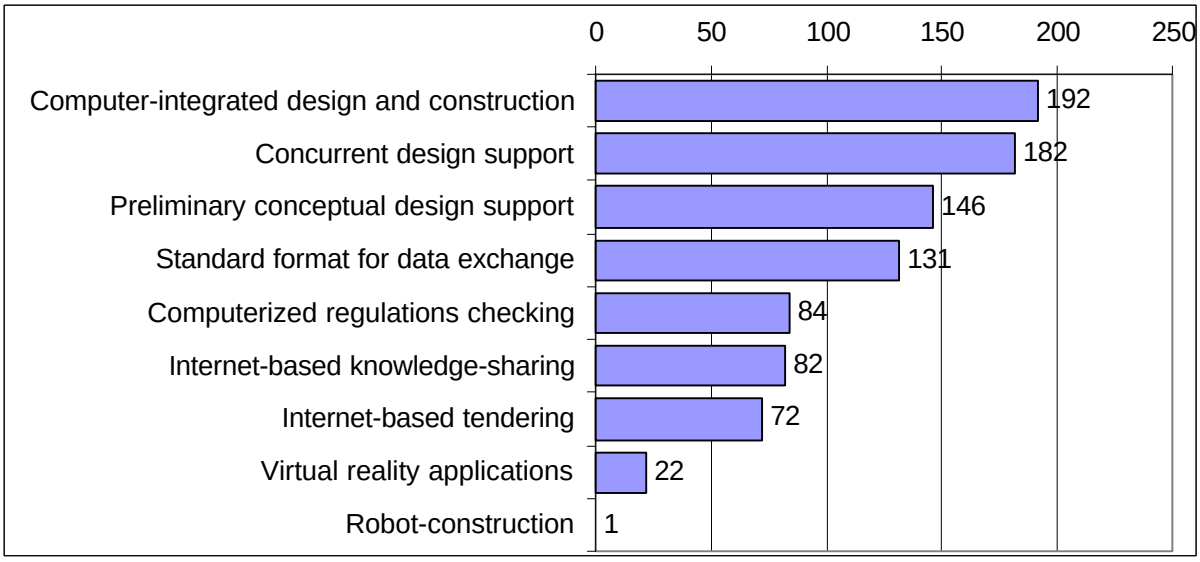


FIG. 23: Research needs identified by the industry.

Therefore, according to the firms surveyed the most important area of research for the industry is the implementation of computer-integrated design and construction, which integrates data and communication among firms. With such an environment, A.E.C. firms would exchange much more information in digital forms. This area of research is currently being addressed by a major international effort, called the International Alliance for Interoperability (IAI), which has developed a standard called the Industry Foundation Classes (IFC's). This standard provides specifications for a set of standardised object definitions, which allows the transfer of information between software applications. This effort is well under way and its commercialisation is to be expected in the near future since several software vendors have already demonstrated software applications that can exchange information using its second release (Kiviniemi, 1999).

The next most important area of research is the development of new design tools that would let several designers work concurrently on a project and that would assist them in exploring many alternatives during the conceptual stages of design. These research needs concur with those identified by the Civil Engineering Research Foundation (CERF) in a report assessing the challenges of the industry for the future. The report states that, based on the results of a world-wide survey, computerisation and the improvement of design technology and practice are two of the most important areas of research for the industry (CERF, 1996). Much work is needed in this still largely unexplored and complex area of research. Improving design technology means the development of new design tools that help designers spend less time and effort on data collection, computation, and preparation of design documentation, and more on problem-solving.

5. CONCLUSIONS

Information technology represents a paradigm shift with respect to the transfer and management of information. This shift has come about recently and has occurred very quickly. The survey presented here was conducted at the end of 1998 and beginning of 1999 to determine the impact of this new technology on the workplace in the architecture, engineering, and construction industry. The respondents were executives and managers in the AEC industry from firms scattered throughout Canada with sizes varying from one employee to more than 2000 employees.

It is clear from the survey that information technology and computers are now an integral part of the day to day business within most of the AEC industry. Almost every single employee in architectural and engineering firms do work on a desktop computer. CAD software is used by almost every architectural and engineering firms to produce most of the drawings they generate. Many business processes such as bookkeeping, invoicing and specification writing are now almost completely computerised and the tendency is toward a greater computerisation of the remaining processes.

The firms of most respondents have adopted the Internet and are now using e-mails and the World-Wide Web on a daily basis. The remaining firms will inevitably adopt this new technology in the coming years if not months. Many firms even have a presence on the Web, and half of those which do not have a presence intend to do so in the near future. However, even though IT has been adopted by most firms surveyed because it provides quick and efficient means of exchanging information digitally, the majority of AEC professionals still exchange design information by means of paper drawings and specifications as they used to do prior to the advent of computers. It is a question of time before the various players get accustomed to this new mode of communication. The AEC industry was a little slower in adopting IT than other service industries that are more information intensive such as the communications industry and business services (Industry Canada, 1997), but this is understandable since the AEC industry tends to be risk avert and prefers to adopt a technology that has been proven. Technological improvement in this industry is usually driven by necessity rather than by the need to be at the cutting edge.

Adopting a new technology always involves significant investments. The great majority of respondents reported that their companies have increased their investment in IT in the past two years and that they will increase them further in the next two years. Factors such as efficiency, demands and competition are all considered important motivators to make new investments in IT. The majority of the respondents consider that the main area for investment in the next two years will be computer-aided design by far followed by the Internet and accounts systems. The staff is in general very receptive and even actively involved in the introduction of new IT solutions.

The advent of IT has been both beneficial and detrimental. According to the respondents, IT has raised productivity in most business processes and particularly in general administration, design and project management. The main benefits achieved by the use of IT is an increase in the quality of documents, an increase in the speed of work, a better financial control, better communications, simpler and faster access to common data as well as a decrease in the number of mistakes in documentation. However, the benefits of IT come at a cost since the complexity of work, the administrative needs, the proportion of new operations and the costs of doing business have all increased. Furthermore, the continual demand for upgrading hardware and software, the high investment costs and the greater know-how required from the staff are perceived as important obstacles to a greater use of IT.

What are the long-term research needs of the firms surveyed with respect to IT? According to the respondents, the two most important areas of research for the industry is the implementation of computer-integrated design and construction, which integrates data and communication among firms as well as the development of new design tools that would let several designers participate and work together on a project and that would assist them in the conceptual stages of design.

6. ACKNOWLEDGEMENTS

The survey was funded by Concordia University and its Faculty Research Development Program. The author acknowledges all the respondents who took the time to answer and return the long survey. This survey would not have been possible without the help of: Richard Drouin, Garrett Austin, Kene Meniru, Richard Tseng, and Philippe Brosseau. The author also wishes to thank Claude Bédard, Solange Richard, Thomas Froese, and

Sheila Anderson for having reviewed the survey.

7. REFERENCES

Bjork B.-C. (1999). Information Technology in construction: domain definition and research issues, *International Journal of Computer Integrated Design and Construction*, SETO, London, May 1999, Vol. 1, No. 1, pp. 3-16.

CMHC (1999). The Future of the Internet and the Housing Sector, CERF (Canada Mortgage and Housing Corporation) Research Report PE0317.

CERF (1996). Engineering and construction for sustainable development in the 21st century: assessing global research needs, CERF (Civil Engineering Research Foundation) report #96-5016A.

Doherty J. M. (1997). A Survey of Computer Use in the New Zealand Building and Construction Industry, *Electronic Journal of Information Technology in Construction*, Vol. 2 http://itcon.org, 13 pages [accessed on June, 1999]

Eastman, C.M. (1999). Building Product Models: Computer Environments Supporting Design and Construction. CRC Press. Boca Raton, Florida, U.S.A.

Erdos, P. (1983). Professional Mail Surveys, Robert E. Krieger Publishing Company. Malabar, Florida, U.S.A.

Futcher K. G. and Rowlinson S. (1998). Information Technology Used by Hong Kong Contractors, Proceedings of the CIB-W78 Conference "The Life-Cycle of Construction IT Innovation - Technology transfer from research to practice" (Bjork B.-C. and Jagbeck A., Editors), Royal Institute of Technology, Stockholm, Sweden, pp. 245-256.

Futcher K. G. and Rowlinson S. (1999). I. T. Survey within the Construction Industry of Hong Kong. 8th International Conference on Durability of Building Materials and Components, Volume 4 - Information Technology in Construction, CIB W78 Workshop, (Lacasse M. A. and Vanier D. J., Editors), NRC Research Press, National Research Council of Canada, Ottawa, Canada, pp. 2306-2315.

Howard R., Kviniemi A. and Samuelsson O. (1998). Surveys of IT in the Construction Industry and Experience of the IT barometer in Scandinavia, *Electronic Journal of Information Technology in Construction*, Vol. 3 http://itcon.org, 13 pages [accessed on January 13, 1999]

Howard R., and Samuelsson O. (1998). IT Barometer - International comparison of IT in building. Proceedings of the CIB Working Commission W78 Conference "The Life-Cycle of Construction IT Innovation - Technology transfer from research to practice" (Bjork B.-C. and Jagbeck A., Editors), Royal Institute of Technology, Stockholm, Sweden, p. 257.

Industry Canada (1997). Survey of Technology Diffusion in Service Industries. Published in May 1997, http://strategis.ic.gc.ca/SSG [accessed on August 5, 1998]

Kiviniemi A. (1999). IAI and IFC - State-of-the-Art. 8th International Conference on Durability of Building Materials and Components, Volume 4 - Information Technology in Construction, CIB W78 Workshop, (Lacasse M. A. and Vanier D. J., Editors), NRC Research Press, National Research Council of Canada, Ottawa, Canada, pp. 2157-2168.

O'Brien M. J. and Al-Biqami N. M. (1999). Survey of Information Technology and the Structure of the Saudi Arabian Construction Industry, 8th International Conference on Durability of Building Materials and Components, Volume 4 - Information Technology in Construction, CIB W78 Workshop, (Lacasse M. A. and Vanier D. J., Editors), NRC Research Press, National Research Council of Canada, Ottawa, Canada, pp. 2327-2337.

Samuelsson O. (1998). IT-Barometem - Uppbyggnad av en undersöknmg av IT-användandet I byggsektorn, Master Thesis No. 330, Dept. of Construction Management and Economics, Kungl Tekniska Högskolan, Stockholm, Sweden.

Statistics Canada (1999). "Canadian Population in 1998", CANSIM, Matrices 6367-6379. http://www.statcan.ca/english/Pgdb/People/Population/demo02.htm [Accessed on August 12, 1999]