Science, Innovation and Electronic Information Division

RESEARCH PAPER

ANALYSIS OF THE SURVEY ON INNOVATION, ADVANCED TECHNOLOGIES AND PRACTICES IN THE CONSTRUCTION AND RELATED INDUSTRIES, 1999

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The Science and Innovation Information Program

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

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

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

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

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

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

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

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

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

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

Preface

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

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

The 1999 Survey of Innovation, Advanced Technologies and Practices in the Construction and Related Industries is the first survey of the advanced technologies and practices in the construction sector. Four surveys of advanced manufacturing technologies were been carried out in 1987, 1989, 1993 and 1998; two surveys of the use of biotechnologies have been carried out in 1996 and 2000; and one survey of electronic commerce and technology was carried out in 1999 and one is currently in the field.

This research paper is the result of a joint 3-year collaborative project with the Institute for Research in Construction of the National Research Council of Canada and the Science, Innovation and Electronic Information Division of Statistics Canada. The broad objective of the project is to measure, understand and assess innovation, advanced technologies and practices of the Canadian construction sector with a view to developing new policies and programs.

As production processes in construction are significantly different from those found in the manufacturing sector, listings of advanced manufacturing technologies that are currently used were not considered to be appropriate descriptors. Consequently, a listing of advanced technologies and advanced practices that are specific to the construction sector was developed in consultation with industry experts.

The qualitative data from the 1999 Survey of Innovation, Advanced Technologies and Practices in the Construction and Related Industries was linked to the quantitative data from the 1997 Survey of Construction. For the purposes of this study, a series of indices were developed from the 1997 survey data and were used to augment the information available on the businesses that were surveyed by the 1999 Survey.

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Executive Summary

This report presents an analysis of the data gathered in the ***Survey on Innovation, Advanced Technologies and Practices in the Construction and Related Industries, 1999***. To provide some information on the financial impact of innovative practices on the companies that are "innovative", Statistics Canada provided a partial linkage to the available 1997 financial data. Through this analysis and based on a review of the relevant literature, we explore how innovation is defined and the current understanding of innovation processes in construction.

Two major questions are reviewed in this study:

- The first question deals with the homogeneity of the Canadian construction industry. Is it a reasonably coherent unit or a number of sub-sectors with distinct characteristics? We examine innovativeness of the industry, perceived obstacles to innovation and sources of information from the perspective of the size of various firms (large, medium and small) as well as various sub-sectors; contractors and specialty trades in residential, non-residential and engineering construction.
- The second question attempts to look at the competitive drivers in the industry. Do typical Canadian construction firms behave according to the current competitive advantage business model, i.e., seeking innovative approaches in response to threats or opportunities in the business environment.

Survey data always has limitations and our analysis is no exception. We do not have any time evolution of the measures of innovation or the financial information. The nature of the construction industry is that many tasks may be accomplished by employees, by sub-contractors, or a mix of the two. For sub-contracts, we do not have a clear picture of the labour versus material content of the expenditure.

A further difficulty is that "innovation" is an attractive but often loosely used term. Everyone wants to be innovative, but a critical view is that few of us bring truly new ideas and practices to our work. For the purposes of analysis, we have had to assume that the use of advanced practices implies innovation. This assumption is open to criticism, but without it, we do not believe that much progress can be made toward an analysis of the survey data.

Major findings from the analysis are as follows.

Descriptive statistics

Pretax operating margins: Contrary to common belief, in 1997 which is the only year for which financial data was available to us, residential contractors seemed to make on the average good margins, especially the larger ones. Moreover, large non-residential contractors tended to make more money than smaller ones, while large building trades firms tended to make less money than smaller ones. All trades and contractors tended to be profitable, except for the residential trade sector.

Innovation: Technology and business innovativeness increases with size: larger firms tend to use three times as many advanced technologies or business practices as small firms. For both advanced technologies and business practices, residential contractors lag significantly behind engineering and non-residential contractors.

Practices: The practices most often cited as sources of competitive advantage dealt with business and management issues (providing such advantage in 77% of the cases); the second most often cited practices as sources of competitive advantage dealt with issues related to information and communications systems (providing such advantage in 46% of the cases).

Obstacles: High cost was considered a major barrier to innovation by most respondents; lack of skilled workers is also a big concern, especially for residential contractors (but not for engineering specialty trade); lack of interest for innovations by clients was a significant issue for residential and non-residential contractors, while lack of in-house expertise was a problem for all. Restrictive codes and standards was seen as an obstacle by non-residential contractors.

Sources of information: Consistent with the results of most surveys on sources of innovation, suppliers are seen as major sources of innovations. Special to the construction industry, trade journals and newsletters are identified by almost all as the second most important source of innovations. Other important sources, in decreasing order of importance, include clients, general contractors, and consulting engineers. In general, residential contractors use less information and access fewer external sources.

Behavioural aspects

Motivations: What drives innovative strategic thinking? The analysis of the respondents' perception of the environment shows that rapid technological change, and, to a lesser extent, materials obsolescence, appears to be a clear impetus for engaging in innovative strategies. The only "negative" effect of rapid technological change is on the hiring of experienced workers, indicating that firms may delay hiring or substitute hiring for technological change.

Threats and opportunities: Competitive threats and consumer/competitor predictability have mixed effects on innovative strategies. For example, for smaller firms in particular, competitive threats tends to be positively associated with the hiring of experienced employees and negatively associated with the hiring of well trained new graduates, indicating that smaller firms tend to consider experienced employees as a competitive tool but that this is not the case for well trained new graduates.

Behaviour change: What innovative strategic thinking drives innovative behaviours (the actual use of technological advances or business practices)? The analysis shows that firm size matters, the most innovative small and medium firms having strong growth strategies (market share expansion, geographic expansion), and the most innovative large firms have product range expansion strategies, in addition to the strategies shared by the most innovative firms of all sizes (hiring well trained new graduates, developing the skills and knowledge of the employees, using multi-skilled teams, improving technology practices/capabilities, developing proprietary technologies). The analysis shows also that industry group matters, confirming the heterogeneity of the construction sector: Globally, the most innovative trade firms working in the residential and non-residential sectors display strong technology, human resource, and marketing strategic thinking, while the most innovative trades firms serving engineering construction display mostly technology strategic thinking. All the most innovative contractors, residential, non-residential and engineering, display strong technology strategic thinking; in addition, the engineering contractors display human resource strategic thinking, and the residential contractors display marketing strategic thinking. Noteworthy is the fact that there is a strong association between technology innovativeness and business innovativeness: an innovative firms is generally innovative in technology and in business at the same time: innovativeness tends to be a culture which permeates all the activities of the firm.

Business environment influences: As could have been expected, there is a strong linkage between the respondents' perception of the environment and their behaviours: more innovative behaviours in environments perceived to be subject to rapid technological change (except for engineering trades), and less innovative behaviours in environments with perceived competitive threats, especially for small firms (residential trades excepted). This seems to indicate that, except for residential trades, innovation is considered an added risk rather than a competitive advantage. And large firms with many suppliers (as well as engineering contractors with many suppliers) tend to be more innovative while small firms with many suppliers tend to be less innovative; this applies also to residential and non-residential trades.

Innovation and profit: The association observed between the 1997 pretax operating margins and the firms innovativeness is weak. Generally, the more profitable small firms tend to display slightly more innovativeness in technology and slightly less innovativeness in business than the other small firms while more profitable large firms tend to have higher technology and business innovativeness than the less profitable large firms. And, surprisingly, the more profitable residential and engineering trades tend to be less innovative than the less profitable firms in the same industry groups while the opposite hold for non-residential trades and non-residential contractors where innovativeness seems to be cost effective.

Obstacles: Globally, while market-related obstacles do not seem to affect innovativeness, both small and large firms tend to respond well to legal and regulatory restrictions, human resources constraints and other types of obstacles, the more innovative firms perceiving a higher number of obstacles than the less innovative firms (either the more innovative firms became so in reaction to the obstacles, or they are just more aware of obstacles than the less innovative firms). When looking at each industry group, market-related obstacles are also associated with innovativeness. While, for all the trades, the more innovative firms tend to perceive a higher number of obstacles than the less innovative firms (market-related obstacles, human resource constraints, legal and regulatory restrictions and other obstacles), this does not apply to the contractors where the innovative firms tend to perceive less obstacles than the less innovative firms (except for restriction-type obstacles for residential trades).

Synthesis and summary

Numerous overview studies of Canadian construction during the last 50 years, referred to in this report, create a picture of a very large, fragmented and heterogeneous industry. This analysis of corporate behaviour and of innovativeness provides numerical evidence of certain similarities between various industrial sub-sectors. It also shows significant differences between large and small firms and between different types of contractor and trade firms. Action that may be contemplated to encourage innovation or to remove certain obstacles will need to take this into consideration.

In general, findings of this report support the proposed conceptual model of entrepreneurial decision making regarding innovation. Construction in Canada does appear to undertake innovative practices in order to support its competitive behaviour but additional longer-term evidence is required to confirm these findings. Current use of such practices was found to be low but poised to grow in the future. It is possible that construction firms in Canada have the same business strategy characteristics as other business enterprises but have been much slower in coming to terms with the new reality of intense global competition based on knowledge and innovation.

Introduction

Knowledge and understanding of the innovation process has been evolving and improving with time, to a great extent promoted by increasing global and local competitive forces. Domestic and international competitive pressures are increasing on all sectors of the economy to deliver ever-greater value to the customer, mostly through innovation. This also applies to the construction industry which represents an important share of the national economy and influences the effectiveness of overall wealth creation. To achieve a better understanding of the construction industry, Statistics Canada in collaboration with the National Research Council of Canada undertook several surveys to measure in a more systematic, quantitative manner the competitive environment of the construction industry, characteristics of various sub-sectors and the propensity of the industry to innovate.

More specifically, this paper presents the statistical analysis of the findings of the Survey of Innovation, Advanced Technologies and Practices in the Construction and Related Industries carried out by Statistics Canada in 1999 on a representative sample of general and specialty trade contractors. Through this analysis and based on a review of the relevant literature, we explore how innovation is defined and the current understanding of innovation processes in construction.

Two major questions are reviewed in this study:

- The first question deals with the homogeneity of the Canadian construction industry. Is it a reasonably coherent unit or a number of sub-sectors with distinct characteristics? We examine innovativeness of the industry, perceived obstacles to innovation and sources of information from the perspective of the size of various firms (large, medium and small) as well as various sub-sectors; contractors and specialty trades in residential, non-residential and engineering construction.
- The second question attempts to look at the competitive drivers in the industry. Do typical Canadian construction firms behave according to the current competitive advantage business model, i.e., seeking innovative approaches in response to threats or opportunities in the business environment.

We present results of our intensive analysis of available survey results and our search of published research made available to us by colleagues and collaborators. We believe that this study breaks new ground in Canada and internationally by looking at industry-wide survey results and by the application of modern statistical approaches to detailed qualitative information.

We feel greatly privileged to have been given the opportunity to participate in this approach to measure innovation in construction in Canada and we wish to thank the staff of Statistics Canada for their encouragement and support in the course of this study.

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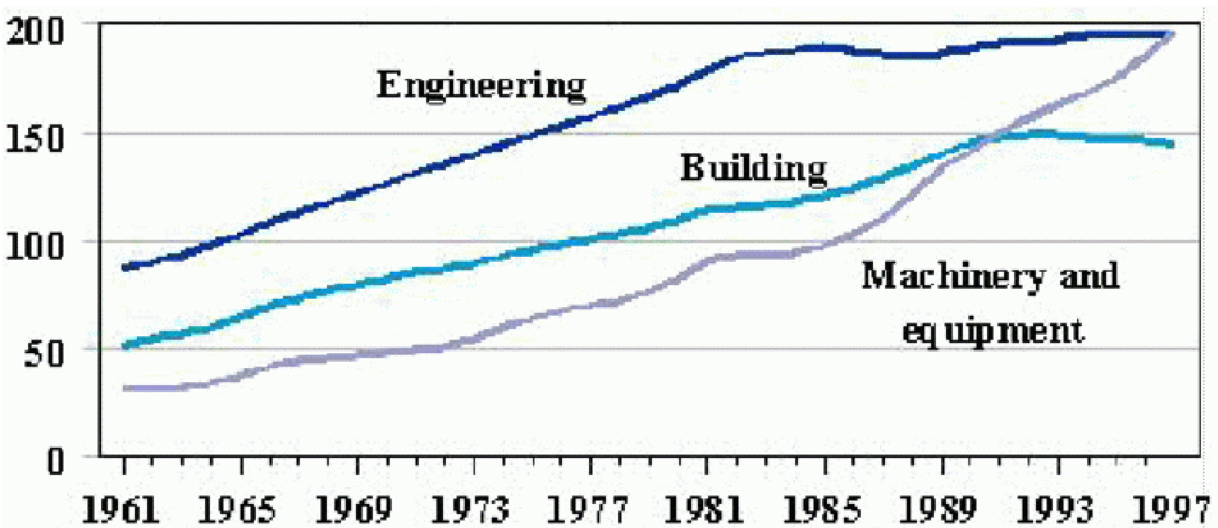
Chapter I: The Canadian Construction Industry

Issues in Canadian Construction

The Construction industry in Canada is very large (the stock increases by approximately $ 100 billion of new construction expenditure per annum), diverse and complex. Figure 1shows the net accumulated stock. Its effectiveness has a huge impact on the economic performance of the country and the accumulated inventory of constructed assets consisting of buildings, roads, bridges, plants, dams and utilities, is valued at some $ 2 trillion.

Figure 1. Net stock of capital, real value. Capital Stock (1986 $ Billions)
[Source: Industry Canada (1998) based on Statistics Canada , ***Flows and Stocks of Fixed Non-Residential Capital in Canada, Matrix 8590.*** **Note the corrected scale of the y axis.]**

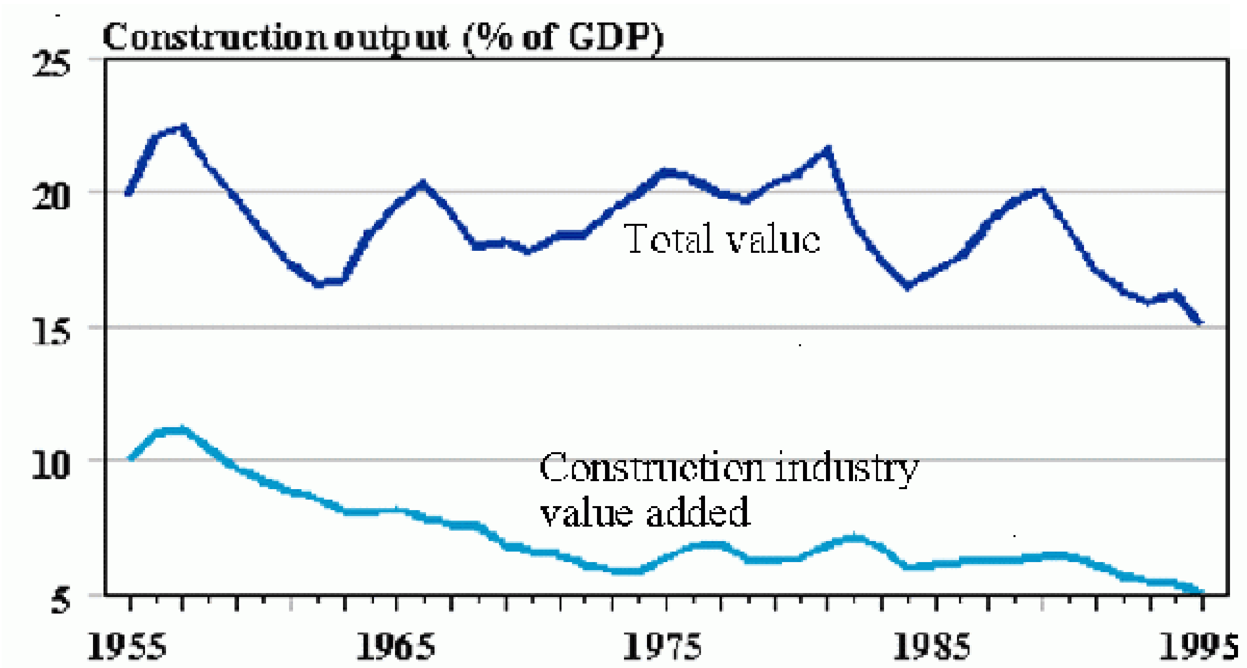


There has been flattening in the growth rate of engineering and non-residential constructed capital stock after rapid post-war expansion, while the demand for machinery and equipment continues to increase. Residential construction also slowed down as the demographic pressure diminished. This may be an indication of a fundamental change that is taking place in the structure of the construction industry of many industrially developed countries (Bon, 1994). Cyclical nature of the demand tends to make such long-term predictions difficult and there is always possibility of major natural disasters (hurricane, flood or earthquake) or destruction by warfare, creating massive destruction and then reconstruction. Under a more optimistic scenario, repair and renovation work is likely to grow as the percentage of the total output. Some (Carassus, 1999) suggest that the industry is now more in the business of optimization of the use of the existing stock rather than in the provision of new facilities.

By various indirect measures (Keys and Caskie, 1975, Seaden 1997, Industry Canada, 1998) such as; total factor or labour productivity, customer satisfaction (Barrett, 1998), R&D intensity (Revay and Associates Ltd. 1993 and 1999) or skill level, construction industry in Canada and other OECD countries has lagged behind other sectors of economy (Figure 2).

Over the years this has been a subject of concern of governments, industry representatives and other interested parties. Various reports have advocated a more rationalized regulatory system, reduction in the adversarial regime between various participants, better risk-sharing, greater investment in R&D or improved training of labour and management. There has been progress in some areas and retrenchment in others.

Figure 2. Construction output as share of GDP.
[Source: Industry Canada (1998) from Statistics Canada, *Gross Domestic Product*, Matrix 6627.]



A lack of innovation has been also tapped as one explanation for the above concern. Building practitioners and their clients have often interpreted all construction as inherently innovative because every construction project, new or repair, can be considered a prototype, at a new and different site and most often with a different owner. Thus, there is significant opportunity and tendency to do something new and/or distinct every time.

At the heart of the matter is whether the industry is truly innovative (i.e., Is it successful at adopting new processes and products?) This chapter explores this question in order to provide background and the analytical framework for the interpretation of survey results.

We begin by briefly presenting an overview of the construction process in Canada to put the survey in its proper context.

Next we provide a description of the particular features of construction projects that make them different from other manufactured products or services.

Since there is some debate as to what innovation is, particularly in the construction industry, our third section summarizes current definitions.

In our fourth section, we describe proposed general models of how innovation happens in a micro-economic context (within a business unit) and in a more macro-economic setting of the external enabling environment. This section concludes that innovation is dependent on complex national socio-economic, cultural and institutional regimes ("systems of innovation"), particularly important for the more traditional, regional-based industries such as construction.

After defining innovation and relating it to general models of innovation, our fifth section specifically examines the measurement of innovation in the construction industry. In this section we also discuss the issue of project-related research and innovation and their influence on the competitive behaviour of construction firms.

In this chapter, we present results of our extensive search of published research as well as of other related documents made available to us by colleagues and collaborators. Knowledge and understanding of the innovation process has been evolving and improving with time, to great extent due to the increasing global and local competitive forces. Accordingly, our review is focussed on more recent sources of information.

How Do We Build in Canada?

Industrial representatives asked to advise Statistics Canada/NRC regarding this survey as well as other reviewed studies (Industry Canada, Service Industries and Capital Projects Branch, 1998) make reference to numerous barriers to innovation in construction related to the acquisition methods, risk avoidance, liability and litigation and other systemic problems. To provide an additional dimension to the context for this paper, a brief description is made of the overall building delivery process in Canada.

Construction is a very old industry and its current practices are deeply rooted in our legal heritage and commercial/industrial traditions, mostly imported from England. In the pre-industrial and early industrial period significant owners (Crown, Church, builders-speculators) would hire directly all construction labour and purchase all supplies, to carry out the work under the on-site supervision of a master carpenter or a master mason. This tradition of construction work with "own forces" continues till now in Canada, particularly by utilities, mining and large manufacturing companies and by some government agencies. It represents a significant share of the overall construction activity.

In early 1800's, in England a new organizational form of construction was introduced (Winch, 1996 and 1999). An owner would retain an independent professional (architect or consulting engineer) to prepare plans (which would reflect his requirements) and to represent his interests during the construction phase. New business arrangement, a building contractor was created. He would be requested to tender a price for all labour and materials needed according to detailed drawings and specifications prepared by the professional. After the work was awarded, the contractor would assume full financial responsibility for the delivery of the complete project to the owner, when certified as satisfactory by the professional. With time, increasing complexity of projects caused further subdivision to general contractors with the overall responsibility and specialty contractors (foundation, mechanical, electrical, roofing) accountable for specific aspects of a project. The approach often referred to as design-bid-built, whereby an owner retains a professional team to complete the design followed by the bidding process generally awarded to the lowest cost tender leading to the actual building process, remains the most common procurement system in Canada, USA, UK and Australia**.**

There have been suggestions by industry groups that the system now incorporates the risk avoidance pattern by all the parties to the contract. This, in turn may be the greatest cause of the lack of innovative behaviour of contractors. The owner retains the design professional and passes on his risk of completeness of the design, accuracy of cost estimate and assurance of quality during construction. After the project has been awarded, the owner and the professional pass on the risk to the contractor of various site, labour and material uncertainties during building process. The contractor in turn undertakes all types of risk avoidance strategies to limit his exposure and to maximize his profit. All this has led to disputes, high level of litigation and fear of liability.

There is no doubt that there are real technical, financial or site-related risks connected with building a project in a most conventional manner with established products and procedures. These risks become amplified when new, innovative approaches are introduced. Yet the delivery system seldom deals in an explicit, balanced manner with risks and associated benefits. There is high concern with liability for specific errors or defects but when large, industry–wide problems occur, and they do, there is no concerted industrial action to fix and improve the performance. The customer is left "holding the bag" or a "leaky condominium", as is the case presently in British Columbia (Barrett, 1998).

Also, it has been often stated (APP, 1998; Economist, 2000) that this "traditional" method of procurement of constructed goods or services, provides the lowest price only in appearance since it creates numerous production and transaction inefficiencies and it may result in a higher cost than necessary. Nevertheless, it is now deeply entrenched in the public perception as "the best deal" and it is generally the mandated purchase method in the public sector. More rational, risk-sharing contractual arrangements have been introduced to Canada, particularly for large oil and gas process projects and they are gradually being accepted in other domains. In other countries, with different traditions and legal systems, other building processes have emerged, possibly more productive. It should be noted however that some of those include preferential buyer-supplier arrangements that could be viewed in Canada as collusive in nature.

Construction Industry Characteristics

Over a number of years there has been an international trend to "industrialise" construction through greater pre-fabrication, modularization, standardisation and other manufacturing-type production techniques. There is almost an implicit wish that if construction was like manufacturing, many of its quality and productivity problems would disappear and innovation would flourish. However, building projects have several distinct characteristics, which make them unlike any other industrial undertaking (ARA Consulting Group, 1997, Carassus, 1998; Carassus, 1999; Toole, 1998):

- Every construction project is located on a distinct site, subject to local environmental and climatic conditions, most likely built by a different work-crew. Even two standard subdivision homes of identical design are likely to be somewhat different.
- Local demands for constructed product are of extreme diversity. Industry responds to the occasional local/regional need for large hospitals, major airports, tunnels, and water treatment plants as well as to the more constant demand for single-family homes, office buildings or street improvements.
- Every new or renovation/repair project is truly a prototype. While some degree of uniformity has been tolerated in the past, with the increase in the wealth of Western industrial countries there has been an ever-growing trend in demanding custom solutions to satisfy real or perceived individual requirements. Some sources suggest (Flanagan et al., 1998) that this drive to customization as well as demands for higher quality can be achieved through the introduction of IT-supported production methods currently used in manufacturing.
- Constructed facilities tend to be very durable, lasting 25-50 years and longer. When obsolete, they are most often repaired, modernized and sometimes radically transformed to suit new requirements rather than disposed of and replaced with new, more typical for manufactured products.
- Aesthetic, safety and environmental design considerations are set not only by the builder or the owner but also by the community at large. Regulation and standards are more rigorous in construction than in most other sectors of economy.
- Construction is highly fragmented and firms tend to control only one of the elements of the overall building process. In manufacturing there is an attempt to integrate the whole process from market demand analysis, through production to distribution and sales. Construction companies have tried to achieve greater control of the production process through alternate delivery systems such as design-build, build-own-transfer (BOT) and other forms, which may allow them greater efficiency.

It can be concluded that the nature of construction site work is unique and significantly different in its characteristics from any other industrial sectors. On the other hand, production of building materials and sub-assemblies may be considered a form of manufacturing.

Defining innovation

With the increasing openness of the world trade and globalization there has been ever-growing interest in what makes firms truly competitive. Opinions on that matter have greatly evolved in the past twenty years and continue to be open to debate. Porter (1998) and others suggest that during the last twenty years Western companies have been responding to the Japanese challenge of superior quality and lower prices through continuous improvement in their operational effectiveness. Thus, re-engineering, lean production, investments in the information technology, TQM and other techniques of optimizing productivity and asset utilization have now all become parts of companies' efforts to remain/become competitive in the global market-place. Porter also suggests that continuous improvement in best practice utilization must now be considered a pre-condition to achieve profitability and that companies have to create unique competitive positions through integration of all their competencies. To have truly lasting competitive advantage they need to offer differentiated, value creating new products to their customers.

These competitive needs as well as spectacular achievements of the high-technology sectors of the economy have driven our interest in new idea generation and its implementation i.e. what is now being considered innovation. There is no generally accepted definition of innovation at the present time, however there has been noticeable convergence as to its principal characteristics.

To illustrate we present a sample of general definitions:

- "the process of bringing new goods and services to market, or the result of that process" (Expert Panel on the Commercialization of University Research ,1999)
- " A technological product innovation is the implementation/commercialisation of a product with improved performance characteristics such as to deliver objectively new or improved services to the customer. A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these" (OECD, 1997a)

Construction industry sources also show a variety of definitions:

- "application of technology that is new to an organization and that significantly improves the design and construction of a living space by decreasing installed cost, increasing installed performance, and/or improving the business process" (Toole, 1998)
- "the successful exploitation of new ideas, where ideas are new to a particular enterprise, and are more that just technology related – new ideas can relate to process, market or management" (Construction Research and Innovation Strategy Panel (CRISP), 1997)
- "Apply innovative design, methods or materials to improve productivity" (Civil Engineering Research Foundation, 1993)
- "anything new that is actually used" (Slaughter, 1993)
- "first use of a technology within a construction firm" (Tatum, 1987)

These definitions may display specific biases of different sources, studies and organizations, nevertheless certain trends and convergence can be observed. Increasingly, innovation appears to be viewed as a process that enhances the competitive position of a firm through the implementation of a large spectrum of new ideas. Recent business-level survey by A.D. Little (Brown, 1998) of factors that allow a firm to be innovative, involving significant sample of companies in 8 OECD countries incl. Canada, disclosed a much more comprehensive and complex image of the innovation process. What distinguishes the "leaders" from the "pack" is their ability to combine marketing, internal organization and technology. "Innovative products don't necessarily build business, often non-innovative products build business, what builds business is innovative companies"

The Innovation Process or How Does it Happen?

If there is some convergence towards a common definition of innovation, there is less agreement as to how new ideas are generated and eventually migrate into innovative processes or products. For the purpose of this review, four general models will be briefly described with a comment as to their relevance to the innovation in the construction industry. The concept of systems of innovation and their limits as to their national dimension are also examined.

- ***Technology push, science-based:*** The Second World War provided a unique implementation opportunity for science and technology. For the first time ever, with the total commitment to the victory by all warring parties and with the mobilization of national resources towards the war effort, new technology-based weaponry was rapidly developed from scientific principles/known technologies to operating products. Atomic bomb, radar, jet-propelled aircraft or mass production of Liberty ships were all developed through close collaboration of scientists, engineers and production personnel. In the post-war years, this linear model of innovation became the reference standard that is now deeply entrenched in various policy instruments of governments as well as in the public perception of innovation. It assumed that basic (pure) research followed by applied research led to experimental development and then to new products/processes. Thus, propensity to innovate of a country, industrial sector or a firm could be measured through its research intensity using several proxy indicators such as private or public expenditure on R&D, citation analysis or education of research-qualified individuals. Recent findings indicate that research endeavour may be more important as an indirect source of knowledge rather than a direct contributor to industrial innovation and that measuring the intensity of knowledge flows, levels of cooperation and effectiveness of technology diffusion may be more relevant, particularly for the traditional industries such as construction. In fact, to support this concept, some countries have established successful technology and best-practice diffusion networks dedicated to construction problems. Internationally (with the exception of Japan) there has been little formal R&D effort directed at construction (UK Department of Environment, 1996) and even less towards the on-site building problems, which has led some to conclude that it is a non-innovative industry .

- ***Market-pull, chain-linked:*** Studies of highly successful and profitable firms (Cooper, 1998) indicate very close ties to the customer base and innovation activity linked to the actual market opportunities. The challenge of arriving at innovative products/processes that are truly competitive i.e. meet clients' needs, have superior quality, reduce costs and present visible benefits, is met by tapping into the vast pools of existing knowledge. Close contacts are established with various knowledge sources and feedback loops are extensively used at different stages of development. Research tends to be viewed as an indirect contributor in this problem-oriented innovation approach. Kline (1985) introduced the concept as follows:

  > "While research in the physical and biological sciences has had an enormous impact on human societies and human lifestyles, ...research is not the direct source of innovations, and much innovation proceeds with little or not input from current research... The first line

> of reference for innovation processes...is not research but the totality of cumulated human knowledge....
>
> Any modern technical person beginning a task in innovation will not turn first to research. On the contrary, one turns first to the current state-of-the-art then to personal knowledge about the governing principles in the field. After that, one goes to the literature, consults colleagues, calls in leading experts. Only when all that does not suffice does one start research. Even then, many innovation projects would be not only unfeasible but would be literally unthinkable without the vast accumulated storehouse of human knowledge attained by several centuries of work by many, many workers in the appropriate fields of research."

This model with internal and market information sources dominant appears to be more representative of what takes place in construction firms. Recent data (Table 1) suggests that it is also valid for different industrial sectors.

- ***Innovation system, firm-centred networks:*** This is the macro/micro-economic model used as the theoretical basis of the Oslo Manual (OECD, 1997a) for measurement of innovation activity. It places the firm as the "innovation dynamo" (where economic benefits of innovation can be appropriated) at the centre of an enabling network of educational, communication, financial, legislative and market factors. It stresses the role of technology as a source of innovation while recognizing the importance of management change. Organizational innovation is known to play a key role but so far there has been very limited development of analytical methods that would allow measuring its impact. Model highlights the significance of strategic intent in a firm and of its market performance due to technologically new or improved products, Technology dissemination, access to sources of information, internal/external barriers and potential impact of public policies are all considered important. Innovation is expected to be "significant" and "new to the firm" (but not necessarily to the particular industrial sector) and bring enhanced performance benefits to the customer. It is generally initiated for competitive reasons, to lower the unit cost of production and/or to obtain greater market share. The focus is on objective performance of new products/process (which can be measured) rather than on subjective or perceived performance. Yet, development of new products or services that primarily appeal to customers' aesthetic perception or personal taste can provide firms with significant competitive advantage. OECD model was devised following extensive studies of advanced manufacturing and high-technology sectors of the economy and it may not be fully applicable of other industrial groupings. So far, there has been very little in-depth analysis of various innovation framework factors related to the construction industry. Current series of surveys on construction by Statistics Canada may provide some quantitative data to validate numerous assumptions made by OECD.

Table 1. Number of innovating enterprises considering the listed sources of information as very important, by percentage of firms. Source: Eurostat Data 1996.

	Architectural and engineering activities and related technical consultancy	Manufacturing	Services
Sources within the enterprise	55	47	51
Other enterprises within the enterprise group	45	25	40
Competitors	13	16	19
Clients	25	42	38
Consultancy enterprises	16	5	11
Suppliers of equipment, material, components of software	15	19	19
Universities or other higher education institutes	5	4	4
Government or private non-profit research institutes	4	3	3
Patent disclosures	1	3	1
Professional conferences, meetings, journals	28	8	15
Computer based information networks	14	4	11
Fairs and exhibitions	20	22	17

- ***Production systems:*** Implementation of new ideas happens through interaction between workers within organizational constraints and structures. Recent work (Amable et al., 1997) suggests that certain features of production systems may be particularly conducive to innovation while others tend to suppress it. The following factors and their consequences are considered as contributing to a positive climate for innovation:

  - Organizational flexibility (leading to) –> rapid response to changes and innovation
  - Employee reward structure connected to corporate profitability –> greater acceptance of technological changes
  - Good and safe work environment –> streamlined production systems
  - General policy of full-employment –> enhanced investment in productivity
  - Markets open to domestic/international competition –> changes in sourcing of supplies, optimization of work-processes, technological changes

  On the other hand, the following factors are considered to have detrimental effect on the innovation climate:

  - Work organized around strict functional definitions –> slow and difficult response to technological changes
  - Frequent lay-offs and technology related unemployment –> resistance to productivity enhancing initiatives
  - Salaries based on market rates or collective agreements –> little employee interest in quality or productivity
  - Acceptance of unsatisfactory work practices –> obsolete equipment not replaced

- Relatively high level of general unemployment –> investment in mass production
- National/regional barriers to trade –> reduced pressure to innovate

This model, based to a great degree on the intensity of employee's involvement and participation suggests that Taylor-type mass-production organization is not conducive to innovation and that new, more flexible work structure needs to evolve to encourage creation of new products or processes. It is believed that this methodological approach is of a particular relevance to the Canadian construction industry. No formal research has been done but it would appear that most of the listed detrimental factors are currently present in the industry. There are also a few of the positive elements, since shortage of skilled labour has encouraged investment in new equipment and open North American market has maintained high level of competition. Some of these factors can be observed in the analysis of Swedish construction industry (McKinsey Global Institute, 1995) that found high costs and low productivity, mainly due to fragmented and inflexible work practices, low level of domestic competition and very strict, performance-driven building regulations.

All these models are mutually complementary and useful attempts to explain this very complex, multi-dimensional activity, however none of the above appear to be a "best-fit" for the features of Canadian construction. Findings from the present survey should be a useful contribution to our understanding of the innovation process in this industry and allow a more rational debate on changes needed to enhance it (Seaden, 1997).

Summarizing Systems of innovation: It is now generally accepted that innovation activity takes place within a "system of innovation". This concept can be approached from the perspective of an industry (construction), technology (opto-electronics) or region (Silicon Valley cluster). Some suggest that high-technology industries are now truly globalized and that their innovation takes place within international alliances. While full analysis of systems of innovation is clearly outside the scope of this paper, for certain industries particularly of the more traditional type such as construction, a "national system" is a useful unit of analysis because of common culture, legal framework, education, customer preference, institutions and many other variables that impact innovation. Amable et al. (1997) identified amongst the highly-industrialized OECD countries four groupings of major national system of innovation: market-driven (USA, Canada, UK, Australia), government-regulated (France, Germany, Italy, Netherlands), socio-democratic (Scandinavian countries) and meso-corporatist (Japan).

For construction, there are significant differences between these groupings in the role of the government as the regulator or the principal customer, in the liberalisation of domestic markets, in labour relations, education and training, in the legal regime and in the methods of financing (Winch and Campagnac, 1995). To achieve consistent and meaningful context for Canada, our search of international sources has been mostly concentrated on information available from the "market-driven" countries.

Measuring Innovation in Construction

During the past 50 years there have many reports in Canada, the United States, the United Kingdom or elsewhere, dealing with various aspects of the industry, often discussing issues of research and innovation and making related recommendations. Yet, published literature search together with review of various reports and other documents from industry, government and academic sources disclosed relatively small number of attempts to look at innovation in construction through a systematic, quantitative analysis.

As previously stated, innovation measurement methodology is still evolving and the underlying theoretical models are still being tested. Innovation is a complex process that can only be examined through indirect, proxy indicators. Numerous indicators and measurement approaches have been proposed over the years but there is no agreement, which of those are valid and accurate. There is no doubt that the available numbers on R&D expenditure, patents issued, scientific publications or on the level of academic achievement of workers in a given sector have significance, particularly in the context of the technology push model of innovation previously described.

In the construction industry, with its highly discontinuous and fragmented structure, measurement problems are even more complex and some of the suggested indicators have not been field-tested. Nevertheless, they represent the current best approximation of our knowledge.

We will present our results first dealing with certain macro-indicators (productivity, cost of construction, share of global markets, R&D intensity) that are likely to measure innovation of all participants in the construction process. Then, we will look at some micro- indicators at firm or project level (who innovates and why, factors influencing micro-productivity). Finally, we will report opinions on project related research and how it may lead to innovation.

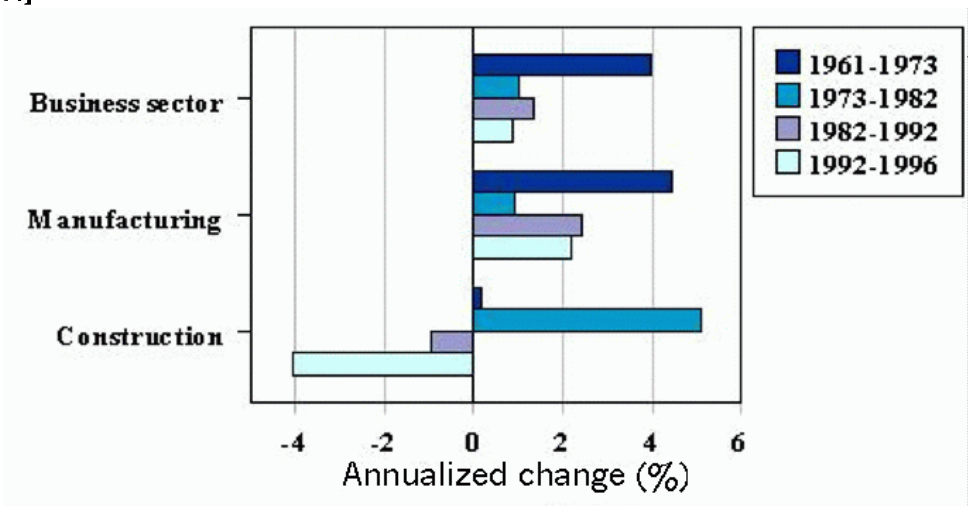
The following four approaches to measure the intensity of construction innovation through proxy macro-indicators are primarily derived from the “technology push” and “market pull” models.

Productivity: Current economic theories suggest that productivity gains arise to great extent through innovation. If that is the case, the productivity record of the Canadian construction industry for the past 50 years can be examined as a potential indicator of innovation. The Economic Council of Canada (Keys and Caskie, 1975) reports the following rates of growth in labour productivity during 1951-71 period measured in increased output per hour:

- Construction 2.9 %
- Manufacturing 4.0%
- Total Economy 3.2%

Recent data (Figure 3) show comparable trends:

Figure 3. Comparison of labour productivity growth rates. [Source: ; Industry Canada, 1998, from Statistics Canada, *Indices of Real Gross Domestic Product per Person-hour Worked of Persons at Work*, Matrix 7927.]



Direct observation would suggest that, for a long time, Canadian growth in labour productivity in construction has been lagging other sectors of the economy and that for the past 20 years it has been decreasing. There have been some attempts to explain this phenomenon through changes in the product mix given that the emphasis of the industry has moved from new construction, where advanced equipment and efficient production techniques can be introduced to repair/renovation work that is much more labour-intensive. However construction productivity growth in Canada has lagged other sectors even during the post-WWII years of 1951-71, with intense new construction activity. Experience from other countries (OECD, 1992) comparing compound annual growth rates in labour productivity for periods 1970-1985 and 1985-93, shows similar results. Some have recorded negative growth (United States, United Kingdom, Austria, Australia) during one of the periods. On the overall, European countries increased their construction labour productivity at an average rate of 0.9% during 1970-85, which was less than in other industries and there as well no obvious correlation between the product mix and productivity could be seen.

Research (Bowlby and Schriver, 1986) indicates a variety of problems with productivity measurement:

- Total factor rather than labour productivity may be a better indicator of innovation. Labour productivity may not be linearly or positively correlated to total factor productivity.
- There may be statistical problems with various price adjustment "deflators" that attempt to normalize the productivity data over a significant period of time.
- There has been product-mix and quality changes in construction output which apparently are not accounted for.

Nevertheless, various adjustments do not appear to be able to fully account for the long-term low productivity and its more recent further decline. There is sharp contrast between industry views that it is productive and statistical evidence as well as some owner's views (Flanagan et al., 1998) that most of construction firms are not performing at a satisfactory level. Looking at the productivity as an indicator, evidence would suggest that construction industry is not as innovative as other sectors of economy and that its propensity to innovate is declining.

Cost of construction: Innovative industries have been able to deliver to their customers, goods of increasing quality at reasonable price. Hence, price performance of a national industry could possibly be viewed as an indicator of performance of its system of innovation. There have been several studies that attempt to compare costs of construction in major industrial countries. Direct comparisons at market prices show large differences and are not very useful because of wide variations in labour and material costs, regulatory standards, practice and specifications. Two recent studies try to adjust for some of those and for the currency exchange rate differences using purchase price parity (PPP) mechanism. One of the studies (Technopolis.IPRA, 1995) shows the following (partial) ranking in cost performance:

Japan	1
France	2
Germany	3
UK	4
USA	5

Another (Langston and de Valence, 1999), using different methodology, arrives at reasonably similar order:

Germany	1
UK	2
USA	3

Relative competitive position of Canada is not known and differences in the national costs of major industrial countries, after adjustments, do not appear to be very significant. There may be larger costs differences between countries in the public works area (France and Germany being ahead of others) than in the buildings sector. Over the years there have been references in the popular and semi-technical press that Canada's construction cost performance is falling behind other countries. Available data is not conclusive enough to justify such statements or to allow relative cost performance to be useful as an indicator of innovation.

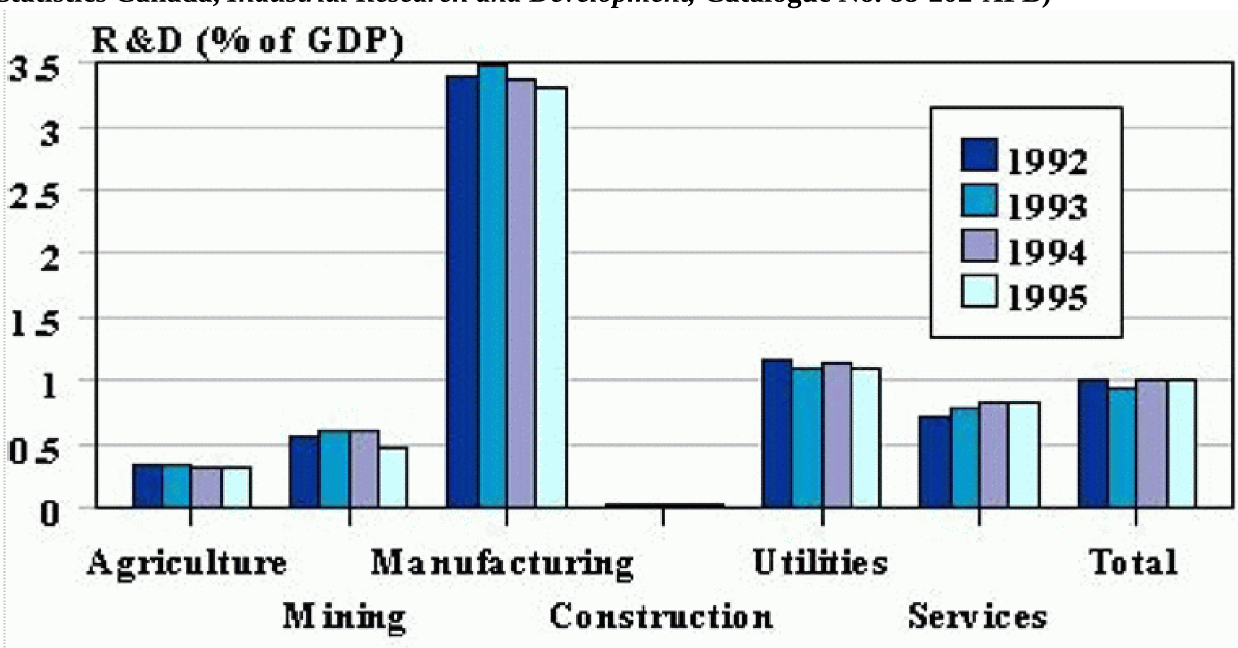
Global Market Share: In many products and services, global market is the place where true innovative solutions and competitive advantage can be demonstrated. Construction companies compete not only domestically but also internationally for a share of a multi-billion global market. Since they often bid on the same project under common physical, labour and material constraints, it could be expected that the most innovative firm would win. Hence, relative global market share could be a candidate as an indicator of innovation.

Analysis of this market (U.S. Department of Commerce, International Trade Administration, 1989) shows a complex picture of various sub-markets, with different competitive characteristics. Conventional, labour intensive projects are now mostly carried out by the national companies or by low labour cost countries, particularly if tendered on a price basis. If and when technical expertise is more important, construction firms tend to operate in an EPC configuration (engineering, procurement and construction) either through a joint venture with consulting groups or through an in-house fully integrated operation. However, most of large construction projects located outside the industrially advanced countries require some form of capital financing and the ability to provide funds at attractive conditions is generally considered as the most critical factor of international success. Many countries offer various forms of export aid to their national companies through tax credits, risk insurance or preferential financing rates. Since construction export statistics present an aggregate picture, it is impossible to distinguish between projects awarded to companies because of their excellence and innovativeness from those where the level of financial assistance made the difference. Hence, relative share of international construction market may indicate that the industry in some countries is more innovative but it may also mean that they have more creative financial arrangements.

R&D Intensity: There is large amount of measurement data on formal R&D activities of Canada and other countries. It is generally presented in the form of inputs (expenditures on R&D, who paid for it and who did it) with less precise quantitative output information on the type of research performed and its purpose.

Construction R&D activity is much less than in other industries (Figure 4):

Figure 4. R&D as a share of contribution to real GDP, by sector. [Source: Industry Canada, 1998 from Statistics Canada, *Industrial Research and Development,* Catalogue No. 88-202-XPB)



During the period 1992-98, based on surveys (Revay and Associates Ltd., 1993 and 1999), overall expenditure on construction R&D activity in Canada (in current $) declined by some 15%. Total R&D expenditure as a share of construction GDP is estimated at 0.01% in 1998. Most of Canadian research was done by public sector and academia, with spending by consultants and contractors going down more than average, from $4.25 million in 1992 (3.1% of '92 total) to $2.6 million in 1998 (2.2% of '98 total). No information is available on how much of R&D work was related to the building process.

In the United States, construction R&D survey (Civil Engineering Research Foundation (CERF), 1993) indicates for 1992 a total expenditure in the range of O.5% of annual revenues of the industry. The distribution of funding sources was:

Federal	63%
Industry	16%
Universities	12%
Non-profit	4%
State	4%

An approximately equal amount (35%) of effort was dedicated to applied research as to development, 14% to basic research, 12% to demonstration and 2.6% to "innovation" defined as "application of innovative designs, methods, or materials to improve productivity". Main program areas were:

Geo-environmental/Water resources	22%
Energy	20%
Materials	16%
Structures	12%
Construction	7%
Infrastructure	6%

The "Construction" program category included some research topics of direct interest to contractors but so did several other program areas, hence it is impossible to determine the level of activity that could be related to the actual building process. Industrial sponsored work was mostly concentrated in the materials area (48%) and was of the development type (56%). The survey did not provide details on research work carried out by contractors but reported a general perception of under-reporting of civil engineering R&D and innovation undertaken by consultants and builders, because "new methods, equipment and techniques are developed to complete work on hand" and are not identified as explicit budget items. Most of technology is perceived as flowing to the construction industry embodied in equipment or materials (Figure 5; OECD, 1997b), confirmed by data from other sources.

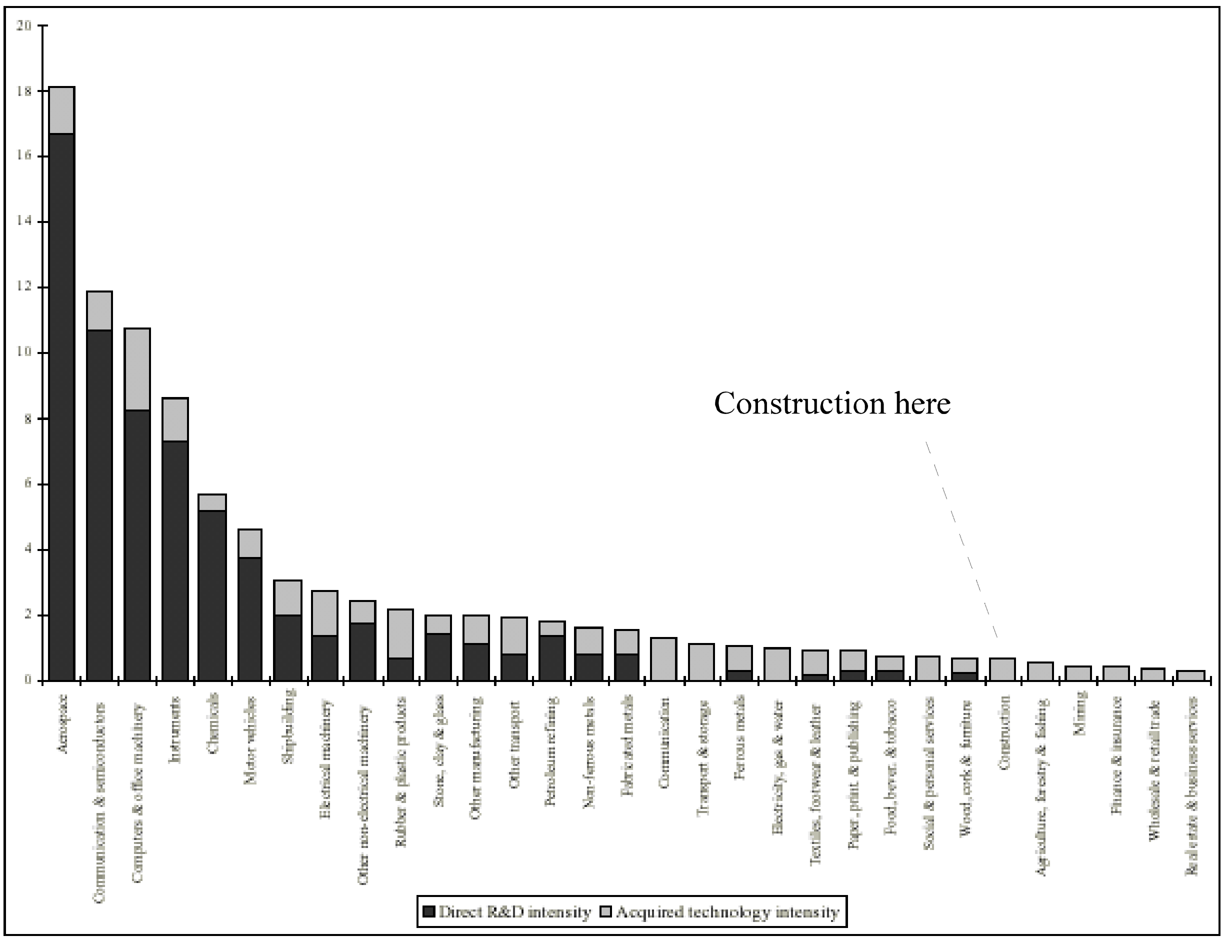
Analysis of R&D activity in the UK (Technopolis.IPRA, 1995 and Department of Environment, 1996) indicates a somewhat different picture. Industrial funding exceeds public sector investment and it represents 60% of the total in 1994, of which 10% is by the construction business sector itself and the balance by supply industries (chemicals, electrical and optical, machinery). Total R&D expenditure as a share of construction GDP was 0.5% in 1993, having fallen down by more than 50% from 1987 and being estimated as lower than most European countries. UK contractors invested 20 million pounds in 1994 in R&D, which represented 0.06% of their annual revenues. A survey of the UK building sector also disclosed evidence of under-reporting of research and innovation in financial reports and a belief that there is significant project related research activity that is not being accounted for.

The above surveys were significantly different in their methodological approaches as to what to include/exclude as construction R&D and how to collect the statistical data. This makes any type of comparative analysis very difficult.

Who innovates and why from the viewpoint of firms or projects: There is limited quantitative information on the actual innovation activity in construction. The following four referenced studies of innovation at a micro-economic level are more closely related to the firm-centred view of the innovation process, while the two Canadian survey studies appear to be based on the production systems view of innovation.

- Pries and Janszen (1995) reviewed 290 innovations introduced to the Dutch construction practice during 1945-1992 period with the following findings:
  - Most intense innovation activity took place immediately after WWII with a decline during the 60's and an increase from late 70's.
  - Innovators, particularly in process area tended to be smaller enterprises, larger companies focussing on product innovation.

Figure 5. Embodied technology flows in the United States, 1993. Source: OECD (1997b)



  - Initially, most of innovations were developed inside the enterprise however since 1980's collaboration with others has become important (over 60% cooperate with two or more firms)

- Approx. 40% of innovations originated from other industrial sectors (chemicals, metals, machinery, electronics) and over 80% came from the suppliers. Attribution to various initiators appears as follows:

Table 2. Initiators of innovations in Dutch construction. Source: Pries and Janszen (1995).

	All innovations (%)	Process innovation	Product innovation
Contractor	**7.5**	**14.6**	**2.9**
Supplier	**72.4**	**56.2**	**82.7**
Architect	**0.9**	**2.2**	**0.0**
Consultant	**11.4**	**16.9**	**7.9**
Miscellaneous	**7.9**	**10.9**	**6.5**

- Slaughter (1993), examined 34 innovations related to the stressed panel construction, primarily used in residential construction with timber framing. Stressed skin panels, which consist of a plastic insulating core between different types of facing material, are used in building construction to provide a continuous external thermal barrier. They are generally pre-manufactured and require special care during assembly to maintain the overall thermal and/or structural integrity. Interviews were conducted with seven companies that manufacture stress panels and six typical construction companies in different locations of the United States. This research has led to several conclusions that may have more general application:
  - Identified innovations dealt primarily with different methods of assembling and connecting the panels or installing residential services (water, power, heating)
  - Builders were the main source for 80% of identified innovations, manufacturers accounted for the other 20%. Builders were able to innovate because of their experience in actual installation of panels under different site conditions and integration with other building sub-systems.
  - Builders identified 70% of panel-related innovations and all connection ideas, but manufacturers were interested in commercializing primarily the panel-type innovations.
  - Builder’s prime motivation to innovate was to avoid costly delays because of special field assembly problems. Actual cost of all innovations was a small fraction of the potential additional cost. The solutions to site problems were willingly shared in the industry and became common practice.
  - Builders had interest and knowledge in innovations that integrate various components and ensure the long-term performance of the overall system, while manufacturers were more interested in innovations that were likely to meet general market needs.

- Nam and Tatum (1992), examined in detail 10 major projects identified as innovative by more than two authoritative professional publications in the U.S. This diverse sample consisted of three buildings and seven heavy construction projects, ranging in cost from $1.6 million to $350 millions, distributed across seven states. Researchers interviewed more than 90 construction professionals involved in these projects in order to clarify some key questions in construction innovation: what is the role of the client and are they inherently technologically conservative as well as what is the relationship between project related technological challenges and innovation. Some interesting perspectives were uncovered that contradict common North American construction attitudes:

- It is generally accepted that "To be innovative you have to have clients in the first place" i.e. construction innovation starts in response to owner's particular demands. As previously discussed this may be a particular feature of the construction industry, since other business sectors innovate in an attempt to anticipate customer's needs and to gain competitive advantage. When the 10 projects were examined, at least five clearly showed that by taking a variety of initiatives such as offering alternative available technology, lowering significantly expected cost or using advanced expertise in concrete construction, designers and contractors were able to strategically influence owner 's demands thus reversing the conventional belief.
- It is also widely believed that owner 's demands are always technologically conservative. This perception is than translated into a general climate of ultra-conservatism in all aspects of construction process, typical for North America. Research into attitudes of home buyers does suggest very strong desire for traditional solutions, which may be a significant inhibitor of technological innovation in this sub-sector. However, in the sample under study, the majority (seven out of ten) of owners including a public utility displayed a positive and progressive attitude towards innovative ideas as long as their principal needs were met.
- What comes first on a construction project, a problem or the technological solution? It is a fundamental assumption in a project environment that problems arise first and solutions/innovations are then found. In fact two distinct categories of innovation were identified; "problem-leads-solution" (in three cases) and "technology-guides-problem" (six cases) when a firm has been developing incrementally particular expertise and then applied it to a new project. It would appear that pre-existing technological can anticipate and shape the nature of problems.
- Another common belief is that to innovate, construction industry adopts or adapts ideas from external sources: manufacturing industry, government, academia or foreign countries. Thirty key ideas were identified in the ten projects originating from thirty-two sources (note: 4 French ideas were included under previous projects). It appears that most of innovation came from within the industry, some adopted from other countries. No direct influence of university or government research was found (Table 3).

Table 3. Sources of innovation in construction in the USA. Source: Nam & Tatum (1992).

Sources	Specific source		Total
Previous projects			**14**
	Designer's previous projects	**11**	
	Contractor's previous work	**3**	
Existing technology			**13**
Inventions			**2**
	By designer	**1**	
	By project team	**1**	
External sources			**3**
	Other industry (oil drilling)	**2**	
	Foreign (German, French)	**1 (5)**	

- Toole (1998) undertook a survey of 100 small- and medium-size builders in order to look at motivators/inhibitors of innovation in the residential sector. It was found that early adopters of innovative ideas are missing large amount of information relevant to their decisions. At the same time there is a general belief that there are no compensating economic advantages to innovative products/processes since they have been known occasionally to fail and thus are resisted by the home buyer. Hence, builders seek very convincing proof that a new product provides a much higher performance when compared to the existing practice. "…most builders feel that building innovations are guilty until proven otherwise". Under those circumstances what causes some home building firms to adopt less well known technological innovations? Many hypotheses were tested using statistical analysis: firm's size, number of years in business, market segment (luxury vs. starter), positive managerial attitude, number of employees gathering information, professional backgrounds of those involved in innovation decisions. It would appear that it is the ability to tap into many trusted sources of information (other builders, in-house testing, subcontractors) about high uncertainty innovations or less trusted (architects, manufacturers, homeowners) for low uncertainty products, that allows firms to proceed. Hence the conclusion that firms able to reduce uncertainty about new products through appropriate gathering and processing of information are more likely to be innovative.

- There is a general assumption that productivity is related to innovation. Two surveys of factors affecting construction productivity have been carried out in Canada during the past 15 years (Construction Industry Development Board, 1984, Hanna and Heale, 1994). First survey had 200 responses from medium- to larger-size general and specialty trade contractors as well as from EPC (engineering-procurement-construction) firms. Second survey had a sample of 58 responses from small- to medium-size firms representing the full spectrum of construction activities. While the two surveys did not use fully comparable questionnaires, there is reasonable convergence in ranking of factors that may impair construction productivity:
  - Common measure of productivity in construction is the time spent completing some standard task. It may be reasonably assumed that respondents used this definition and not the macroeconomic ratio of total inputs of labour and materials to output.
  - Project conditions such as seasonal variation in weather (hot or cold) significantly impact productivity.
  - Labour related factors were considered important. Restrictive union rules, lack of motivation, foreman supervision were some of the specific issues.
  - Poor site management practices ranked high as a negative factor. Ineffective communication among owners, designers, contractors, suppliers and labour; change orders; availability of clear working drawings and specifications; frequent equipment breakdowns and materials management are some of the more significant management issues identified.
  - Education and training was not considered a significant productivity factor although lack of skilled tradesman or trained supervisors received middle ranking as to its importance.
  - Government role in inspection or regulation was not perceived as a negative factor.

Project-related research and innovation

Discussion which follows is based on the current consensus (OECD, 1997a) that it is the business firm which is the primary locus of innovation. It is at that level that decisions are made to invest in innovative practices or equipment in order to achieve a competitive advantage. It is also where benefits of such investment can be appropriated over an extended period of time.

These concepts of innovation related decision making have been developed over the last decade and have not been systematically analysed in the context of the construction industry. Hence, observations which that follow should be considered tentative.

It should also be noted that the Conceptual Model of Innovation for the Construction Industry Data used to analyse the results of this survey in Chapter IV is also based on a logic that firms adopt innovative practices as a reaction to perceived threats or opportunities in their business environment in order to achieve a competitive advantage.

There is a belief in the industry that there is much more research and innovation in construction than formal R&D statistics would imply. Significant funds may be invested to resolve problems associated with specific difficulties at various stages of project development, from planning and site investigation through design to actual construction and commissioning. Particularly for the larger projects, new methods may have to be created and pilot-tested, new customized equipment designed, simulation models modified to suit special project conditions and design techniques refined to obtain more precise results. Other industrial sectors would classify and account for such activities under applied research or development. In construction practice such expenditures are generally absorbed in the budget of a specific project and not recorded as R&D. It has been suggested that on large, complex projects, related costs may be in the range of 0.5%-1.0 of the overall budget.

From the innovation perspective the important issue is how the construction firm handles the newly acquired knowledge. Two strategically distinct scenarios are available:

- Some firms consider such knowledge as an important business asset that can lead to future opportunities, possibly at improved profit margins. They are likely to invest resources outside the direct project expenditures in enhancing the capability of their employees through acquisition of technology (and other lessons learned) from every project. They would also have some form of an internal storage and retrieval system of internal expertise that will be continuously updated, constituting a competitive asset of “know-how”. This operational mode is based on the belief that firms can influence market conditions to their advantage by seeking out construction opportunities where they can offer to the owner special skills that will enhance project delivery and its performance. Thus they can negotiate from a “win-win” position.
- Other firms consider lessons learned from a project as site specific because of the unique characteristics of every situation and thus of limited value in future work. It is the project team, likely to be disbanded on completion, which primarily masters this new knowledge. Some of it may be shared with others in the industry through technical press or migration of employees but there is no deliberate effort to capture and reuse such knowledge within the firm. These firms believe that construction markets are essentially customer-driven and their success depends on their management ability to bring together the necessary labour and materials and offer the best price. If some technical

> problem occurs during the implementation of the project there is an expectation that the team in charge will have the necessary professional qualifications to resolve it. The predominant approach is that construction is a “zero-sum” game with a predetermined total cost/benefit package and thus business negotiations tend to be of the “win-loss” type.

These two scenarios present an extreme picture of “market makers” and “order takers”. In practice, firms tend to have blended competitive strategies, with an emphasis on one of the above organizational behaviours.

Because of the difficulty of accounting for the actual value of the project-related R&D and not knowing how the results are diffused and implemented in the industry, its value is generally not included in the innovation statistics of construction (Construction Forecasting and Research Limited, 1996)

Chapter II: 1999 Survey and Data Preparation

Population and Sample

The population for the *Innovation, Advanced Technologies and Practices in the Construction and related Industries Survey* conducted in 1999 by Statistics Canada included all the 110,305 firms in all Canadian provinces and territories that met the following criteria:

- over $50,000. in gross business income;
- and belonging to the following industry groups and industries as defined by North American Industrial Classification System (NAICS) codes:
  - 2311 Land subdivision and land development
  - 23121 Building construction - residential
  - 23122 Building construction - non-residential
  - 2313 Engineering construction
  - 2314 Construction management
  - 2321 Site preparation work
  - 2322 Building structure work
  - 2323 (excluding 23233) Building exterior finishing work
  - 23233 Roofing and related work
  - 2324 Building interior finishing work
  - 2325 (excluding 23251 and 23252) Building Equipment Installation
  - 23251 Electrical work
  - 23252 Plumbing, Heating, Air Conditioning Installation
  - 2329 Other Special Trade contracting.

A stratified sample of 2,461 firms was selected for the survey conducted in the Spring and Summer of 1999. Firms that were out of the scope, out of business, inactive, or did not respond were removed. This resulted in 1800 completed questionnaires representing 95,912 firms. Data verification, edit and imputation was completed by Statistics Canada. Sampling weights were also provided by Statistics Canada in the file used for data analysis.

The ***Innovation, Advanced Technologies and Practices in the Construction and related Industries Survey*** (Appendix A) does not contain any financial or operational information. Selected operational and financial ratios derived from some 1997 financial data were added by Statistics Canada to the file used for data analysis, specifically the firms':

- Ratio of advertising, sales promotions and marketing expenditures to total operating revenue

(Ratio1), and to total employees (Ratio 2);

- Construction orientation, ratio of revenue from construction and related activities to total operating revenue (Ratio 3);
- Ratio of salaries and wages of field workers and of office and administrative staff to total operating revenue (Ratio 4)
- Pretax operating margin: total operating revenue minus total operating expenses divided by total operating revenue (Ratio 5)
- Purchased goods and services: ratio of construction work subcontracted out plus cost of materials and supplies plus architectural, interior design, drafting, engineering, scientific and technical services to total operating revenue (Ratio 6) and to total employees (Ratio 7);
- Ratio of construction work subcontracted out plus cost of materials and supplies plus architectural, interior design, drafting, engineering, scientific and technical services to revenue from construction activities and related services (Ratio 8);
- Total value added per employee: ratio of total operating revenue minus construction work subcontracted, minus cost of material and supplies, minus architectural, interior design, drafting, engineering, scientific and technical services to total employees (Ratio 9);
- SIZE index (= 1 if revenue between $50,000 and less than $1million, = 2 if revenue between $1million and less than $10 million, = 3 if revenue is $10 million or over);
- Wages and Salaries index, an index rather than the actual total wages and salaries paid by each firm to respect confidentiality: firms in the sample were ordered by increasing Wages and Salaries paid, divided into 20 groups of equal size, and assigned an "index" equal to the median of the Wages and Salaries paid by the firms in their group.

In the interest of confidentiality, no financial or operational value (revenues, expenditures, number of employees...) which could have led to the identification of a specific firm was included in the data file made available to the researchers.

Data Preparation

It was decided very early in the work on the survey data that all the data transformations and analyses would be run through scripts to ensure easy verification and replication. Given that we wanted a very strong and flexible scripting facility, we chose to do most of our computations with the statistical package *Stata* This worked very well, except for cluster analysis, which *Stata* does not (at this time) support. Cluster analyses were carried out in the *SAS* system.

Preliminary statistical analysis of the operational and financial ratios of firms in the sample by NAICS grouping showed that NAICS industry groups 2311 and 2314 were quite different from the other groups, with, in particular, significantly more variability in value added per employee and pretax operating margin. It was judged that these two industry groups were not really representative of the Construction Sector; they were therefore removed from the sample. Industry group 2314 (managing construction projects for a fee) probably belongs more to the service sector than to construction; its level of risk, management processes, educational backgrounds are different from those of other construction industries. And industry group 2311 (land subdivision and land development) probably includes a number of firms dealing mainly with the financial aspects of the acquisition/subdivision/resale of land rather than actual construction activities. Removal of industry groups 2311 and 2314 from the sample resulted in a working sample of 1739 firms representing 90,753 firms in the population (Table 4).

Part of the analysis focuses on the Contractors (residential, non-residential, engineering), and on the Specialized Trades working with them. For this study, the Trades were rearranged in three sub-groups according to their main orientation: serving principally the residential sector, serving principally the non-residential sector, or serving principally the engineering contractors. Trades who declared a 50/50 orientation towards the residential and the non-residential sector were not included in the subgroups (there were 74 such firms in the sample). The resulting subgroups, listed in Table 4, are the following:

TR, Trades, mostly residential orientation (356 firms in sample, 27006 in the population);
TN Trades, mostly non-residential orientation (704 firms in sample, 27129 in population);
TE, Trades, mostly engineering orientation (113 firms in sample, 3576 in population);
CE Contractors, Engineering construction (industry group 2313, 227 firms in sample, 3968 in population);
CR Contractors, Residential (industry group 23121, 108 firms in sample, 18287 in population);
CN Contractors, Non-Residential (industry group 23122, 153 firms in sample, 3873 in population);

Table 4. Population and sample

Note: "Total Wages" estimated from wages and salary index supplied by Statistics Canada

sector	Sector	Population # firms	Total Wages $millions	Sample # firms	% population	% wages	% sample
TR/TN	Trades, resid. & non-resid.	6914	1583	78	7.6	4.9	4.5
TR	Trades, mostly residential	27006	6104	356	29.8	18.9	20.5
TN	Trades, mostly non-residential	27129	11401	704	29.9	35.4	40.5
TE	Trades, mostly engineering	3576	2438	113	3.9	7.6	6.5
CE	Contractors, Engineering	3968	4727	227	4.4	14.7	13.1
CR	Contractors, Residential	18287	2680	108	20.2	8.3	6.2
CN	Contractors, Non-Residential	3873	3286	153	4.3	10.2	8.8
Total	Total	90753	32219	1739	100.0	100.0	100

Note: Tables may have different totals because of missing values

size	SIZE	Population # firms	Total Wages	Sample # firms	% population	% wages	% sample
1	Total Revenue < $1 million	74846	11617	633	82.5	36.1	36.4
2	Total Revenue < $10 million	15030	14460	839	16.6	44.9	48.2
3	Total Revenue >= $10 million	855	6141	267	0.9	19.1	15.4
	Total	90731	32218	1739	100.0	100.0	100.0

Note: Tables may have different totals because of missing values

	Number of Firms, population By sector and size (# of firms)	Small firms	Medium firms	Large firms	Percentages of firms in population		
					Small	Medium	Large
TR/TN	Trades, resid. & non-resid.	6603	290	21	8.8	1.9	2.4
TR	Trades, mostly residential	24848	2123	35	33.2	14.1	4.0
TN	Trades, mostly non-residential	21734	5235	160	29.0	34.8	18.2
TE	Trades, mostly engineering	2315	1227	35	3.1	8.2	4.0
CE	Contractors, Engineering	2090	1662	215	2.8	11.1	24.5
CR	Contractors, Residential	15069	3041	176	20.1	20.2	20.1
CN	Contractors, Non-Residential	2185	1453	235	2.9	9.7	26.8
Total	Total	74644	15031	877	100.00	100.00	100.00

Note: Tables may have different totals because of missing values or round-off errors

	Total Wages paid, population By sector and size ($millions)	Small firms	Medium firms	Large firms	Percentages of total wages in population		
					Small	Medium	Large
TR/TN	Trades, resid. & non-resid.	718	381	483	6.2	2.6	7.9
TR	Trades, mostly residential	4378	1639	88	37.7	11.3	1.4
TN	Trades, mostly non-residential	3907	6015	1479	33.6	41.6	24.1
TE	Trades, mostly engineering	378	1576	484	3.3	10.9	7.9
CE	Contractors, Engineering	359	2569	1800	3.1	17.8	29.3
CR	Contractors, Residential	1469	967	243	12.6	6.7	4.0
CN	Contractors, Non-Residential	409	1314	1563	3.5	9.1	25.5
Total	Total	11618	14461	6140	100.00	100.00	100.00

Note: Tables may have different totals because of missing values or round-off errors
Note: Category TR/TN respondents reported 50/50 split of business between residential and non-residential construction. Data included here for information but subsequently dropped from analysis.

Preliminary statistical analysis of the financial and operational ratios of our resulting total sample of 1739 firms showed:

- very little variability in Ratio 3 (construction orientation) with mean values of over 98% in all sectors (the only exception being industry group 2323 at 97%) and small variances; Ratio 3 has therefore limited predictive power to explain differences between firms and was dropped from the analysis.
- very strong correlations between the ratios to "total revenue" and the ratios to "total employees". As the quality of the "number of employees" variable is questionable, especially in the construction sector with its mix of full time, part time, and seasonal employees, and as "number of employees" had more missing values (52) than "total revenue" (12), Ratio 2 and Ratio 7 using the "number of employees" were dropped from the analysis in favour of those using "total revenue". Ratio 9 (value added per employee) is reported, but was only used for descriptive statistics because, as the number of employees is a divisor, we need to be cautious in its interpretation.

Firm-Weighted Statistics and Wages and Salaries-Weighted statistics

Firm-weighted statistics give the same importance to each firm in the population, irrespective of size: when estimating averages for example, the operating practices or operational results of a firm with annual operating income of $500,000 are given the same importance as the operating practices or operational results of a firm with operating income of $50 million. In this case, if the operating margin of the smaller firm was 6% and that of the larger firm was 2%, the firm-weighted average would be 4%. *Firm-weighted statistics are easy to understand but may not be representative of the actual socio-economic impact of the firms.*

Size-weighted statistics give more importance to the larger firms in the population, probably a better representation of the overall socio-economic impact of a large firm employing many people compared with that of a small firm with limited sales and employment. For example, a firm with $50 million in operating income will probably have a significantly larger impact on the economy than a firm with $500,000 in operating income . In this case, if the operating margin of the smaller firm was 6% and that of the larger firm was 2%, the size-weighted average would be slightly above 2%, our two-firm "industry" being dominated by the larger firm. *Size-weighted statistics are more difficult to understand but are more representative of the actual socio-economic impact of the firms.*

This report includes *Firm-weighted statistics* and some *Wages and Salaries-weighted statistics* using a "wages and salaries" index supplied by Statistics Canada. Wages and Salaries have been used as a proxy for the value added or the "size" of the firms.

Data Recoding

Questions 2 of the questionnaire (Appendix A) dealing with the importance of several strategic factors for the success of the business includes a dichotomous answering scheme with "0" for a question that is judged not relevant, and a Likert-style 5-point scale otherwise ("1"= low importance; "5"= high importance). Observation of the frequency distribution of the responses to the 20 questions of Questions 2 showed good continuity for the frequencies of "0" and of "1" to "5", in all but two cases, giving the impression that respondents were in fact using an implicit 6-point scale ("0" to "5"). Various recoding schemes were considered in a preliminary analysis of the data of Questions 2: considering a "0" answer as a missing value; using the response as a straight 6-point scale; recoding "0" as "1" and "1" and "2" as "2" to go back to a 5-point scale and correct a "dip"in the distribution of some of the answers, "1" and "2" tending to have lower frequencies than "0" or "3". Working directly with the original data and its "0" to "5" 6-point scale gave the best statistical results (using a Factor Analysis, Chapter IV), the other scales leading to similar inferences but with more variability and therefore less precision. *The responses to the questions of Questions 2 were therefore used with no transformation, and considered as a 6-point Likert style scale.*

Data Limitations

The *Innovation, Advanced Technologies and Practices in the Construction and related Industries Survey* performed in 1999 does not include financial data. Statistics Canada provided us with approximate wage and salary expenses for 1997 grouped into 20 categories by size and replaced by the median value of the appropriate group to ensure confidentiality. Information on number of employees, in our mind an important factor in productivity and innovation, could not be made available. Therefore, we must be cautious in our interpretation of some of the operating ratios.

Though the questions on the survey questionnaire were organized to reflect the 1997 period, there is still some concern of "hindsight" rather than responses that would have been given earlier. However, major drivers of construction demand, demographics and interest rates have remained reasonably constant between

1997 and 1999. On the other hand, there has been an increase in customer and business confidence and public sector investment in construction, which may have influenced responses regarding business environment and related strategies.

Because there is only a single time point for the financial data, we have no way to truly measure trends in profitability, revenues or similar economic changes, even though this is clearly one of the goals of the study. We must make our inferences from responses on the *Innovation, Advanced Technologies and Practices in the Construction and related Industries Survey* to questions about innovation and its outcomes.

Statistical Analysis Considerations

There are a number of issues that can possibly cloud our results from a statistical perspective:

- Respondents do not answer all the questions. Statistics Canada had, however, imputed a response for cases where the respondent failed to respond for all questions except Question 8. In this case (see Table 10 and the related discussion) the non-response rate varies across groups, providing information which was used in the analysis.
- The distribution of the responses may not be Gaussian, while some of the statistical measures of reliability, for example, confidence intervals, assume that the distribution of means or proportions are at least approximately Gaussian, generally on the basis of the Central Limit Theorem. We believe that our sample and sub-sample sizes are large enough that this is so, but note that our raw data is often binary or categorical, and that we have sometimes aggregated such information.
- In common with many similar behavioural studies, we observe many cases where regression models exhibit very small R^2 statistics that are nonetheless statistically significant. This may be disconcerting. The implication is that the model we are using explains very little of the variability about the mean of a response variable, but that the amount that actually is "explained" is unlikely to be simply by chance.
- In order to have the survey data reflect the population of interest, we have used weighted measures throughout. As always, there are many ways to actually carry out the weighting, especially in the presence of missing values. We have chosen to use the weights provided to us with the survey data, which are in the form of real numbers (rather than frequencies). In some cases, the *Stata* software we used for the analysis required us to specify that we were using such "analytic weights". Some statistical techniques did not allow such weights within this package (for example, they may have required frequency weights, which are integers).
- Given the considerations above, we have sometimes used several approaches to uncover similar information in the survey data. We believe this is a sensible and conservative approach.

Chapter III: Descriptive Analysis and Results

Descriptive statistics on the firms covered by the survey and on survey questions are provided in this Chapter. In summary, the issues considered are:

- Operational characteristics, that is, financial ratios
- Advanced technologies and business practices currently used or planned
- Obstacles to innovation
- Sources of information
- Technological or business practices with biggest impact on business.

The analysis of the perception that survey respondents have of the business environment, of their business strategies, and of the relationships between those behavioural variables and the advanced technologies and business practices currently used or planned is given in Chapter IV.

Part of the analysis will be based on the total sample (1739 firms, representing a total population of 90,753 firms). The sample will also be segmented by size and by industry groups and industries.

The size categorization is defined as follows:

- Small firms, with annual revenue between $50,000 and $1,000,000.
- Medium firms, with annual revenue from $1,000,000 up to $10,000,000
- Large firms, with annual revenue of $10,000,000 and above.

The six industry sectors we shall use are:

- TR Trades, mostly residential orientation;
- TN Trades, mostly non-residential orientation;
- TE Trades, mostly engineering orientation;
- CE Contractors, Engineering construction (industry sector 2313);
- CR Contractors, Residential (industry sector 23121);
- CN Contractors, Non-Residential (industry sector 23122);

Operational Characteristics

Part of the analysis of innovative practices in Canada is based on the relationship observed between some of those practices and the firms' pretax operating margin. As noted earlier, selected operating ratios on the firms in the sample were derived from 1997 financial data supplied to us by Statistics Canada. This section starts with a short descriptive analysis of the following ratios:

RATIO1: Advertising and sales promotion: Ratio of advertising and sales promotion + marketing and market research to total operating revenue

RATIO4: Salaries and wages: Ratio of salaries and wages of field workers + salaries and wages of office and administrative staff to total operating revenue

RATIO5: Pre-tax operating margin (pre-tax net income as a percentage of sales): Ratio of total operating revenue - total operating expenses to total operating revenue

RATIO6: Purchased goods and services: Ratio of construction work sub-contracted out + cost of materials and supplies + architectural, interior design, drafting, engineering, scientific and technical services to total operating revenue;

RATIO9: Total value added per employee: Ratio of total operating revenue - construction work sub-contracted out - cost of materials and supplies - architectural, interior design, drafting, engineering, scientific and technical services to total employees. As noted in Chapter II, data on "total value added per employee" is of limited quality; descriptive statistics are provided for information but interpretation should be done with caution.

Table 5a Operating ratios, mean values by size, Firm-weighted
See text for discussion of Ratio 9.

	Total Sample	Small firms (S)	Medium firms (M)	Large firms (L)	Significant paired differences, by firm size (p<=0.01; scheffe)
Sample size	1735	633	839	263	
Ratio 1	0.8%	0.8%	0.7%	0.5%	L < M , L < S , M = S
Ratio 4	0.345	0.35	0.27	0.22	S > M > L
Ratio 5	3.6%	3.4%	4.5%	3.4%	no significant differences
Ratio 5 wages-weighted	1.3%	-0.25%	1.8%	2.8%	S = M , S < L , M = L
Ratio 6	0.42	0.4	0.52	0.61	S < M < L
Ratio 9 ($)	54041	45894	84984	174643	S < M < L

Advertising and sales promotion, as a percentage of total revenue (Ratio 1, Tables 5a and 5b): This ratio could be considered as a partial measure of managerial innovativeness, active marketing and selling activities being less customary in the construction sector than in the commercial sector of the economy.

- On the average these expenditures represent 0.8% of total revenue;
- Small- and medium-sized firms spend relatively more than larger firms;
- Trades spend marginally more than engineering and non-residential contractors, but the same as residential contractors.

Salaries and wages as a percentage of total revenue (Ratio 4, Tables 5a and 5b):

- On the average, salaries and wage expenditures represent 34.5% of total revenue.
- Smaller firms have significantly larger ratios than medium-sized firms, the largest firms using the

least labour, in relative terms.

- Engineering firms have significantly more direct employees than non-residential and residential contractors.
- Trades have relatively more direct employees than contractors

Table 5b. Operating ratios, mean values by size and by sector of activity, Firm-weighted
See text for discussion of Ratio 9.

	Building Trades, serving mostly :			Contractors			Significant paired differences, by sector (p<=0.01; scheffe)
	Resid-ential TR	Non-res-idential TN	Engineer-ing TE	Engineer-ing constr'n CE	Resid-ential CR	Non-res-idential CN	
Sample size	356	704	113	227	108	153	
Ratio 1	0.8%	0.7%	0.7%	0.3%	0.7%	0.5%	TR>CE, TR>CN, TN>CE
Ratio 4	0.34	0.37	0.43	0.33	0.27	0.25	TE>TR, TR>CR, TR>CR, TE>TN, TN>CR, TN>CR, TE>CE, TE>CR, TE>CN, CE>CR, CE>CN
Ratio 5	-2.2%	5.9%	3.6%	4.6%	7.9%	-1.7%	TN>TR, TN>CN, CE>TR, CR>TR, CR>CN
Ratio 5 wages-weighted	-3.5%	1.7%	0.7%	2.1%	9.2%	1.5%	TR< all others CR> all others
Ratio 6	0.4	0.37	0.29	0.37	0.54	0.66	CR>TR, CN>TR, TR>TE, CR>TN, CN>TN, CR>TE, CN>TE, CR>CE, CN>CE, CN>CR
Ratio 9	50777	52190	67732	59656	53852	54232	no significant differences

Purchased goods and services, including subcontracting, as a percentage of total revenue (Ratio 6, Tables 5a and 5b): This variable proved difficult to interpret because of the aggregation of subcontracting with the purchase of goods and services. However, it appears to confirm the findings for Ratio 4 that:

- Larger firms purchase more goods and services than smaller ones
- Non-residential contractors purchase significantly more goods and services than residential contractors who in turn purchase significantly more than engineering contractors.
- Trades generally purchase less goods and services than residential and non-residential contractors but are at generally the same level as engineering contractors.

Value added per employee (Ratio 9, Tables 5a and 5b): This is significantly higher in larger firms than in medium-sized or smaller firms, but there appears to be no difference between industry sectors. Given the questionable quality of our data on "total value added per employee", caution should be used with these results.

Pretax operating margin (Ratio 5, Tables 5a and 5b):
When focussing on firm-weighted statistics,

- The average pretax operating margin is 3.6%
- Residential contractors (7.9%) and non-residential trades (5.9%) make significantly more than non residential contractors (-1.7%) and residential trades (-2.2%); other differences are marginal and not significant.

A comparison of firm-weighted and wage-weighted means provides interesting information. The fact that wage-weighted average pretax operating margin (1.3%) for all the firms in the population is lower than the firm-weighted average (3.6%) shows that *globally*, the firms with the largest wage and salaries expenditures have the lowest pretax operating margin. When one looks at each industry sector separately, however, the situation is different:

- For the trades and for engineering construction contractors, the data shows that the larger firms generally make marginally less money (lower operating margins);

- For the residential and the non-residential contractors, however, the situation is reversed, with the larger firms (the firms with the largest wage and salaries expenditures) making marginally more money than the smaller firms (higher operating margin).

Innovation Variables

Questions 3 and 4 of the Survey deal with advanced technologies and with business practices *"currently used"* or *"plans to use within two years"* . Some of those technologies or practices (Table 6) are more appropriate for some industry sectors than others. It will therefore not be surprising to observe sector differences. And, even if there is no measure of commitment for the "plans to use", those answers may indicate trends in technology and business practices adoption.

Table 6. Questions 3 and 4 in Survey (advanced technologies / business practices)

Questions 3: Please check which of the following advanced technologies your business either: currently uses, plans to use within two year; or has no plans to use within two years or is not applicable to your business.		Questions 4: Please check which of the following business practices your business either: currently uses, plans to use within two years; or has no plans to use within two years or is not applicable to your business.	
c29	E-mail	c49	Computerized inventory control
c30	Digital photography for progress reporting	c50	Computerized estimating software
c31	Office-to-site video links or video conferencing	c51	Computerized project management systems and/or scheduling systems
c32	Company computer networks (LAN or WAN)	c52	Quality control certification (e.g. ISO 9000, R2000, etc.)
c33	Laser-guided equipment	c53	Written market analysis report to evaluate needs and opportunities of your business
c34	Automated systems and programmable machines	c54	Written documentation of technological improvements developed by your business
c35	GPS (Global Positioning System)	c55	Written evaluation of new ideas in order to develop options for your business
c36	High performance concrete	c56	Written strategic plan
c37	Composite materials (e.g. fibre reinforced plastics)	c57	Design-build contracts
c38	Recycled plastic components	c58	Build-operate-transfer (BOT) contracts
c39	Remote sensing and monitoring systems (e.g. "smart" detection systems)	c59	Post-commissioning inspection or maintenance
c40	Bio-remediation clean-up	c60	Long-term working arrangements with other businesses
c41	Preassembled air, water, power distribution systems (e.g. "drop-in systems)		
c42	«Clean room» technology		
c43	Deconstruction and reuse systems		
c44	Computer aided design		
c45	Modelling or simulation technologies		
c46	Electronic exchange of CAD files		

The following aggregate statistics, based on the usage of the advanced technologies and business practices listed in the survey, were used in this study as proxies for innovative behaviour and hence as measures of the innovativeness of firms. As we note elsewhere, some of the advanced technologies or business practices may not appear especially innovative (e-mail) or may apply to only some of the respondents (GPS, high-performance concrete). In aggregate form, however, it is felt that firms using a larger number of such technologies or practices demonstrate a higher level of interest in new or recently developed technologies or practices than the other firms, thus show a higher level of "innovativeness", thereby justifying the use of these proxies for innovativeness and innovative behaviour. The variables used are essentially sums of binary forms of the relevant variables, 1 for Yes, 0 for No, in answer to a question of the form "Do you currently use ..." or "Do you plan to use ...". (There were different codings of the same question in the survey, so we transformed the data before aggregation.)

INTECCU: innovative technology behaviour; total number of advanced technologies currently used (Survey, Questions 3; maximum: 18)
INBUSCU, innovative business behaviour; total number of business practices currently used (Survey, Questions 4; maximum 12)
INNOVCU: innovative behaviour; total number of advanced technologies and business practices currently

used (Sum of INTECCU and INBUSCU; maximum: 30)

INTECCPU, INBUSCPU, INNOCPU are equivalent counts for the number of technologies and business practices currently used and planned for use within two years.

Table 7 presents descriptive statistics for these aggregate variables and Table 8 gives percentages of current and of current and planned use for the individual advanced technologies listed in Table 6.

Advanced Technologies - usage (Survey responses C29-46, definitions, Table 6; statistics, Tables 8a and 8b)

From the total industry use perspective there is consistency between the current use and planned-within-2-years use. The order of use for the technologies that are currently used is as follows (from most popular to the least, with some minor regrouping).

The most popular are the communication and computerized design technologies (total sample use 20% to 38%)

- e-mail
- networked computers
- CAD
- electronic exchange of CAD files is currently at 7% but is expected to grow rapidly.

Growth in the use of these technologies, planned over the next two years, is expected to be significant. Applying the principle that a buying intent is translated into an actual purchase at a rate of 30%-50% (Howard, 1994; Rossiter and Percy, 1997), the overall use in communication and computerized design technologies should rise in the order of 10%-30% per annum.

Table 7. Descriptive statistics for aggregated advanced technologies and business practices, all firm-weighted, total sample and by size of firm, and by industry sector.

	Total sample			Small firms			Medium firms			Large firms		
Variable	Mean	[95% C.I.]		Mean	[95% C.I.]		Mean	[95% C.I.]		Mean	[95% C.I.]	
# observ	1735			633			839			263		
INTECCU	1.93	1.82	2.04	1.66	1.49	1.82	3.09	2.92	3.27	5.32	4.92	5.73
INTECCPU	3.35	3.19	3.50	3.03	2.78	3.28	4.71	4.49	4.93	7.17	6.73	7.62
INBUSCU	1.97	1.86	2.09	1.72	1.54	1.91	3.06	2.88	3.24	4.80	4.47	5.14
INBUSCPU	3.31	3.16	3.46	2.99	2.75	3.24	4.69	4.49	4.90	6.50	6.12	6.88
INNOVCU	3.90	3.70	4.11	3.38	3.06	3.70	6.15	5.84	6.47	10.13	9.47	10.78
INNOVCPU	6.66	6.37	6.94	6.02	5.55	6.50	9.40	9.03	9.77	13.67	12.96	14.39

By industry sector

	Trades, residential			Trades, non-residential			Trades, engineering		
Variable	Mean	[95% C.I.]		Mean	[95% C.I.]		Mean	[95% C.I.]	
# observ	356			704			113		
INTECCU	1.67	1.49	1.86	2.25	2.06	2.43	2.23	1.77	2.68
INTECCPU	3.51	3.16	3.86	3.43	3.18	3.67	3.43	2.85	4.01
INBUSCU	2.39	2.08	2.69	2.15	1.98	2.33	1.33	0.95	1.72
INBUSCPU	3.78	3.43	4.13	3.78	3.53	4.02	2.83	2.24	3.41
INNOVCU	4.06	3.59	4.53	4.40	4.07	4.73	3.56	2.82	4.30
INNOVCPU	7.29	6.62	7.97	7.20	6.75	7.65	6.26	5.23	7.29

Sectors (continued)

	Contractors, engineering			contractors, residential			Contractors, non-residential		
Var.	Mean	[95% C.I.]		Mean	[95% C.I.]		Mean	[95% C.I.]	
# observ	227			108			153		
INTECCU	4.15	3.77	4.53	1.17	0.84	1.51	2.94	2.45	3.44
INTECCPU	6.09	5.66	6.52	2.14	1.60	2.69	5.84	5.32	6.36
INBUSCU	3.32	2.99	3.66	1.08	0.70	1.45	2.45	2.06	2.83
INBUSCPU	4.64	4.29	4.99	1.86	1.36	2.36	4.42	3.98	4.87
INNOVCU	7.47	6.83	8.12	2.25	1.61	2.90	5.39	4.57	6.20
INNOVCPU	10.73	10.02	11.44	4.00	3.01	4.98	10.26	9.44	11.09

This is followed by various technologies primarily related to the construction process (total sample use 7% to 15%)

- laser guided equipment
- automated systems and programmable machines
- remote sensing (smart systems)
- high performance concrete
- composites
- deconstruction and reuse
- pre-assembled “drop-in” systems
- recycled plastics

In general, engineering and non-residential contractors are greater users of these technologies than various trades and residential contractors. Overall, discounted increase in the use of these construction process technologies is in the order of 5%-10% per annum.

Remaining technologies are either not popular or are of a very specialized nature (total sample use 1.5% to 5%)

- modelling / simulation
- clean room" technologies
- digital photography for progress reports (@ 3%) will show the most rapid rise in the use over next two years (350%)
- "bio-remediation"
- GPS
- video conferencing

All sectors indicate some to very significant increase in the use of these technologies.

Advanced Technologies - Intensity of use (Survey responses C29-46, definitions, Table 6; statistics, Table 7, Tables 8a and 8b)

In general, based on Tables 7 and 8:

- Intensity of use of all technologies increases with the size of the enterprise.
- Larger firms use three times as many technologies (5.4) as the small companies (1.6).
- Engineering and non-residential contractors use three times as many technologies as residential contractors.

Projected use confirms the above trends.

- Generally speaking, between engineering construction and non-residential contractors there is reasonable similarity in high use of two technologies (e-mail and networked computers), but engineering is a greater user than non-residential contractors of CAD and exchange of CAD files. Other technology use varies depending on its suitability for the sector. Overall, engineering is a somewhat greater user of technologies (4.1 vs 2.9). Projected use will reduce the gap (6.1 vs 5.8)
- Specialty trades use generally fewer technologies than engineering and non-residential contractors, but more than residential contractors. Residential specialty trades are considerably more computer intensive than residential contractors, particularly in the of CAD and in the electronic handling of CAD files.
- Questions 3 of the survey proposes 18 advanced technologies. Most of these have been available to the construction industry for the last 5-10 years and sometimes longer. Even if this list is adjusted for technologies that appear to be highly specialized in nature, or of very low usage, survey respondents had a choice among 12 technologies. Total sample mean use (Table 7) is 1.93 technologies, with the lowest sector use by residential contractors, at 1.17 technologies. This appears to be a very low level of technology use. However, there is a significant intent to increase the intensity, with a discounted projected rate in the order of 15% per annum.

Business Practices - Usage (Survey questions C49-60 ; definitions, Table 6; statistics, Tables 9a and 9b)

From the total industry use perspective there is consistency between the current and planned within 2 years use. The order of use for the business practices currently used is as follows (from most to least popular).

Table 8a Percentages of businesses currently using ("cu") or currently and planning to use ("cpu") various advanced technologies, Firm weighted, total sample and by size.

Variable (see Table 6)	**Total sample** --cu--	--cpu--	**Small firms** –cu–	--cpu--	**Medium firms** –cu–	--cpu--	**Large firms** –cu–	--cpu--
c29	37.8%	61.2%	33.5%	56.7%	56.9%	81.5%	75.2%	95.0%
c30	3.3%	14.5%	1.9%	11.6%	9.3%	27.3%	19.6%	38.3%
c31	1.4%	4.3%	1.3%	2.8%	1.7%	11.6%	3.6%	10.9%
c32	22.2%	31.6%	16.3%	24.5%	48.6%	63.3%	76.8%	90.7%
c33	14.5%	25.2%	11.3%	23.5%	29.1%	32.4%	39.4%	46.2%
c34	12.5%	21.9%	11.2%	21.1%	18.1%	24.7%	27.1%	37.3%
c35	1.5%	5.9%	1.2%	4.8%	2.5%	10.6%	7.3%	14.1%
c36	12.0%	14.4%	10.8%	12.3%	16.5%	23.0%	39.1%	42.6%
c37	11.3%	17.7%	9.8%	16.1%	17.7%	24.7%	36.4%	40.8%
c38	7.3%	13.2%	6.8%	12.8%	9.2%	14.1%	19.8%	30.1%
c39	12.9%	16.1%	11.9%	14.7%	17.2%	21.5%	23.7%	34.8%
c40	2.8%	4.9%	2.4%	4.4%	4.7%	6.8%	10.6%	17.1%
c41	8.2%	11.5%	8.2%	11.3%	7.4%	11.9%	16.5%	22.8%
c42	3.2%	7.1%	3.2%	7.5%	3.1%	4.6%	10.6%	15.6%
c43	9.5%	12.8%	10.0%	13.4%	6.8%	9.4%	14.6%	23.6%
c44	20.5%	35.5%	17.6%	32.8%	32.7%	47.3%	55.9%	66.9%
c45	4.5%	15.3%	4.1%	14.5%	6.2%	18.3%	13.7%	28.5%
c46	7.4%	21.8%	4.2%	18.0%	21.6%	38.2%	42.7%	61.9%

Table 8b Percentages of businesses currently using ("cu") or currently and planning to use ("cpu") various technologies, Firm weighted, by industry sector.

Variable (Table 6)	Trades residential --cu--	--cpu--	Trades non-residential –cu–	--cpu--	Trades, engineering –cu–	--cpu--	Contractors engineering –cu–	--cpu--	Contractors residential –cu–	--cpu--	Contractors, non-residential –cu–	--cpu--
c29	37.2%	65.9%	39.5%	61.5%	44.8%	71.9%	64.5%	87.4%	22.9%	39.0%	50.3%	84.0%
c30	0.7%	14.6%	4.1%	11.7%	5.5%	19.8%	12.2%	29.0%	1.6%	13.0%	18.5%	34.5%
c31	1.5%	3.0%	1.6%	3.6%	2.9%	5.0%	1.4%	5.1%	0.1%	4.4%	5.6%	15.7%
c32	30.5%	34.2%	19.0%	35.9%	29.8%	47.0%	38.5%	43.2%	12.4%	20.7%	32.2%	45.3%
c33	9.2%	34.1%	14.2%	18.8%	23.8%	24.5%	22.5%	34.9%	18.9%	20.6%	22.6%	33.7%
c34	7.3%	30.1%	21.1%	24.7%	8.2%	10.5%	46.1%	51.4%	2.9%	3.9%	12.4%	23.3%
c35	0.1%	7.0%	1.3%	4.4%	13.2%	19.2%	4.6%	12.7%	0.2%	3.1%	2.3%	7.8%
c36	7.3%	8.3%	7.3%	9.0%	27.4%	35.7%	25.8%	32.2%	15.8%	19.1%	28.0%	31.1%
c37	9.0%	10.5%	11.6%	17.6%	19.9%	26.2%	15.9%	23.4%	8.2%	17.9%	19.6%	51.0%
c38	7.0%	9.3%	8.7%	14.4%	2.9%	6.7%	7.4%	14.3%	2.2%	10.2%	11.4%	44.2%
c39	9.9%	10.2%	23.3%	28.3%	9.6%	9.6%	24.7%	32.8%	2.0%	2.8%	9.8%	18.2%
c40	4.7%	6.2%	1.7%	6.0%	2.7%	2.8%	7.7%	10.6%	0.4%	1.2%	3.9%	4.7%
c41	4.3%	5.4%	12.9%	18.8%	4.2%	4.2%	26.6%	35.6%	2.0%	2.2%	10.1%	13.3%
c42	0.7%	4.4%	6.8%	12.5%	0.6%	0.9%	2.2%	3.0%	2.4%	2.9%	3.9%	25.3%
c43	7.1%	9.1%	10.8%	15.4%	2.2%	4.6%	25.0%	26.6%	11.1%	11.5%	12.4%	38.3%
c44	25.8%	42.0%	21.7%	30.5%	12.8%	25.9%	48.1%	65.4%	7.1%	26.2%	30.8%	62.3%
c45	2.8%	25.8%	5.7%	9.2%	2.8%	8.5%	22.0%	46.7%	2.6%	6.9%	9.1%	21.5%
c46	2.5%	30.9%	13.3%	20.7%	9.5%	20.1%	19.7%	54.6%	4.6%	8.6%	11.5%	29.8%

There is a group of business practices that is now well established (total sample use 24% to 31%)

- Design-built
- Computerized project management
- Computerized estimating
- Long-term partnerships with others

This is followed by several practices (total sample use 8% to 17%) that are reasonably established amongst the larger firms and are expected to be introduced in medium-sized firms over the next 2 years. It appears that many businesses are interested in more formalized (written) practices than in the past and that this trend will accelerate

- Written strategic plan
- Post commissioning inspection/maintenance
- Written evaluation of new ideas
- Written documentation of technological improvements
- Computerized inventory control
- Written marketing plan

A limited number of firms (5%) used some of the following practices

- Quality control certification
- BOT contracts

Business Practices - Intensity of use (Survey questions C49-60 ; definitions, Table 6; statistics, Table 7, Tables 9a and 9b)

We observe, in general, that:

- Intensity of use of all practices increases with the size of the enterprise. Projected use confirms this trend.
- Larger firms use three times as many business practices (4.8) as the small companies (1.7). Projected use confirms this trend.
- Compared to residential contractors, non-residential contractors use twice as many business practices, and engineering contractors use three times as many.
- Overall use of business practices is more or less the same as of technologies.
- In global terms, engineering contractors and non-residential contractors have a similar rate of use of all the business practices except for BOT, long term partnering, and post-commissioning work which are used significantly more by engineering contractors. Residential contractors are systematically behind the other two contractor groups.
- Specialty trades and engineering/non-residential contractors are approximately equal in use of business practices, however
    - Residential specialty trades show high use of formalized business planning through written documentation of technological improvements, evaluation of new ideas and strategic plans. In these areas residential specialty trades are almost an order of magnitude ahead of residential contractors.
    - Non-residential trades show high use of post commissioning maintenance, almost

three times higher than non-residential contractors.

- Intentions of planned use generally confirm the order of importance of the present use. Assuming a 40% discount factor between intent and implementation, total sample increase in the use of design-built contracts will grow at 5% per annum, of post commissioning work at 6% per annum, while formalization of various documents (marketing, strategic plan, etc.) is expected to grow at 15%-30% per annum. There is also expectation that the intensity of use of various computer-based practices (project management, inventory control) will rise by 15%-30% per annum.

Table 9a. Percentages of businesses currently using ("cu") or currently and planning to use ("cpu") various business practices, Firm weighted.

Variable (see Table 6 for definition)	Total sample		Small firms		Medium firms		Large firms	
	--cu--	--cpu--	–cu–	--cpu--	–cu–	--cpu--	–cu–	--cpu–
c49	10.6%	27.8%	5.7%	23.2%	33.1%	49.0%	36.4%	55.3%
c50	27.0%	50.9%	22.9%	47.3%	45.0%	66.8%	72.5%	92.0%
c51	28.1%	48.3%	23.4%	43.1%	48.9%	72.5%	69.7%	85.7%
c52	4.9%	14.2%	3.4%	11.7%	11.4%	25.2%	22.5%	41.5%
c53	8.2%	21.2%	6.3%	18.7%	16.2%	32.4%	26.3%	42.6%
c54	11.6%	17.2%	12.0%	16.5%	9.1%	19.8%	22.4%	33.8%
c55	13.9%	25.1%	13.9%	24.2%	13.2%	28.3%	30.3%	48.5%
c56	17.1%	27.6%	15.8%	24.5%	21.9%	41.4%	41.2%	56.6%
c57	30.8%	38.4%	28.4%	35.9%	41.1%	49.4%	65.5%	68.7%
c58	5.0%	8.4%	4.5%	7.8%	7.1%	10.2%	13.3%	24.5%
c59	16.3%	20.8%	14.4%	18.2%	24.6%	32.5%	34.6%	41.7%
c60	23.8%	30.9%	21.4%	28.4%	34.2%	41.9%	45.8%	59.5%

Table 9b Percentage of businesses currently using ("cu") or currently and planning to use ("cpu") various business practices, Firm weighted.

Variable (see Table 11 for definition)	Trades residential		Trades non-residential		Trades engineering		Contractors engineering		Contractors residential		Contractors non-residential	
	--cu--	--cpu--	–cu–	--cpu--	–cu–	--cpu--	–cu–	--cpu--	–cu–	--cpu--	–cu–	--cpu–
c49	6.4%	30.3%	15.5%	36.2%	16.9%	27.8%	19.9%	32.0%	7.7%	14.2%	18.0%	30.5%
c50	37.1%	58.8%	24.8%	54.1%	14.7%	48.5%	41.0%	64.4%	18.2%	29.5%	39.3%	82.8%
c51	31.5%	52.4%	33.0%	56.0%	14.3%	47.8%	58.2%	75.4%	16.1%	29.2%	46.3%	65.8%
c52	4.0%	14.7%	3.6%	16.4%	9.8%	22.5%	16.5%	24.5%	5.2%	6.8%	10.2%	28.2%
c53	8.4%	35.7%	10.3%	16.9%	3.3%	14.5%	7.5%	23.0%	6.9%	12.2%	6.8%	18.9%
c54	27.5%	30.0%	6.1%	16.1%	2.6%	14.1%	5.6%	18.4%	1.4%	3.7%	3.3%	9.5%
c55	30.0%	37.0%	9.4%	24.9%	5.5%	18.0%	7.6%	14.2%	3.7%	14.3%	8.4%	23.8%
c56	28.7%	39.2%	18.4%	30.5%	5.7%	14.8%	12.9%	19.9%	4.6%	12.5%	18.1%	37.6%
c57	34.9%	40.7%	30.8%	38.4%	19.6%	20.9%	51.7%	56.2%	22.3%	30.3%	46.3%	76.2%
c58	4.0%	5.6%	5.7%	12.9%	5.3%	6.7%	21.3%	26.2%	2.0%	3.0%	7.6%	13.5%
c59	7.9%	13.0%	31.3%	37.9%	8.8%	13.6%	40.3%	45.3%	3.8%	6.0%	12.0%	16.1%
c60	18.2%	20.8%	26.4%	37.3%	26.9%	33.5%	49.9%	64.9%	15.8%	24.0%	28.2%	39.3%

- Questions 4 of the survey proposes 12 business practices. Most of these have been increasingly used in other industries for the past decade. Eliminating Build-operate-transfer (BOT) contracts and quality control certification, which may apply to a limited number of firms, and design-built as well as post-commissioning, which are construction-type specific, we are left with 8 practices which are currently considered as "good management". These can be grouped into

- formalizing (writing) business strategies
- using widely-available computer software
- establishing long-term working relationships.

Total sample mean use of business practices (Table 7) is 1.97, with the lowest sector use by residential contractors at 1.08. This appears to be a very low level of "good management" business practices. However, there is intent to increase the use in a significant manner at a discounted projected rate in the order of 15% per annum.

Innovations with biggest impact on business (Questions 8 of Survey; statistics, Tables 10a and 10b)

In Questions 8 of the survey (Appendix A), industry respondents were requested to provide "a brief description of the technological or business practice change or improvement which had the biggest impact on your business during the last three years", as well as an indication of whether that change or improvement "provide[d] your business with a significant advantage over your competitors". 870 firms in the sample (approximately half of the sample), representing 41,410 firms in the population (45.6%) provided a description. The analysis in this section is based on firm-weighted statistics; the percentages given in this section are therefore estimates of the firms in the population represented by firms in the sample rather than percentages of the actual number of firms observed in the sample. On this basis, 41% indicated that the change or improvement had provided them with a significant advantage, 48% indicated that it did not, and 11% did not address the issue.

The descriptions provided by the respondents were coded by Statistics Canada staff into fourteen themes ranging from human resources (HUM) and business strategy (STR) to regulations (REG) and safety (SAF) (Table 10a, bottom section). A frequency analysis of the responses led to a regrouping of the themes dealing with related issues into the seven groups of Tables 10a and 10b to allow for further analysis, as some of the original themes had too few responses either for statistical significance or would have to be suppressed for confidentiality. These seven groups deal with issues related to business and management, information and communications systems, construction processes, ISO certification, regulations and safety, software applications, and -- a catch-all category -- other issues.

As noted above, only about half of the respondents, representing 45.6% of the population (Table 10a) provided written information on the technological or business practice change or improvement ***which had the "biggest impact" on their business***; response rates were lower for small firms (43.7% of population) and higher for larger firms (65.4%), and relatively even among industry sectors except for the residential contractors which, at 25.7%, had a significantly lower answering rate.

Responses show that in about half of the cases (50.4%, the technological or business practice changes or improvement which were selected did provide the firms with a significant competitive advantage; in 40% of the cases, it did not give any competitive advantage; in 10% of the cases there was no answer as to competitive advantage. The expression of significant advantage is highest for the medium-sized firms, lowest for the large firms; it is also higher for the residential and non-residential trades, lower for the contractors.

Globally, the practices most often cited deal with business and management issues (28.4% of the practices cited), providing significant competitive advantage in 77.7% of the cases. The second most cited practices deal with information and communication systems (24% of the cases), providing competitive advantage in only 46.5% of the cases. Construction process issues (18.4%) and software applications (15.3%) come next, providing competitive advantage in 53% and 44.7% of the cases respectively. Other applications such as ISO certification, regulation and safety issues, were cited by only a very small number of respondents. Of the few who did cite ISO certification (only medium and large firms), close to 70% noted that it did give them significant competitive advantage. And 52.4% of the few large firms who cited regulations and safety issues as the improvement or change with biggest impact on their business noted that it did give than significant competitive advantage; the other firms, however, did not associate regulation and safety issues with competitive advantage.

Whereas business management issues are the most often-cited practices by small firms (with 80% judging that it gave them significant competitive advantage), computers and communications come first for medium and large firms, with good competitive advantage for the medium firms (65% of the cases), but only limited competitive advantage for the larger firms (35.7% of the cases).

By industry sector, the most often-cited technology or business practice change or improvement with biggest impact on the business are:

- ***specialty trades, residential***: business management issues (giving competitive advantage in 91% of the cases)
- ***specialty trades, non-residential****:* information and communication systems, and construction processes (giving competitive advantages in close to 70% of the cases);
- ***speciality trades, engineering****:* business management issues (giving competitive advantage in 44.5% of the cases)
- ***contractors, engineering construction***: information and communication systems, and construction processes (giving competitive advantages in about 32% and 52% of the cases respectively);
- ***contractors residential****:* information and communication systems, and software applications; whereas information and communication systems seem to be a good source of competitive advantage (in 60.7% of the cases), software is not (providing significant advantage in only 12.6 of the cases).
- ***contractors, non-residential****:* information and communication systems (cited by 60.3% of the respondents) but a source of significant competitive advantage in only 14.1% of the cases: in that sector, it seems that information and communication systems have become normal business practices and do not any more confer competitive advantage.

Obstacles to Innovation (Questions 7; definitions Table 11; statistics, Table 12)

The obstacles to innovation listed in Questions 7 of the Survey fall into four categories (Table 11): product and clients (c87 to c89), restrictions (c90, c91), human resources (c92 to c95), and other obstacles (c96 to c98).

In general, there is no evidence of size dependency.

For 45% to 70% of businesses in the total industry sample, two issues are seen to be of great concern.

- High cost is perceived as a uniform problem to all.
- Lack of skilled workers is a big concern, especially for residential contractors, a concern for others and no concern for engineering specialty trade.

Table 10a. Technological or business practice changes with biggest impact on your business -Firm-weighted (Questions 8)

Technological or Business Practice (see "abbreviations", below)	Total sample			Small firms			Medium Firms			Large firms		
	Freq.	**% Signif. Adv**	**% No answer**	**Freq.**	**% Signif. Adv**	**% No answer**	**Freq.**	**% Signif. Adv**	**% No answer**	**Freq.**	**% Signif. Adv**	**% No answer**
AHS: ARR,HUM,STR	28.4%	77.7%	3.8%	30.2%	80.5%	1.5%	22.5%	63.1%	16.1%	10.9%	69.1	6.6
CCI: CAD,COM,ICT	24.0%	46.5%	4.0%	19.9%	37.6%	3.8%	39.3%	65.1%	4.3%	39.5%	35.7	5
DEP: DES,EQP,PDT	18.4%	53.0%	11.0%	19.6%	51.3%	12.2%	13.9%	63.4%	3.6%	14.5%	35.0%	14.7%
SOF	15.3%	44.7%	6.5%	15.1%	44.4%	7.7%	15.7%	46.2%	2.8%	16.5%	39.2	0
RS: REG,SAF	5.2%	2.5%	35.6%	6.0%	1.1%	38.4%	2.4%	12.5%	10.0%	2.7%	52.4	0
ISO	0.4%	68.3%	9.1%	0.0%	0.0%	0.0%	1.6%	68.6%	8.7%	3.9%	66.4	11.7
Other (generally irrelevant)	8.3%	3.2%	37.9%	9.2%	2.3%	37.1%	4.6%	9.9%	39.3%	11.8%	6.5	60.8
Responding firms (%)	**100.0%**	**50.4%**	**10.1%**	**100.0%**	**48.8%**	**10.5%**	**100.0%**	**57.8%**	**8.4%**	**100.0%**	**38.1**	**12.5**
Responding firms (population)	**41410**			**32687**			**8164**			**559**		
% of population	45.6%			43.7%			54.3%			65.4%		
Total firms (population)	90731			74846			15030			855		

Note: Among the respondents who have proposed a specific Technological or Business Practice Change or Improvement, percentage who said that it gave them a significant competitive advantage (% **Signif.Adv.**), and percentage who did not indicate whether it gave or did not give them such advantage (% **No answer).**

Abbreviations:

AHS: Business and management	ARR	Business arrangements (other than design-build)	HUM	Human resources
	STR	Business Strategy		
CCI: Information and communication systems, etc	CAD	Computer-aided design	COM	Communications technologies
	ICT	Information and communications technologies, general		
DEP: Construction processes	DES	Design-Build	PDT	Products: new products and systems
	EQP	Equipment and building practices or techniques		
ISO	ISO	ISO certification		
RS: Regulatory environment	REG	Regulations (other than safety)	SAF	Safety
SOF	SOF	Software applications		

Table 10b. Technological or business practice changes with biggest impact on your business -Firm-weighted (Questions 8)

Technological or Business Practice (see "abbreviations", Table 14-a)	**Trades, residential**			**Trades, non-residential**			**Trades, engineering**			**Engineering contractors**			**Residential contractors**			**Non-residential contractors**		
	Freq.	**% Signif. Adv**	**% No ans-wer**	**Freq.**	**% Signif. Adv**	**% No ans-wer**	**Freq.**	**% Signif. Adv**	**% No ans-wer**	**Freq.**	**% Signif. Adv**	**% No ans-wer**	**Freq.**	**% Signif. Adv**	**% No ans-wer**	**Freq.**	**% Signif. Adv**	**% No ans-wer**
AHS: ARR, HUM, STR	54.3%	91.0%	0.4%	13.8%	45.6%	18.2%	50.1%	44.5%	4.7%	8.6%	73.6%	0.0%	19.5%	77.1%	1.6%	6.1%	33.3%	1.1%
CCI: CAD, COM, ICT	12.0%	37.6%	0.6%	25.4%	64.7%	8.4%	21.6%	36.5%	0.0%	36.5%	31.7%	4.9%	25.3%	60.7%	2.8%	60.3%	14.1%	0.9%
DEP: DES, EQP, PDT	13.5%	50.3%	10.8%	25.0%	68.3%	17.3%	4.7%	52.5%	25.0%	29.0%	52.2%	2.0%	17.2%	0.0%	0.0%	3.4%	91.9%	0.0%
SOF	6.7%	24.9%	40.2%	18.3%	63.9%	1.5%	12.1%	38.0%	1.8%	16.5%	1.8%	0.0%	28.7%	12.6%	0.0%	18.8%	51.8%	2.2%
ISO	0.0%	--	--	<1%	--	--	<2%	--	-2.0%	<1%	--	--	0.0%	--	--	<2%	--	--
RS: REG, SAF	7.6%	0.0%	39.6%	3.3%	9.9%	0.7%	2.6%	0.0%	0.0%	<2%	--	--	5.2%	0.0%	0.0%	<1%	--	--
Other (generally irrelevant)	6.0%	3.8%	75.0%	13.7%	2.4%	8.7%	7.7%	6.8%	88.7%	7.6%	17.1%	22.6%	4.1%	0.0%	97.6%	9.1%	0.0%	97.5%
Responding firms (%)	**100%**	**62.6%**	**11.9%**	**100%**	**52.5%**	**10.5%**	**100%**	**37.8%**	**11.1%**	**100%**	**35.1%**	**4.5%**	**100%**	**34.0%**	**5.0%**	**100%**	**25.4%**	**9.8%**
Responding firms (population)	**13425**			**14072**			**1711**			**2079**			**4705**			**2273**		
% of population	49.7%			51.9%			47.8%			52.4%			25.7%			58.7%		
Total firms (population)	27006			27129			3576			3968			18287			3873		

Note: Among the respondents who have proposed a specific Technological or Business Practice Change or Improvement, percentage who said that it gave them a significant competitive advantage (% **Signif.Adv.**), and percentage who did not indicate whether it gave or did not give them such advantage (% **No answer).**

Table 11. Questions 7 in Survey

Please check the major obstacles for your business to using new and improved building products, building systems and construction equipment.			
c87	High cost of products/systems and equipment	c93	Lack of in-house expertise
c88	Lack of interest by clients	c94	Inability to train workers within the required time
c89	Resistance to change by businesses with which your business has joint projects	c95	Worker resistance to change
c90	Risk of legal liability	c96	Lack of technical support from vendors
c91	Restrictive codes and standards	c97	Lack of technical support from consultants
c92	Shortage of skilled workers	c98	Inability to evaluate new products and equipment

There is a group of obstacles seen as problems by 20%-25% of the total industry sample:.

- Lack of interest by clients is perceived as an issue by 50% of residential and non-residential contractors, but engineering and all trades are much less concerned.
- Lack of in-house expertise is a problem to all, more acute for residential trades and non-residential contractors.
- Restrictive codes are seen as a bigger problem by non-residential contractors and bigger firms, otherwise it is a seen as a uniform concern.
- Workers resistance to change is a bigger problem for residential contractors and for larger firms.
- Not being able to train workers within the required time is somewhat less of a problem for trades.

This is followed by a group of obstacles that do not seem to be very significant (approx. 15% or less of the total sample).

- Being able to evaluate new products is more important to non-residential contractors.
- Resistance to change by partners is more important to non-residential and residential contractors; engineering contractors and trades don't see it being significant.
- Risk of legal liability is an issue for non-residential contractors (32%), a problem for engineering contractors and larger firms (about 20%) but for residential contractors or trades it is not significant.
- Lack of technical support by vendors is not of great significance to anyone.
- Lack of technical support by consultants is a problem for non-residential contractors and no others.

Table 12. Percentage of businesses identifying specific obstacles to innovation, Firm-weighted (for variable definitions, see Table 11)

Variable	Total sample	Small firms	Medium firms	Large firms	Trades residential	Trades non-residential	Trades engineering	Engineering contractors	residential contractors	Non-residential contractors
# observ.	1735	633	839	263	356	704	113	227	108	153
c87	70.7%	71.5%	66.5%	71.5%	74.5%	68.1%	77.0%	53.7%	72.3%	68.1%
c88	24.8%	24.6%	25.1%	32.4%	11.0%	19.2%	11.8%	12.7%	49.0%	45.7%
c89	12.1%	12.0%	12.6%	11.9%	6.7%	13.1%	5.0%	7.5%	22.8%	22.6%
c90	11.9%	11.0%	16.2%	20.4%	11.7%	11.5%	12.6%	20.4%	7.6%	32.4%
c91	21.9%	20.6%	27.7%	38.7%	16.2%	26.6%	29.8%	18.0%	16.9%	40.1%
c92	45.5%	46.9%	38.5%	48.2%	44.6%	39.4%	13.5%	33.4%	68.0%	35.7%
c93	24.4%	24.7%	23.1%	26.8%	39.0%	16.3%	9.6%	17.9%	20.7%	35.9%
c94	17.0%	16.1%	21.4%	19.7%	11.7%	17.1%	16.4%	13.9%	21.1%	25.1%
c95	22.0%	20.9%	26.7%	33.6%	17.1%	21.3%	26.5%	18.1%	34.2%	19.2%
c96	9.5%	8.7%	12.8%	16.7%	10.1%	12.2%	10.9%	11.7%	1.1%	4.0%
c97	5.8%	5.5%	7.5%	12.4%	8.1%	3.8%	2.5%	5.7%	1.7%	25.5%
c98	14.6%	14.7%	13.4%	22.2%	15.1%	14.7%	8.9%	11.5%	13.0%	29.0%

Sources of information for innovations (Survey Questions 6; definitions, Table 17; statistics Table 18)

Nineteen different potential sources of information for innovations were proposed in Questions 6 of the Survey (Table 17). Some of those sources of information appear to be more appropriate for certain types of construction activities, hence industry sector differences can be expected.

Table 13. Questions 6 in Survey

Please indicate your sources of information on advanced technologies and advanced practices, such as those listed in Questions 3 and 4.			
c66	Trade shows and conferences	c76	Government facility owners or managers
c67	Trade journals and newsletters	c77	Non-government facility owners or managers
c68	Trade associations	c78	Federal information programs
c69	Computer based information networks (including internet)	c79	Federal research organizations
c70	Suppliers of materials, supplies, machinery and equipment	c80	Provincial research organizations
c71	Clients	c81	Universities and colleges
c72	General contractors	c82	Regulatory and standards organizations
c73	Specialty trades	c83	Testing and evaluation service firms
c74	Consulting engineers	c84	Business consultants
c75	Architects		

Two sources of information dominate (total sample use 55% to 72%)

- Suppliers
- Trade journals and newsletters

This is followed by information sources within close working relationships (approximately 40%-45% of the total sample)

- Clients
- General contractors
- Consulting engineers

These are followed in importance by trade oriented sources (approximately 30% of the sample)

- Internet
- Trade shows/conferences
- Trade assoc.
- Specialty trades

Next comes a random group of information suppliers (declining 21% to 13%)

- Architects
- Regulatory/standards
- Business consultants
- Non-government owners
- Government owners

Finally, these are followed by specialized sources (declining 12% to 3%)

- Universities
- Federal research organizations
- Testing/evaluation firms
- Provincial research organizations
- Federal information programs

For each industry sector, the main sources of information are as follows:

- for residential contractors: suppliers, general contractors, specialty trades, clients, trade journals;
- for non-residential contractors: suppliers, clients, consulting engineers, architects, specialty trades;
- for engineering construction contractors: suppliers, trade journals, consulting engineers, general contractors, clients;
- for residential trades: suppliers, trade journals, clients, consulting engineers, computer networks and the Internet;
- for non-residential trades: suppliers, trade journals, clients, general contractors, trade associations;
- for engineering trades: suppliers, trade journals, clients, computer networks and the Internet, trade shows and conferences.

The use of such information increases with firm size. In general, residential contractors use less information and access fewer external sources; non-residential and engineering trades use somewhat less information than the corresponding contractors while residential trades are greater and sometimes significantly greater users than residential contractors.

Table 14 Percentage of businesses using a given source of information for innovations (see Table 13 for variables definition)

Variable	Total sample	Small firms	Medium firms	Large firms	Trades residential	Trades non-residential	Trades engineering	Engineering contractors	Residential contractors	Non-residential contractors
# observ	1735	633	839	263	356	704	113	227	108	153
c66	31.7%	27.2%	52.1%	63.9%	24.8%	42.6%	34.9%	42.2%	24.8%	28.5%
c67	54.5%	51.0%	70.2%	82.8%	64.5%	60.2%	54.4%	85.1%	25.7%	48.7%
c68	31.3%	27.2%	49.5%	69.8%	28.4%	46.7%	22.2%	42.9%	15.2%	38.0%
c69	32.6%	30.5%	41.1%	60.3%	37.2%	34.6%	36.8%	51.9%	18.5%	33.5%
c70	71.5%	69.7%	79.9%	81.5%	73.8%	77.5%	78.0%	85.6%	54.0%	88.4%
c71	44.9%	42.7%	54.8%	60.1%	43.4%	48.4%	46.5%	51.2%	32.9%	73.0%
c72	39.8%	40.5%	36.6%	33.3%	25.7%	47.6%	20.4%	52.9%	45.1%	58.2%
c73	30.1%	29.3%	33.2%	42.3%	19.9%	31.6%	20.4%	18.6%	38.2%	62.7%
c74	37.7%	34.7%	51.2%	62.8%	38.6%	42.3%	26.8%	63.4%	24.9%	67.9%
c75	21.4%	18.6%	34.2%	43.1%	11.6%	31.0%	12.1%	14.8%	16.0%	66.3%
c76	13.0%	13.8%	9.4%	8.4%	27.0%	10.8%	5.0%	9.5%	0.7%	5.9%
c77	13.3%	13.7%	11.2%	14.4%	23.6%	13.0%	7.0%	11.3%	2.6%	15.2%
c78	3.4%	2.4%	7.9%	7.2%	4.9%	2.3%	3.9%	5.3%	2.7%	6.4%
c79	9.5%	10.4%	5.3%	5.8%	27.1%	1.7%	0.7%	3.4%	2.0%	7.0%
c80	3.5%	2.9%	5.9%	9.0%	5.8%	2.3%	2.0%	2.8%	3.1%	4.4%
c81	12.0%	12.6%	9.1%	13.8%	26.3%	7.0%	2.5%	6.9%	1.7%	7.3%
c82	17.6%	17.6%	17.0%	35.9%	16.1%	25.5%	10.7%	20.6%	10.9%	12.3%
c83	7.5%	6.6%	10.6%	28.9%	6.8%	7.3%	5.7%	11.8%	6.8%	14.2%
c84	17.3%	16.8%	19.2%	31.6%	32.6%	13.8%	7.5%	7.6%	8.3%	15.0%

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Chapter IV: Conceptual Model Analysis and Results

A Conceptual Model of Innovation for Construction Industry Data

In Chapter I, we reviewed a number of viewpoints of the process of innovation by firms in different industries, but especially construction. Based on the ideas encountered there, and the questions posed in the survey questionnaire for the present exercise, we have developed a conceptual model to describe the linkages between the business environment, business strategy, innovative practices and business outcomes, all subject to modification or influence of the business characteristics, that is, size or industry sector, and the presence of major obstacles to the use or profit from innovation. We recognize that there are many limitations to the validation of such a model. In particular, the survey may not have asked the "right" questions to allow such validation, or the respondents may not have answered them even if they are present. Moreover, the "outcomes" are principally financial ratios from a survey that represents essentially a single time point. Thus we cannot easily infer a trend in outcomes. As we have mentioned in the first section of Chapter II, there were also some further restrictions on the financial data.

We based our data analysis on a model (Figure 6) which represents a logical interpretation of the variables based on theory and general industry knowledge. Overall, the model represents a series of inter-relationships among numerous variables that correspond to various sections of the survey and financial data. Conceiving and testing a model appeared necessary to avoid extensive and meaningless "data-mining" and to provide a useful context for interpreting the results.

As expected, the heart of the model concerns both business (survey Questions 3) and technological (Questions 4) innovative practices. We investigated the effects of innovative practices on financial outcome measures (the ratios from the financial data supplied to us). Our reasoning is predicated on the belief that innovation will lead to improved profitability and perceptions of competitive advantage on the part of management. Both of these factors are argued as the main results that managers expect to achieve when investing resources in innovative practices.

The model also illustrates a number of variables that lead to innovative practices. It is believed that these variables are the inputs or antecedent conditions necessary for managers to engage in innovative practices. Foremost among these variables is the business environment (Questions 1) which reflects managers' perceptions of the market conditions regarding competition, customers and suppliers. We expect certain management perceptions will provide the impetus for innovation investments. For example, certain market conditions (competitive pressure) should lead to higher levels of innovation since managers need to innovate to attain competitive advantages. Secondly, three sources of variables pertaining to managers' attitudes toward their business strategy, human resources and technology (Questions 2) are related to innovative practices. In the case of business strategy, we expect that if managers hold pro-active attitudes toward their markets or customer base would lead to higher levels of innovative practices in order to take advantage of certain market conditions or customer opportunities. Similarly, positive beliefs in human resource policies (e.g., training) or technological investments (e.g., research and development) reflect an overall and favourable attitude toward innovation which would lead to actual innovation practices (i.e., tangible behaviour).

We believe business characteristics (i.e., size, sector) may also influence the nature of innovation practices. Larger firms may have greater levels of resources allowing them to engage in more or a wider variety of innovations. Furthermore, we believe that innovation practices may differ between residential versus non-residential firms or trades versus contractors.

Finally, obstacles (Questions 7) that hinder innovation appear to be a significant factor in our investigation. Managers' beliefs that certain limitations that exist in their market, human resources, and the external supply service could provide reasons for managers not to engage in innovation practices.

We developed a conceptual model (Figure 6) to guide the statistical analysis so that it corresponds to the survey and the construction and innovation literature. In addition, this analysis uses the calculated variables of innovative practices, major obstacles, and financial outcomes discussed previously in Chapter III. Throughout the analysis we continue to investigate the effects of different sizes and sectors. We tested the model with multivariate statistics in various stages. Elaboration of each analysis in relation to the model is explained within each section but we provide a brief overview here.

Perceived business environment variables (Questions 1) and views of business strategy variables (Questions 2) are psychological variables since they reflect the perceptions and beliefs of managers (Table 15). As such they are amenable for multi-variate statistical procedures like factor analysis which summarize many variables into fewer higher order variables or factors. Such a procedure permits greater parsimony of the model and provides a simpler interpretation of statistics. We relied on principal component analysis that produced rotated and orthogonal (i.e., uncorrelated) factor solutions. The factor analysis resulted in five factors representing business environment, five factors representing marketing strategy, four factors representing human resource strategy and three factors representing technology strategy.

Figure 6. Model for analysis of innovation in construction.

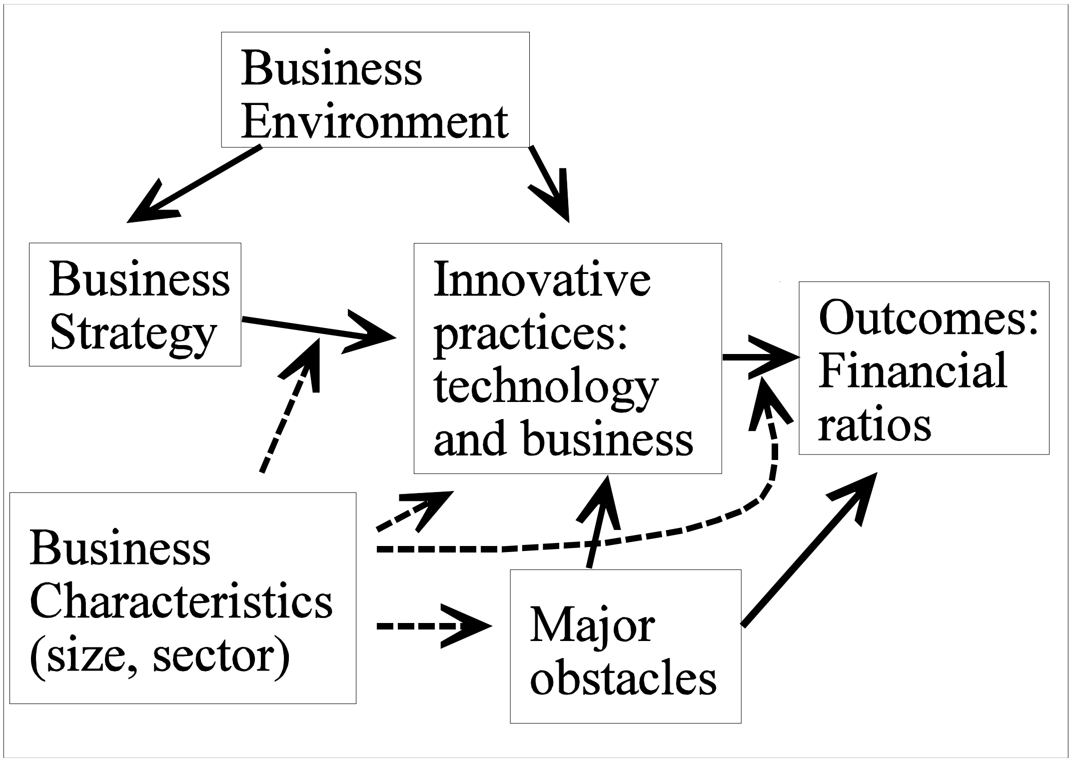

Table 15. Survey Questions 1 and 2

Questions 1: For your business, please indicate how strongly you are or disagree with the following statements	c14 Attracting new clients
c1 My clients' needs are easy to predict	c15 Providing a broader range of services to your clients
c2 My client can easily find a substitute for my services	c16 Ensuring employees are aware of business issues and opportunities
c3 My competitors' actions are easy to predict	c17 Encouraging and rewarding your employees to seek out technological improvements
c4 My competitors can easily substitute among suppliers	c18 Encouraging and rewarding your employees to seek out organizational improvements
c5 The arrival of new competitors is a constant threat	c19 Providing training programs for employees
c6 Materials and supplies quickly become obsolete	c20 Hiring new graduates from colleges and universities
c7 Technologies in the office are changing rapidly	c21 Hiring experienced employees
c8 Technologies on the construction/building site are changing rapidly	c22 Participating in apprenticeship programs
	c23 Using teams which bring together people with different skills
Questions 2: Please rate the importance of each of the following factors for the success of your business	c24 Introducing new user-friendly technologies
c9 Developing unique expertise or a unique market	c25 Investing in research and development
c10 Delivering products or services which reduce the client's operating costs	c26 Protecting intellectual property (patents, trademarks, copyrights, etc.)
c11 Seeking business outside of your present geographical region of activity	c27 Enhancing your engineering capabilities
c12 Increasing your market share	c28 Participating in the development of industry standards and practices
c13 Building and enhancing relationships with existing clients	

We used multiple regression analysis to test directional relationships indicated in Figure 6. This chapter groups our analysis into sections that correspond to the factors; relationship between business environment and business strategy variables, relationship between business strategy and innovation variables, relationship between innovation variables and pretax operating margin, relationship between innovation and obstacles variables. Finally, we present a cluster analysis that attempts to determine if groups of innovative firms would emerge.

Creation of Business Environment and Business Strategy Variables

In this section we report the creation of the seventeen factors derived from thirty-six responses from questions one and two of the survey. As done previously, we continue to report results for firm-weighted data (Table 16a) initially and then compare the results with wage-weighted data (Table 16b).

A factor analysis of the eight business environment variables produced a five factor solution that explained 80.5% of the variation. We did not accept a four factor solution since it only explained 72.7% of the variation and we did not accept a six factor solution since it produced four single variable factors that appeared less parsimonious. The five factors were identified based on their composition which are included in brackets; *rapid technological change* (c7, c8), *competitive threats* (c2, c5), *consumer/competitor predictability* (c1, c3), *many suppliers* (c4) and *materials obsolescence* (c6).

A factor analysis of the seven business strategy variables produced a five factor solution that explained 88.9% of the variation. We chose to investigate an eighth business strategy variable as a human resource variable since it referred to employee knowledge. We considered a three factor solution that provided strong interpretation, however we eventually discounted it since it only explained 71.7 % of the variation. The five factors were identified as *market share expansion* (c9, c12), *client retention* (c13, c14), *expanded product range* (c15), *geographic expansion* (c11), and *awareness of clients operating costs* (c10).

Eight human resource variables produced a four factor solution that explained 82.6% of the variation. Similar to the above two factor analyses, a five factor solution was less interpretable and the three factor solution only explained 76.5% of the variation. Four variables (c16, c17, c18, c19) represented an *employees skills/ knowledge development* factor. The remaining factors represented *hiring experienced workers* (c21), *hiring well trained new graduates* (c22) and *multi-skilled teams* (c23). However, these latter factors are not completely "clean" since two variables from the first factor load with two other factors.

Table 16a. Factor definition (Firm weighted))

Variables		Correlations
Questions 1: Business Environment		(80.5% of the variance)
	Rapid technological change	**c7** , c8
	Competitive threats	**c2** , c5
	Consumer/competitor predictability	c1 , **c3**
	Many suppliers	**c4**
	Materials obsolescence	**c6**
Questions 2: Business Strategy		
2-1: Marketing strategy		(88.9% of the variance)
2.1.1	Market share expansion	c9 , c12
2.1.2	Client retention	**c13** , c14
2.1.3	Expanded product range	**c15**
2.1.4	Geographic expansion	**c11**
2.1.5	Awareness of clients operating costs	**c10**
2-2: Human resources strategy		(82.6% of the variance)
2.2.1	Employees skills/knowledge development	c16 , c17 , **c18** , c19
2.2.2	Hiring experienced employees	c16 , **c21**
2.2.3	Hiring well trained new graduates	c20 , **c22**
2.2.4	Multi-skilled teams	c17 , c20 , **c23**
2-3: Technology strategy		(86.4% of the variance)
2.3.1	Improving technology practices/capabilities	**c24 ,** c25 , c27
2.3.2	Developing proprietary technologies	c25 , **c26**
2.3.3	Developing industry standards/practices	**c28**

Table 16b. Factor definition (Wage weighted)

Variables		Correlation
Questions 1: Business Environment		(80.9% of the variance)
	Rapid technological change	**c7** , c8
	Competitive threats	c2 , c5
	Consumer/competitor predictability	**c1 , c3**
	Many suppliers	**c4**
	Materials obsolescence	**c6**
Questions 2: Business Strategy		
3-1: Marketing strategy		(86.8% of the variance)
3.1.1	Market share expansion	c9, **c12**
3.1.2	Client retention	**c13 , c14**
3.1.3	Expanded product range	**c15**
3.1.4	Geographic expansion	**c11**
3.1.5	Awareness of clients operating costs	c9, **c10**
3-2: Human resources strategy		(80.4% of the variance)
3.2.1	Encouraging employees to seek technological or organizational improvements	**c17 , c18 ,** c19
3.2.2	Hiring Experienced Employees	**c21,** c22
3.2.3	Helping employees to be aware of business issues	c16
3.2.4	Hiring new employees or using multi-skilled teams	c20 , c22, c23
3-3: Technology strategy		(84.9% of the variance)
3.3.1	Improving technology practices/capabilities	**c24 ,** c25, c27
3.3.2	Developing proprietary technologies	c25, **c26**
3.3.3	Developing industry standards/practices	**c28 ,** c27

Note on correlations: >0.85 = **bold**; 0.85 to 0.70 = underlined; otherwise >=0.45

The technology variables produced a three factor solution that explained 86.4% of the variation. We identified *improving technology practices/capabilities* (c24, c25, c27), *developing proprietary technologies* (c26) and *developing industry standards/practices* (c28).

The wage weighted data provided fairly similar factor structures. The exact same factors emerged for perceived business environment. A very minor difference occurred for the marketing strategy and technology strategy factors (one variable had an additional correlation with a different factor for each). We noted a substantial difference in the factor structure for the human resources strategy variables with slightly less variance explained (i.e., 80.4% vs. 82.6%). As a result, we conceived different factor names.

Factor means by firm size are given in Table A5, Appendix A.

Relationship between Business Environment and Business Strategy Variables

Our first set of regressions investigated the effects of five business environment factors on each of twelve business strategy factors for the firm weighted data (Table 17a). An important result is that all twelve regression equations are significant which indicates preliminary support for our conceptual model.

Despite this result, we note that the variance explained (R^2) is consistently below 10% for nine regressions which is somewhat below what one might expect for behavioural research. In contrast, among the three other regressions, the environment factors predict *extended product range*, *employees skills/knowledge development,* and *improving technology practices/capabilities* with 14%, 21% and 13% respectively. Thus, we find stronger support for these three business strategy factors versus the remaining nine.

Each regression has at least three significant environment factors with three regressions having all five environment factors as significant predictors. Surprisingly, *client retention* has a very low variance explained (R^2) however all five environment factors are significant.

Table 17a. Relationship between business environment and business strategy (Firm weighted)

N=1739. All regression p-values <0.0001 *Significance levels of coefficients: .05 *; .01 **; .001 ****

Business Environment	2.1.1	2.1.2	2.1.3	2.1.4	2.1.5	2.2.1	2.2.2	2.2.3	2.2.4	2.3.1	2.3.2	2.3.3
Rapid technological change	.27***	.06**	.13***	.13***	.23***	.36***	-.10***	.18***	.22***	.35***	.24***	.14***
Competitive threats	-.07**	.12***	.28***	.11***	-.06*	.19***	.09***	-.16***	-.06**	-.06**	0.01	0.04
Consumer/competitor predictability	-.02	.06**	.13***	.02	.09***	.12***	-.00	-.06*	.13***	-.01	.10***	.10***
Many suppliers	-.07**	.07**	.05*	-.20***	.00	.10***	.20***	-0.03	-.15***	-.08***	-.06**	-.04*
Materials obsolescence	0.02	-.06**	.14***	.10***	.02	.13***	-.07**	.02	.00	0.02	.12***	-.11***
R2	0.08	0.031	0.136	0.077	.062	0.21	0.06	0.06	0.09	0.13	0.09	0.05

Legend for column headings:

2-1: Marketing strategy	**2-2: Human resources strategy**	**2-3: Technology strategy**
2.1.1 Market share expansion	2.2.1 Employees skills/knowledge development	2.3.1 Improving technology practices/capabilities
2.1.2 Client retention	2.2.2 Hiring experienced employees	2.3.2 Developing proprietary technologies
2.1.3 Extended product range	2.2.3 Hiring well trained new graduates	2.3.3 Developing industry standards and practices
2.1.4 Geographic expansion	2.2.4 Multi-skilled teams	
2.1.5 Awareness of clients operating costs		

Table 17b. Relationship between business environment and business strategy (Wage weighted)
*N=1739. All regression p-values <0.0001 Significance levels of coefficients: .05 *; .01 **; .001 ****

Business Environment	3.1.1	3.1.2	3.1.3	3.1.4	3.1.5	3.2.1	3.2.2	3.2.3	3.2.4	3.3.1	3.3.2	3.3.3
Rapid technological change	.24***	.11***	.16***	.12***	.28***	.41***	-0.02	0.03	.23***	.44***	.15***	.11***
Competitive threats	.07***	0	.26***	.10***	-.07**	0.04	-.07**	.25***	-0.04	0.02	.05**	-0.02
Consumer/competitor predictability	-0.01	.05*	.08***	0.02	-0.02	.10***	-.14***	.12***	0	-0.02	0.03	.10***
Many suppliers	-0.02	0	0.03	-.10***	-0.03	0	-0.02	.09***	-.08***	-.08***	-0.03	-.11***
Materials obsolescence	.06*	-.09***	.12***	.12***	0.04	.18***	-.14***	.06**	0.04	.09***	.09***	-.07**
R2	0.07	0.02	0.12	0.05	0.09	0.22	0.04	0.09	0.06	0.21	0.04	0.04

Legend for column headings:

3-1: Marketing strategy
3.1.1 Market share expansion
3.1.2 Client retention
3.1.3 Expanded product range
3.1.4 Geographic expansion
3.1.5 Awareness of clients operating costs

3-2: Human resources strategy
3.2.1 Encouraging employees to seek tech. or organiz. improvements
3.2.2 Hiring experienced employees
3.2.3 Helping employees to be aware of business issues
3.2.4 Hiring new employees or using multi-skilled teams

3-3: Technology strategy
3.3.1 Improving technology practices/capabilities
3.3.2 Developing proprietary technologies‘
3.3.3 Developing industry standards and practices

Rapid technological change is consistently a significant and the strongest predictor for all twelve business strategies. It presents a positive relationship in eleven cases, so it appears to be a clear impetus for engaging in strategic business decisions; and, it has a negative impact upon *hiring experienced workers,* thus indicating that firms may delay hiring or substitute hiring with technological change. Similarly, *competitive threats* tend to lead to a reduction in five business strategies, most notably *hiring well trained new graduates*. Thus, firms appear not to invest in human resources when the environment presents conditions suggesting otherwise. Alternatively, the industry does not see educated employees as a competitive tool.

As suggested above, the remaining four environmental factors significantly predict eight to ten dependent factors, many with fairly substantial strength (i.e., coefficient greater than .10).

Our regressions for the wage weighted data support the firm weighted data as all twelve equations are significant (Table 17b). However, once again the variance explained (R^2) is weak in the similar nine regressions and strong in the same three regressions (i.e., product range, employee knowledge, technological skills).

Rapid technological change is still a strong predictor since it is significant in ten of twelve regressions. The effects of three of the remaining four environmental factors continue to show uniformity as they are significant in half of the regressions. Surprisingly, the final environmental factor, *materials obsolescence* is significant in ten regressions which is similar to *rapid technological change.* This combination of materials and technology is interesting since they appear to be more related to innovation than the other environmental factors that focus more on the behaviour of other stakeholders.

In contrast to the firm weighted data, each regression has at least only two significant environment factors and no regression has all five environment factors as significant predictors. And, *client retention* continues to have a very low variance explained (R^2) but only has three significant environment factors. Furthermore, the number of negative relationships for *competitive threats* drops from five to two.

Relationship between Business Strategy and Innovation Variables

These regressions investigated the effects of the twelve business strategies on the three innovation variables, i.e., overall, technological and business practices. The regressions were done within blocks; five marketing strategy factors on three innovation variables, four human resource factors on three innovation variables and three technology factors on three innovation variables. The regressions were also done for the total data set, for each of the three firm sizes and for the seven industry sectors.

We begin with overall innovation which contains both technology and business innovation (Table 18a). For the total data, eleven of twelve factors are significant predictors with the only exception being "expanded product range". The R^2 for each of the three regressions is substantial in the 26% to 31% range which is about the expected range for behavioural research.

Growth appears to be critical for innovation from a marketing standpoint since *market share expansion* and *geographic expansion* are strong predictors. An important human resource strategy is to foster multi-skilled teams since this factor is the strongest predictor of innovation. Finally, two of three technological strategies appear equally important for innovation.

Expanding the analysis to the three sizes we make two observations. First, we note that the variance explained ($R^{2)}$ for the three regressions of the medium and large sized firms are consistently lower versus small sized firms. However, small and medium sized firms each have ten of twelve significant factors predicting innovation. Together, these points indicate that the conceptual model is supported fairly well for small and medium sized firms alike. Second, there is a substantial difference for large firms as only seven factors significantly predict innovation. Further, the nature of these factors are also important to note. *Expanded product range*, *employee skill/knowledge development*, *multi-skilled teams* are all substantially stronger predictors of innovation for large sized firms versus small and medium sized firms.

Regressions for each sector (Table 18b) produce interesting results.

- For non residential, human resource and technology factors strongly predict innovation for trades (vs. contractors), and marketing factors strongly predict innovation for the contractors (vs. trades)
- For residential, marketing and technology factors equally predict innovation for both contractors and trades, and human resource factors strongly predict innovation for trades (vs. contractors).
- For engineering, marketing factors strongly predict innovation for trades (vs. contractors), and human resource and technology factors equally predict innovation for both contractors and trades.

We interpret this as evidence that a unified "construction industry" may be an illusion and that recommending generic "best practices" for the industry is not advocated. This implies that within the conceptual model each sector is driven by different variables. Various combinations of the three sources of business strategy factors predict innovation when looking across six different industry players, suggesting that each sector may have its own business characteristics.

We continue with business practices innovation (Table 19a). For the total data, again eleven of twelve factors are significant predictors with the same exception. The R^2 for each of the three regressions is substantial in the 26% to 32% range.

Compared to the overall innovation results, we find similar results. Growth factors, *multi-skilled teams* and two of three technological strategies still appear to be a important reasons for business innovation.

Table 18a. Relationship between business strategy and INNOVCU (Firm weighted)

All regression p-values <0.001 *Coefficient levels of significance: *** p<=0.001; **p<=0.01; * p<=.05*

Firm Size	**Total**	**Small**	**Medium**	**Large**
Sample size	**1739**	**633**	**839**	**267**
Population (weights)	**90731**	**74846**	**15030**	**855**
2-1: Marketing strategy				
Market share expansion	1.3***	1.19***	1.01***	
Client retention	0.49***	0.44***	0.45*	
Expanded product range			0.46**	1.56***
Geographic expansion	1.41***	1.31***	1.24***	
Awareness of clients operating costs	1.08***	1.14***	0.86***	0.81*
R2	0.26***	0.29***	0.11***	0.09***
2-2:Human resources strategy				
Employees skills/knowledge development	1.0***	0.90***	1.2***	2.02***
Hiring experienced employees	-0.28**	-0.35**		
Hiring well trained new graduates	0.98***	0.87***	1.07***	0.88*
Multi- skilled teams	1.77***	1.84***	.94***	2.26***
R2	0.27***	.30***	.11***	0.14***
2-3: Technology strategy				
Improving technology practices/capabilities	1.67***	1.71***	1.06***	1.81***
Developing proprietary technologies	1.04***	0.85***	1.71***	1.53***
Developing industry standards/practices	1.44***	1.34***	1.45***	
R2	0.31***	0.34***	0.19***	0.09***

Table 18b. Relationship between business strategy and INNOVCU (Firm weighted)

All regression p-values <0.001 *Coefficient levels of significance: *** p<=0.001; **p<=0.01; * p<=.05*

Sector	Trades Residential	Trades Non-residential	Trades Engineering	Contractor Engineering	Contractor Residential	Contractor Non-residential
Sample size	**356**	**704**	**113**	**227**	**108**	**153**
Population (weights)	**27006**	**27129**	**3576**	**3968**	**18286**	**3873**
2-1: Marketing strategy						
Market share expansion	1.16***	1.23***	1.61***		0.98***	1.2**
Client retention	0.42*				0.81**	
Expanded product range	0.51*	.47**		-0.92**	-0.80*	
Geographic expansion	2.16***	.57***	1.25***		0.84*	1.59***
Awareness of clients operating costs	1.06***	1.02***	1.26**	1.21**	0.59*	1.43***
R2	0.47***	0.13***	0.41***	0.14***	0.37***	0.34***
2-2:Human resources strategy						
Employees skills/knowledge development	1.8***	0.42**		2.06***	1.41***	1.53**
Hiring experienced employees	-0.59**	-0.47***		1.27**		
Hiring well trained new graduates	0.47*	1.38***	1.02*	2.37***		
Multi-skilled teams	1.91***	1.59***	1.94***	1.71***	1.49***	1.53**
R2	0.39***	0.28***	0.25***	0.41***	0.19***	0.14***
2-3: Technology strategy						
Improving technology practices/capabilities	1.38***	1.83***	1.16**	3.65***	1.42***	1.09*
Developing proprietary technologies	1.03***	1.13***	1.70***	1.40***	1.44**	1.65***
Developing industry standards/practices	1.90***	1.38***	0.85*	1.76***	1.57***	1.34**
R2	0.40***	0.29***	0.26***	0.34***	0.33***	0.14***

For the three firm sizes, we find very similar results for small and medium firms as most business strategy factors predict business innovation. The R^2 for the three regressions for small sized firms is again consistently strong. For medium sized firms, the R^2 for the technology strategy regression is stronger than the other two regressions. Again these facts offer support for the conceptual model for small and medium sized firms.

We observe a difference for large firms since only five factors significantly predict business innovation and the same three factors that predict overall innovation also standout for predicting business innovation.

The business innovation regressions for each sector yield similar results (Table 19b)

- For non-residential, human resource and technology factors strongly predict business innovation for trades (vs. contractors), and marketing factors strongly predict business innovation for contractors (vs. trades).
- For residential, marketing, human resource and technology factors strongly predict business innovation for trades (vs. contractors).
- For engineering, marketing factors strongly predict business innovation for trades (vs. contractors), and human resource and technology factors strongly predict business innovation for contractors (vs. trades).

Table 19a. Relationship between business strategy and INBUSCU (Firm weighted)

All regression p-values <0.0001 *Levels of significance: *** p<=0.0001; **p<=0.01; * p<=.05*

Firm Size **Sample size** **Population (weights)**	**Total** **1739** **90731**	**Small** **633** **74846**	**Medium** **839** **15030**	**Large** **267** **855**
2-1: Marketing strategy				
Market share expansion	0.73***	0.72***	0.31**	
Client retention	0.31***	0.28***	0.34**	
Expanded product range				0.74***
Geographic expansion	0.84***	0.79***	0.74***	
Awareness of clients operating costs	0.61***	0.64***	0.45***	
R2	0.27***	0.31***	0.10***	0.08***
2-2: Human resources strategy				
Employees skills/knowledge development	0.64***	0.59***	0.71***	1.25***
Hiring experienced employees	-0.16**	-0.20**		
Hiring well trained new graduates	0.48***	0.45***	0.45***	
Multi-skilled teams	0.98***	1.05***	0.36***	1.24***
R2	0.26***	0.31***	0.07***	0.19***
2-3: Technology strategy				
Improving technology practices/capabilities	0.87***	0.94***	0.44***	0.72**
Developing proprietary technologies	0.65***	0.53***	1.07***	1.00***
Developing industry standards/practices	0.89***	0.82***	1.01***	
R2	0.32***	0.35***	0.24***	0.12***

The conceptual model holds to some degree for residential and non-residential for business innovation. In general it appears that all three business strategies are more important for trades versus contractors. Thus, recommending generic “best practices” may be suggested for business innovation, but the practices recommended will be different for the different sectors.

We finish with technology innovation (Table 20a). For the total data, eleven of twelve factors are significant predictors with the same exception. The R^2 for each of the three regressions is weaker in the 17% to 21% range. And we continue to observe the same five factors predicting both technological and business innovation.

Table 19b. Relationship between business strategy and INBUSCU (Firm weighted)

All regression p-values <0.0001 *Levels of significance: *** p<=0.0001; **p<=0.01; * p<=.05*

Sector	Trades Residential	Trades Non-residential	Trades Engineering	Contractor Engineering	Contractor Residential	Contractor Non-residential
Sample size	**356**	**704**	**113**	**227**	**108**	**153**
Population (weights)	**27006**	**27129**	**3576**	**3968**	**18286**	**3873**
2-1: Marketing strategy						
Market share expansion	0.78***	0.66***	0.70***			0.61**
Client retention					0.49**	
Expanded product range		0.22**			-0.59**	
Geographic expansion	1.46***	0.17*		0.42*	0.55**	0.77***
Awareness of clients operating costs	0.88***	0.54***		0.62**		0.54**
R2	0.51***	0.13***	0.19***	0.09***	0.32***	0.30***
2-2: Human resources strategy						
Employees skills /knowledge development	1.32***			1.25***	0.82**	0.81***
Hiring experienced employees	-0.42***					
Hiring well trained new graduates		0.68***	0.84***	0.98***		
Multi-skilled teams	1.31***	0.87***	0.94***	0.82***	0.63**	0.69**
R2	0.45***	0.26***	0.20***	0.30***	0.13**	0.16***
2-3: Technology strategy						
Improving technology practices/capabilities	0.98***	0.85***	0.49*	1.78***	0.65***	
Developing proprietary technologies	0.73***	0.47***	0.62***	0.82***	0.89**	0.69***
Developing industry standards/practices	1.24***	0.70***	0.82***	0.96***	0.98***	0.59**
R2	0.44***	0.23***	0.19***	0.33***	0.32***	0.11***

For three sizes, we find very similar results as eleven and ten business strategy factors are significant for small and medium sized firms respectively. We still see less of a difference for large sized firms since eight business strategy factors significantly predict technology innovation. Overall, firms almost consistently use the same strategies regardless of size for technology innovation. However, the R^2 for the regressions for the medium and large sized firms are consistently lower despite this similarity.

The technology regressions for each sector lead to similar results (Table 20b).

- For non-residential, human resource and technology factors strongly predict technology innovation for trades (vs. contractors), and marketing factors strongly predict technology innovation for contractors (vs. trades).
- For residential, marketing, human resource and technology factors strongly predict technology innovation for trades (vs. contractors).
- For engineering, marketing factors strongly predict technology innovation for trades (vs. contractors), human resource factors strongly predict technology innovation for contractors (vs. trades), and technology factors equally predict technology innovation for both contractors and trades.

Table 20a. Relationship between business strategy and INTECCU (Firm weighted)

All regression p-values <0.001 *Levels of significance: *** p<=0.001; **p<=0.01; * p<=.05*

Firm Size **Sample size** **Population (weights)**	**Total** **1739** **90731**	**Small** **633** **74846**	**Medium** **839** **15030**	**Large** **267** **855**
2-1: Marketing strategy				
Market share expansion	.57***	.47***	.71***	
Client retention	.18**	.16*		
Expanded product range			.30***	.83***
Geographic expansion	.57***	.52***	.49***	
Awareness of clients operating costs	.47***	.50***	.41***	.49*
R2	.17***	.18***	.09***	.07**
2-2: Human resources strategy				
Employees skills/knowledge development	.36***	.31***	.49***	.77*
Hiring experienced employees	-.12*	.15*		.58*
Hiring well trained new graduates	.50***	.42***	.62***	.62*
Multi- skilled teams	.80***	.79***	.58***	1.02***
R2	.20***	.21***	.11***	.09***
2-3: Technology strategy				
Improving technology practices/ capabilities	.80***	.77***	.61***	1.09***
Developing proprietary technologies	.39***	.32***	.65***	.54*
Developing industry standards/practices	.56***	.52***	.44***	
R2	.21***	.24***	.10***	.05**

Table 20b. Relationship between business strategy and INTECCU (Firm weighted)

All regression p-values <0.001 *Levels of significance: *** p<=0.001; **p<=0.01; * p<=.05*

Sector **Sample size** **Population (weights)**	**Trades Residential** **356** **27006**	**Trades Non-residential** **704** **27129**	**Trades Engineering** **113** **3576**	**Contractor Engineering** **227** **3968**	**Contractor Residential** **108** **18286**	**Contractor Non-residential** **153** **3873**
2-1: Marketing strategy						
Market share expansion	.38***	.57***	.91***		.69***	.59*
Client retention	.21*				.32*	
Expanded product range	.26*	.25**	.34*	-.68***		
Geographic expansion	.70***	.40***	1.04***			.82***
Awareness of clients operating costs	.18*	.48***	.84***	.59**	.36**	.89***
R2	.32***	.11***	.48***	.16***	.35***	.30***
2-2: Human resources strategy						
Employees skills/knowledge development	.49***	.30***		.81***	.59**	.72*
Hiring experienced employees	-.16*	-.34***	.82**	1.01***		
Hiring well trained new graduates	.30***	.70***		1.39***		
Multi- skilled Teams	.60***	.72***	1.00***	.89***	.86***	.84**
R2	.23***	.23***	.25***	.42***	.21***	.10**
2-3: Technology strategy						
Improving technology practices/ capabilities	.40***	.98***	.67**	1.87***	.77***	.73*
Developing proprietary technologies	.30***	.66***	1.08***	.58***		.96***
Developing industry standards/practices	.67***	.68***		.79**	.60***	.75**
R2	.26***	.27***	.26***	.26***	.25***	.12***

Relationship between Business Environment and Innovative Behaviours

Regression analysis was used to estimate the similarities between innovative behaviours (INNOVCU, INBUSCU and INTECCU) and the perceptions of the respondents on their business environment (five business environment factors).

The following similarities have been observed (Tables 21a and 21b):

- Increasingly innovative behaviours as the respondent's perception of rapid technological change increases, except for Engineering Trades which shows the reverse relationship;
- Decreasing innovative behaviours with the increase of perceived competitive threats, except for Residential Trades which seem to be more innovative with increasing perceived competitive threats;
- Increasingly innovative behaviours for large firms with a larger number of suppliers; this applies also to Engineering Contractors (not surprising as those are generally large firms); decreasing innovative behaviours for small firms with a large number of suppliers; this applies also to Residential and Non-Residential Trades, which are often smaller firms.
- limited similarities between innovative behaviours and consumer/competitor predictability, except for Residential Trades (more innovative in case of higher predictability) and Engineering Contractors (less innovative in case of higher predictability).
- limited similarities between innovative behaviours and perceived material obsolescence, except for Residential Trades and Engineering Contractors (more innovative in case of higher perceived material obsolescence) and for Residential Contractors (slightly less innovative in case of higher perceived material obsolescence).
- And very little difference was observed between technology innovative behaviours and business innovative behaviours as they related to the perceived business environment.

Table 21a. Relationship between business environment and innovative behaviours (Firm weighted)

Levels of significance: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

Firm size Sample Size	**Total** 1739	**Small** 633	**Medium** 839	**Large** 267
Overall Innovative behaviour (INNOVCU)				
Rapid technological change	1.52**	1.50***	.58**	1.13*
Competitive threats	-0.49**	-.34*	-.82***	
Consumer/competitor predictability		.28*		
Many suppliers	-.88**	-1.07***		1.92***
Material obsolescence				
R2	0.17***	.23***	.04***	.12***
Innovative Busines behaviour (INBUSCU)				
Rapid technological change	.91***	.91***		.76**
Competitive threats			-.36***	
Consumer/competitor predictability	.20***	.26**		
Many suppliers	-,59***	-.71***		.87***
Material obsolescence				
R2	.20***	.28***	.03***	.13***
Innovative Technology behaviour (INTECCU)				
Rapid technological change	.61***	.59***	.37**	
Competitive threats	-.39***	-.33***	-.46***	
Consumer/competitor predictability				
Many suppliers	-.30***	-.36***		1.05***
Material obsolescence				
R2	.12***	.15***	.04***	.09***

Globally, those results are as expected: More innovative behaviours (higher rate of adoption of advanced technologies or "new"business practices) in environments perceived to be subject to rapid technological changes, and less innovative behaviours in environments with perceived competitive threats (which may indicate that firms consider innovations as an added risk rather than a source of competitive advantage).

Relationship between Innovation Variables and Pretax Operating Margin

Thus far the analysis has examined the environment factors that provide the impetus for key business strategies that foster innovation. The next step in the conceptual model is to investigate whether innovation is worthwhile financially. Are higher levels of innovation related to higher profits? We examined this question with two analyses. Tables 22a and 22b present correlations between the pretax operating margin variable and the three innovation variables and compare the average of each innovation variable above and below the median pretax operating margin.

In some instances, the tests on the correlations and the above/below median measures appear inconsistent, for example, for the "ALL FIRMS" segment of Table 22a.. We remind the reader that the tests are founded on distributional and other assumptions that may not be supportable. Moreover, we are looking at two-dimensional relationships here, and the sector sub-samples may be quite different in their behaviour.

Table 21b. Relationship between business environment and innovative behaviours (Firm weighted)

*Levels of significance: *** p < 0.001; ** p < 0.01; * p < 0.05*

Sector	**Trades Residential**	**Trades Non-Residential**	**Trades Engineering**	**Contractor Engineering**	**Contractor Residential**	**Contractor Non-Residential**
Sample Size	356	74	113	227	108	153
Overall Innovative behaviour (INNOVCU)						
Rapid technological change	1.79***	2.04***	-1.48*	1.44**		1.79**
Competitive threats	.39*	-.80***		-2.19***	-1.14**	
Consumer/competitor predictability	.72***		-1.07**			
Many suppliers	-1.19***	-.51**		.67*		
Material obsolescence	.71***					
R2	.43***	.20***	.17***	.19***	.20***	.08*
Innovative Busines behaviour (INBUSCU)						
Rapid technological change	1.09***	1.05***		.51*		
Competitive threats	.41***	-.34***		-.76***	-.66**	
Consumer/competitor predictability	.60***			.41**		
Many suppliers	-.84***	-.37***		.61***		
Material obsolescence	.40***			.52**	-.43*	
R2	.48***	.18***	0.07	.16***	.17***	.08*
Innovative Technology behaviour (INTECCU)						
Rapid technological change	.70***	.99***	-1.12**	.93**	.43*	1.25**
Competitive threats		-.46***		-1.44***	-.48**	
Consumer/competitor predictability			-.93***			
Many suppliers	-.36***				-.49**	
Material obsolescence	.31***					
R2	.28***	.16***	.26***	.18***	.20***	.08*

The data for all firms indicates mixed results (Table 22a). The correlation for overall and business innovation is negative implying that innovation may actually produce a cost to firms in the form of lower profits. Although this relationship is low, its significance raises another question regarding whether future profits would be stronger. In contrast, higher levels of technology innovation appear for firms that have a pretax operating margin above the median. Combining results, we find that technology innovation and business innovation may have different effect on profits in the construction industry.

These results are mostly upheld for small sized firms which may be a function of the firm-weighted data since small sized firms are a large part of the data. In contrast, we observe no significant differences for large sized firms. However, we find the only significant correlation and mean difference for technology innovation for medium sized firms

The results across the different sectors (Table 22b) provide interesting results that again support the point of no single construction industry. In general, it appears that innovation is positively associated with profitability for the non-residential sector. For both trades and contractors, we observe a general trend towards higher levels of innovation with higher levels of pretax operating margin. For residential, in contrast, we observe a negative relationship for trades and no relationship for contractors.

Overall for contractors, innovation either has no or a positive effect on profitability. However, for trades innovation has a negative effect on profitability for two of three players (i.e., residential, engineering).

Wage-weighted data (Tables 23a and 23b) support the finding of a positive relationship for technology innovation and a negative relationship for business innovation with profitability for the total data set. As a result, overall innovation tends to have a neutral effect as the effects of two components appear to cancel one another.

Again small sized firms do not appear to achieve higher levels of profits with innovation while large sized firms do appear to succeed. In between, medium sized firms produce mixed results that mirror the total data.

Perhaps our most significant and divergent finding is the size of the positive and significant correlation for innovation and profit for non-residential contractors (Table 23b). In fact the amount of innovation is almost double when comparing firms above and below the profitability median. These result also hold for non-residential trades but the strength and significance is less.

In general, we find a negative relationship for both trades and contractors in the residential sector. The results for engineering are less encouraging as we observe a negative and no relationship for trades and contractors respectively.

Table 22a. Relationship between innovation variables and pretax operating margin (POM) (Firm weighted), total sample and by size.

*Levels of significance: *** p<=0.001; **p<=0.05; * p<=.01*

Asterisks outside boxes are for the significance of the difference in mean value conditioned on median of POM.

POM: pretax operating margin
INTECCU: total number of advanced technologies currently used (maximum: 18)
INBUSCU: total number of business practices currently used (maximum 12)
INNOVCU: total number of advanced technologies and business practices currently used (maximum: 30)

ALL FIRMS

N=1739 Variable	Correlation with POM	mean value when POM is below median	is above median	
INTECCU	0.02	1.79	2.08	***
INBUSCU	-.09***	2.07	1.86	
INNOVCU	-.04*	3.86	3.95	

LARGE FIRMS (Total Revenue >= $10 million)

N=261 Variable	Correlation with POM	mean value when POM is below median	is above median
INTECCU	-.03	5.34	5.47
INBUSCU	0.08	4.56	5.15
INNOVCU	0.02	9.9	10.6

SMALL FIRMS (Total Revenue < $1 million)

N=633 Variable	Correlation with POM	mean value when POM is below median	is above median	
INTECCU	0	1.6	1.72	
INBUSCU	-.12*	1.9	1.51	*
INNOVCU	-.07*	3.5	3.24	

MEDIUM FIRMS (Total Revenue < $10 million)

N=822 Variable	Correlation with POM	mean value when POM is below median	is above median	
INTECCU	.08*	2.83	3.36	**
INBUSCU	-.01	2.98	3.13	
INNOVCU	0.04	5.81	6.5	*

Table 22b. Relationship between innovation variables and pretax operating margin (Firm weighted), by sector.

Trades, Residential

N=338 Variable	Correlation with POM	mean value when POM is below median	is above median	
INTECCU	0	1.64	1.74	
INBUSCU	-.19***	2.71	1.81	**
INNOVCU	-.12**	4.34	3.56	

Contractors, Residential

N=99 Variable	Correlation with POM	mean value when POM is below median	is above median
INTECCU	0.13	0.96	1.48
INBUSCU	-0.01	0.98	1.21
INNOVCU	0.06	1.94	2.69

Trades, Engineering

N=112 Variable	Correlation with POM	mean value when POM is below median	is above median	
INTECCU	-.24**	3.03	1.69	**
INBUSCU	-.05	1.59	1.16	
INNOVCU	-0.18	4.63	2.85	*

Contractors, Engineering

N=222 Variable	Correlation with POM	mean value when POM is below median	is above median
INTECCU	0.03	4.29	4.04
INBUSCU	0.1	3.38	3.28
INNOVCU	0.07	7.67	7.32

Trades, Non-residential

N=689 Variable	Correlation with POM	mean value when POM is below median	is above median	
INTECCU	0.08	1.93	2.54	**
INBUSCU	0.1	2.02	2.26	
INNOVCU	0.1	3.95	4.77	*

Contractors, Non-Residential

N=146 Variable	Correlation with POM	mean value when POM is below median	is above median	
INTECCU	-.00	2.43	3.82	**
INBUSCU	0.09	1.92	3.33	***
INNOVCU	0.04	4.35	7.16	***

Table 23a. Relationship between innovation variables and pretax operating margin (POM)(Wage weighted), total sample and by size.

*Levels of significance: *** p<=0.001; **p<=0.05; * p<=.01*

Asterisks outside boxes are for the significance of the difference in mean value conditioned on median of POM.

POM: pretax operating margin

INTECCU: total number of advanced technologies currently used (maximum: 18)

INBUSCU, total number of business practices currently used (maximum 12)

INNOVCU: total number of advanced technologies and business practices currently used (maximum: 30)

ALL FIRMS

N=1678 Variable	Correlation with POM	mean value when POM is below median	mean value when POM is above median	
INTECCU	.05*	3.43	3.84	**
INBUSCU	-.07**	3.43	3.28	
INNOVCU	0	6.87	7.12	

LARGE FIRMS (Total Revenue >= $10 million)

N=261 Variable	Correlation with POM	mean value when POM is below median	mean value when POM is above median	
INTECCU	.06	6.05	7.88	***
INBUSCU	.07	5.58	6	
INNOVCU	.07	11.6	13.9	***

SMALL FIRMS (Total Revenue < $1 million)

N=587 Variable	Correlation with POM	mean value when POM is below median	mean value when POM is above median	
INTECCU	-.08*	1.96	1.73	
INBUSCU	-.22***	2.41	1.59	***
INNOVCU	-.17***	4.38	3.32	**

MEDIUM FIRMS (Total Revenue < $10 million)

N=822 Variable	Correlation with POM	mean value when POM is below median	mean value when POM is above median	
INTECCU	.07*	3.29	3.92	***
INBUSCU	-.07*	3.38	3.36	
INNOVCU	-.00	6.68	7.29	*

Table 23b. Relationship between innovation variables and pretax operating margin (POM) (Wage weighted), by sector.

Trades, Residential

N=338	**Correlation**	**mean value when POM**		
	with	**is below**	**is above**	
Variable	**POM**	**median**	**median**	
INTECCU	0.1	1.87	2.52	**
INBUSCU	-.20**	2.99	2.47	
INNOVCU	-.09***	4.87	5.00	

Contractors, Residential

N=99	**Correlation**	**mean value when POM**	
	with	**is below**	**is above**
Variable	**POM**	**median**	**median**
INTECCU	-.06	1.96	1.78
INBUSCU	-.09***	1.57	1.57
INNOVCU	-.08*	3.52	3.35

Trades, Engineering

N=112	**Correlation**	**mean value when POM**		
	with	**is below**	**is above**	
Variable	**POM**	**median**	**median**	
INTECCU	-.08*	4.87	4.04	
INBUSCU	-.14	4.76	3.04	**
INNOVCU	-.12**	9.64	7.07	*

Contractors, Engineering

N=222	**Correlation**	**mean value when POM**	
	with	**is below**	**is above**
Variable	**POM**	**median**	**median**
INTECCU	-.00	5.16	5.27
INBUSCU	.004	4.34	4.25
INNOVCU	.001	9.51	9.53

Trades, Non-residential

N=689	**Correlation**	**mean value when POM**		
	with	**is below**	**is above**	
Variable	**POM**	**median**	**median**	
INTECCU	.10**	3.12	3.55	*
INBUSCU	.03	3.41	3.4	
INNOVCU	.07*	6.53	6.95	

Contractors, Non-Residential

N=146	**Correlation**	**mean value when POM**		
	with	**is below**	**is above**	
Variable	**POM**	**median**	**median**	
INTECCU	.24**	4.16	7.13	***
INBUSCU	.24**	3.31	5.33	***
INNOVCU	.25**	7.47	12.46	***

Relationship of Innovation Variables and Innovation Obstacles

As with the previous section, we investigate this relationship with the same two analyses; correlation and comparison of means above and below the median. Of importance here is whether we should expect a positive or negative relationship. We suggest a positive relationship is useful since it indicates that firms perceive obstacles yet continue to innovate despite them. A negative relationship is troublesome since it indicates that firms do not attempt to innovate when they perceive problems in the environment.

Three of four innovation obstacles are positively related to total innovation for the total sample data. Furthermore, there is a clear descending order from *restriction, human resource, external and market* (with the last having no observed effect). In Tables 24a and 24b, we label these obstacle variables OBS-RESTRIC, OBS-HR, OBS-EXT and OBS-MARKET respectively. They are regroupings of the responses to questions c87 to c98 (Table 11) as indicated in Table 24a. Across the three firm sizes we find systematic differences (Table 24a).

- Small sized firms do not perceive any *external advice* obstacles. Perhaps smaller firms do not rely on outside help to any degree while working on smaller projects. Therefore, they would not perceive any of these obstacles.

- Medium sized firms do not perceive any *restriction* (i.e., legal/regulatory) obstacles. It is unclear why this is true for these firms only.

- Large sized firms do not perceive any *human resource* (i.e., labour skills or concernts) obstacles. Not surprisingly, large firms likely offer a better working environment on a number of dimensions. Thus, construction worker supply would be of little concern for these firms.

The relationships of Table 24b further confirm the contention that the construction industry is comprised of several sectors that offer differing support for the conceptual model. While the overall data does not support a relationship for innovation and *market* obstacles it is in fact fairly strong for all three trades (i.e., residential, non-residential, engineering).

Another interesting finding is a negative relationship for all four innovation obstacles with innovation for non-residential and engineering contractors. These are the only sectors where it appears that when the managers perceive obstacles they may be less innovative. In contrast, residential contractors innovate more when confronted with *restriction* and *external* obstacles. Thus, contractors react very differently when faced with obstacles depending upon the nature of their sector.

Table 24a. Relationship of INNOVCU and innovation obstacles (Firm weighted), total sample and by size.

Levels of significance: *** p<=0.001; **p<=0.05; * p<=.01

Asterisks outside boxes are for the significance of the difference in mean value conditioned on median of POM.

OBS-MARKET (c87-c89) **OBS-HR (92-c95)**

OBS-RESTRIC (c90-c91) **OBS-EXT (c96-c98)**

ALL FIRMS

N=1678	**Correlation with INNOVCU**	**mean value when INNOVCU**		
Variable		**is below median**	**is above median**	
OBS-MARKET	0.02	1.08	1.06	
OBS-RESTRIC	.21***	0.28	0.45	***
OBS-HR	.13***	1	1.24	***
OBS-EXT	.07**	0.3	0.3	

LARGE FIRMS (Total Revenue >= $10 million)

N=261	**Correlation with INNOVCU**	**mean value when INNOVCU**		
Variable		**is below median**	**is above median**	
OBS-MARKET	0.07	1.11	1.23	
OBS-RESTRIC	.18***	0.59	0.62	
OBS-HR	-0.03	1.24	1.37	
OBS-EXT	.16**	0.41	0.7	**

SMALL FIRMS (Total Revenue < $1 million)

N=587	**Correlation with INNOVCU**	**mean value when INNOVCU**		
Variable		**is below median**	**is above median**	
OBS-MARKET	0.03	1.09	1.07	
OBS-RESTRIC	.24***	0.22	0.43	***
OBS-HR	.19***	0.96	1.23	***
OBS-EXT	0.04	0.23	0.36	**

MEDIUM FIRMS (Total Revenue < $10 million)

N=822	**Correlation with INNOVCU**	**mean value when INNOVCU**		
Variable		**is below median**	**is above median**	
OBS-MARKET	0.01	1.03	1.05	
OBS-RESTRIC	0.02	0.42	0.46	
OBS-HR	-.08*	1.23	0.96	***
OBS-EXT	.15***	0.24	0.43	***

The total wage-weighted data results (Table 25a) are consistent with the firm-weighted data results except that all four innovation obstacles are positively and consistently related to innovation. Systematic differences by firm size continue (Table 25a).

- Small sized firms change from no perceived *external* obstacles to a negative relationship indicating that there is a possibility that less of a network hinders innovation for these firms.

- Medium sized firms continue to have mixed results with few perceived obstacles.

- Large firms appear consistent with the overall data while perceiving all innovation obstacles.

Table 24b. Relationship of INNOVCU and innovation obstacles (Firm weighted), by sector

Trades, Residential

N=356 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	.17**	0.81	1.04	***
OBS-RESTRIC	.29***	0.15	0.41	***
OBS-HR	.26***	0.83	1.44	***
OBS-EXT	-0.1	0.32	0.34	

Trades, Non-residential

N=704 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	.24***	0.91	1.14	***
OBS-RESTRIC	.14***	0.38	0.39	
OBS-HR	’.33***	0.83	1.1	***
OBS-EXT	.19***	0.27	0.36	

Trades, Engineering

N=113 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	.27**	0.89	1.17	*
OBS-RESTRIC	.17**	0.37	0.7	*
OBS-HR	-.16	0.67	0.63	
OBS-EXT	.08	0.22	0.26	

Contractors, Engineering

N=227 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	-.06	0.86	0.58	**
OBS-RESTRIC	.04	0.51	0.22	**
OBS-HR	-.22***	1.08	0.5	***
OBS-EXT	-.08	0.39	0.15	**

Contractors, Residential

N=108 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	-.07	1.47	1.26	
OBS-RESTRIC	.49***	0.17	0.71	***
OBS-HR	0.09	1.48	1.16	
OBS-EXT	.35***	0.11	0.47	**

Contractors, Non-Residential

N=153 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	-.35***	1.43	1.15	
OBS-RESTRIC	-.38***	0.86	0.3	***
OBS-HR	-.35***	1.22	0.95	
OBS-EXT	-.34***	0.63	0.42	

Table 25a. Relationship of INNOVCU and innovation obstacles (Wage weighted), by firm size

*Levels of significance: *** p<=0.001; **p<=0.05; * p<=.01*

Asterisks outside boxes are for the significance of the difference in mean value conditioned on median of POM.

OBS-MARKET (c87-c89) **OBS-HR (c92-c95)**
OBS-RESTRIC (c90-c91) **OBS-EXT (c96-c98)**

ALL FIRMS

N=1678	**Correlation**	**mean value when INNOVCU**		
Variable	**with INNOVCU**	**is below median**	**is above median**	
OBS-MARKET	.11***	1.03	1.14	**
OBS-RESTRIC	.12***	0.36	0.53	***
OBS-HR	.08**	1	1.08	
OBS-EXT	.12***	0.33	0.41	**

LARGE FIRMS (Total Revenue >= $10 million)

N=261	**Correlation**	**mean value when INNOVCU**		
Variable	**with INNOVCU**	**is below median**	**is above median**	
OBS-MARKET	.18***	0.97	1.46	***
OBS-RESTRIC	.13*	0.44	0.44	
OBS-HR	0.06	1.16	1.43	*
OBS-EXT	.16**	0.43	0.78	***

SMALL FIRMS (Total Revenue < $1 million)

N=587	**Correlation**	**mean value when INNOVCU**	
Variable	**with INNOVCU**	**is below median**	**is above median**
OBS-MARKET	0.01	1.06	1.05
OBS-RESTRIC	.13***	0.33	0.39
OBS-HR	.08**	1.07	1.01
OBS-EXT	-.08**	0.32	0.33

MEDIUM FIRMS (Total Revenue < $10 million)

N=822	**Correlation**	**mean value when INNOVCU**		
Variable	**with INNOVCU**	**is below median**	**is above median**	
OBS-MARKET	0.04	1.01	1.1	*
OBS-RESTRIC	.10**	0.39	0.68	***
OBS-HR	-.02	1.04	0.9	
OBS-EXT	0.03	0.31	0.32	

The results for wage-weighted data by sector are fairly consistent with firm-weighted data (Table 25b). Non-residential contractors still appear less innovative in the face of all four obstacles although this is less so for engineering contractors. In fact, this relationship is mostly in the expected positive direction as was and still is the case for residential contractors. In general, trades also continue to innovate despite perceiving obstacles.

Cluster Analysis

Cluster analysis is a family of statistical techniques that attempt to group observations in a data set together by a variety of measures of similarity or, conversely, to separate them based on measures of difference. The RFP for the analysis of the Innovation in Construction Survey required that a cluster analysis be performed "on all variables". In consultation with the Project Officer, we have not performed such a clustering, as there are many variables that have limited rates of response, thereby rendering the clustering applicable only to the subset of respondents. We have, however, carried out several attempts at clustering based on different criteria available in the SAS software system, and in particular using the FASTCLUS procedure.

Table 25b. Relationship of INNOVCU and innovation obstacles (Wage weighted), by sector

Trades, Residential

N=356 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	.15**	0.87	1.12	***
OBS-RESTRIC	.17**	0.19	0.36	**
OBS-HR	.23***	0.9	1.29	***
OBS-EXT	-.09	0.32	0.35	

Trades, Non-residential

N=704 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	0.06	0.97	1.06	
OBS-RESTRIC	.13***	0.41	0.69	***
OBS-HR	.13***	0.91	0.86	
OBS-EXT	.12**	0.32	0.35	

Trades, Engineering

N=112 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	.43***	0.92	1.53	***
OBS-RESTRIC	-.08**	0.39	0.45	
OBS-HR	.39***	0.74	1.13	
OBS-EXT	.52***	0.27	0.09	**

Contractors, Engineering

N=227 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	.19***	1.06	1.17	
OBS-RESTRIC	.25***	0.33	0.6	**
OBS-HR	-.04	1.41	1.12	*
OBS-EXT	.06	0.46	0.38	

Contractors, Residential

N=108 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	0.1	1.26	1.18	
OBS-RESTRIC	.38***	0.15	0.79	***
OBS-HR	.02	1.49	1.33	
OBS-EXT	.49***	0.08	0.56	***

Contractors, Non-Residential

N=153 Variable	Correlation with INNOVCU	mean value when INNOVCU is below median	mean value when INNOVCU is above median	
OBS-MARKET	-.23**	1.28	1.1	
OBS-RESTRIC	-.33***	0.69	0.33	**
OBS-HR	-.17*	1.1	1.02	
OBS-EXT	-.22***	0.51	0.47	

In doing this, we chose to use the "impute" option so we would not lose too many observations to missing values. Clearly, this is a danger. To get a reasonable coverage of the variables, we included the responses c1 to c28 (which describe the opinions of the respondents on the environment for the construction sector and business and technology strategies), the financial variables ratio1 to ratio9, and the "advanced technologies and business practices variables, which are transformed versions of the responses c29 to c57. (Because the responses to these variables were coded in such a way that the numerical value is not related to the degree of innovation, we did not want to use the raw data.)

By specifying a maximum number of clusters ranging from 3 up, we were able to see how many clusters were needed to "explain" the variation in the data by looking at the reported R_squared statistic for the set of clusters. We have not verified that this value, output by SAS, has the conventional meaning, but the results appear to be consistent with a definition that the statistic is defined as:

1 - (sum of squared deviations from the model) / (sum of squared deviations from the mean)

Furthermore, we assume that the "mean" in this case is the centroid of the data under a scaling that is applied in FASTCLUS. We used the variable final_wg as a weighting variable in all calculations.

Our clusterings showed a fairly rapid increase in R_squared until we had 6 clusters, then levelled off with about 95% of the variation explained. Saving the cluster variable, we then put the data into Stata and found that there were not clean explanations of the clusters that were obvious. Worse, one cluster takes in the vast majority of the observations. Summarizing the variable INNOVCU, which accumulates all current "innovative" activities, for the clusters computed, we find only one small cluster obviously different from the rest.

Table 26. Illustration of explanatory power of clusters developed using firm-weights calculations for variable *INNOVCU*

	Summary of INNOVCU			
cluster	Mean	Std. Dev.	Freq.	Obs.
1	4.9927122	3.4028112	2451.874	65
2	4.0042456	4.4634462	80709.82	1601
3	4.0367703	6.1777111	204.0476	11
4	3.2240692	2.9720027	917.69141	13
5	1.4137315	2.4988723	4676.4894	29
6	4.7836398	4.8271454	1792.9236	20
Total	3.9050438	4.3948507	90752.846	1739

Unfortunately, without weighting, our summary looks very different. There is one small group that now stands out, though the standard deviation of the innovation variable shows us that the "innovativeness" of these very few companies is by no means uniform.

Table 27. Illustration of explanatory power of clusters developed using unweighted calculations for variable *INNOVCU*

	Summary of INNOVCU		
cluster	Mean	Std. Dev.	Freq.
1	7.6153846	5.8967478	65
2	5.6477202	5.1129318	1601
3	12.9090910	8.9045443	11
4	4.6153846	3.9694345	13
5	2	3.305839	29
6	8.35	6.2431015	20
Total	5.7297297	5.2249167	1739

Our results do not mean that a sensible clustering is not possible. However, we have tried a variety of sets of variables, including our principal component factors, and appear to get similar results. Thus we are confident that any "good" clustering will be based on relationships that are less obvious than those detectable with the obvious algorithms.

Appendix A -- Selected Tables

Descriptive statistics on Survey Questionss 1 and 2

Definition of the variables:

Table A-1. Questions 1 and 2 in the Survey.

Questions I: For your business, please indicate how strongly you are or disagree with the following statements		c14	Attracting new clients
c1	My clients' needs are easy to predict	c15	Providing a broader range of services to your clients
c2	My client can easily find a substitute for my services	c16	Ensuring employees are aware of business issues and opportunities
c3	My competitors' actions are easy to predict	c17	Encouraging and rewarding your employees to seek out technological improvements
c4	My competitors can easily substitute among suppliers	c18	Encouraging and rewarding your employees to seek out organizational improvements
c5	The arrival of new competitors is a constant threat	c19	Providing training programs for employees
c6	Materials and supplies quickly become obsolete	c20	Hiring new graduates from colleges and universities
c7	Technologies in the office are changing rapidly	c21	Hiring experienced employees
c8	Technologies on the construction/building site are changing rapidly	c22	Participating in apprenticeship programs
Questions II Please rate the importance of each of the following factors for the success of your business		c23	Using teams which bring together people with different skills
c9	Developing unique expertise or a unique market	c24	Introducing new user-friendly technologies
c10	Delivering products or services which reduce the client's operating costs	c25	Investing in research and development
c11	Seeking business outside of your present geographical region of activity	c26	Protecting intellectual property (patents, trademarks, copyrights, etc.)
c12	Increasing your market share	c27	Enhancing your engineering capabilities
c13	Building and enhancing relationships with existing clients	c28	Participating in the development of industry standards and practices

Table A-2. Descriptive statistics and 95% confidence intervals., Firm-weighted.
Full sample (N=1735)

Variable	Mean	[95% C.I.]		Variable	Mean	[95% C.I.]		Variable	Mean	[95% C.I.]	
c1	3.45	3.40	3.5	c11	1.95	1.87	2.02	c21	3.79	3.72	3.86
c2	3.82	3.76	3.87	c12	3.15	3.07	3.24	c22	2.64	2.56	2.73
c3	3.08	3.04	3.13	c13	4.34	4.28	4.39	c23	2.27	2.18	2.36
c4	3.32	3.26	3.39	c14	4.22	4.16	4.27	c24	2.60	2.51	2.69
c5	3.73	3.67	3.79	c15	3.32	3.24	3.39	c25	1.58	1.50	1.66
c6	2.54	2.49	2.59	c16	3.54	3.46	3.62	c26	1.32	1.24	1.39
c7	3.59	3.53	3.65	c17	2.60	2.51	2.69	c27	3.00	2.91	3.09
c8	3.31	3.25	3.37	c18	3.03	2.95	3.12	c28	2.76	2.67	2.84
c9	2.91	2.82	3.00	c19	3.03	2.94	3.11				
c10	3.15	3.06	3.24	c20	1.69	1.62	1.76				

Table A-3. Descriptive statistics and 95% confidence intervals., Firm-weighted. By firm size.

	Small firms			Medium firms			Large firms		
Variable	Mean	[95% C.I.]		Mean	[95% C.I.]		Mean	[95% C.I.]	
'# observ.	633			839			263		
c1	3.48	3.40	3.57	3.26	3.20	3.33	3.36	3.22	3.49
c2	3.87	3.78	3.97	3.55	3.47	3.64	3.69	3.56	3.82
c3	3.10	3.03	3.18	2.99	2.91	3.06	2.89	2.77	3.00
c4	3.32	3.21	3.43	3.36	3.27	3.44	3.40	3.26	3.54
c5	3.75	3.65	3.85	3.63	3.55	3.71	3.71	3.57	3.84
c6	2.55	2.47	2.63	2.50	2.42	2.57	2.32	2.20	2.44
c7	3.53	3.43	3.63	3.87	3.80	3.94	3.82	3.68	3.95
c8	3.32	3.22	3.42	3.27	3.20	3.35	3.30	3.19	3.41
c9	2.80	2.64	2.96	3.39	3.28	3.51	3.72	3.56	3.88
c10	3.13	2.98	3.27	3.25	3.12	3.38	3.48	3.27	3.68
c11	1.82	1.69	1.95	2.52	2.41	2.63	2.72	2.54	2.90
c12	3.02	2.88	3.16	3.78	3.67	3.88	3.92	3.78	4.06
c13	4.31	4.21	4.40	4.48	4.42	4.55	4.57	4.47	4.67
c14	4.16	4.06	4.25	4.51	4.45	4.57	4.37	4.26	4.48
c15	3.34	3.21	3.46	3.22	3.12	3.33	3.27	3.10	3.44
c16	3.53	3.40	3.66	3.56	3.47	3.65	3.71	3.56	3.85
c17	2.48	2.32	2.64	3.13	3.02	3.23	3.48	3.34	3.62
c18	2.94	2.80	3.09	3.43	3.34	3.52	3.62	3.47	3.76
c19	2.89	2.75	3.04	3.66	3.57	3.75	3.76	3.64	3.89
c20	1.60	1.48	1.71	2.07	1.97	2.18	2.62	2.44	2.80
c21	3.72	3.60	3.84	4.14	4.07	4.21	3.95	3.80	4.10
c22	2.54	2.40	2.68	3.11	3.00	3.22	3.48	3.32	3.64
c23	2.16	2.00	2.31	2.77	2.65	2.90	3.15	2.96	3.34
c24	2.48	2.33	2.63	3.19	3.08	3.30	3.51	3.35	3.67
c25	1.53	1.39	1.66	1.83	1.72	1.94	1.96	1.79	2.13
c26	1.30	1.17	1.43	1.38	1.26	1.49	1.56	1.36	1.76
c27	2.94	2.79	3.09	3.24	3.13	3.35	3.71	3.57	3.84
c28	2.65	2.50	2.80	3.22	3.11	3.33	3.61	3.46	3.76

Table A-4a. Descriptive statistics and 95% confidence intervals., Firm-weighted
By industry sector - trades.

	Specialty trades, residential			Specialty trades, non-residential			Specialty trades, engineering		
Variable	Mean	[95%	C.I.]	Mean	[95% C.I.]		Mean	[95% C.I.]	
Observ	356			704			113		
c1	3.71	3.58	3.83	3.24	3.16	3.32	3.17	2.95	3.39
c2	3.94	3.81	4.07	3.58	3.48	3.67	3.28	3.05	3.51
c3	3.02	2.92	3.13	3.04	2.97	3.11	2.87	2.71	3.03
c4	3.06	2.91	3.22	3.23	3.13	3.33	3.50	3.29	3.71
c5	3.85	3.72	3.99	3.49	3.39	3.58	3.99	3.84	4.15
c6	2.69	2.59	2.79	2.48	2.40	2.56	2.65	2.47	2.83
c7	3.90	3.77	4.02	3.73	3.65	3.82	3.78	3.62	3.95
c8	3.54	3.41	3.67	3.30	3.23	3.38	3.71	3.53	3.89
c9	3.57	3.38	3.76	2.83	2.68	2.97	2.32	1.93	2.72
c10	3.51	3.33	3.70	3.37	3.24	3.50	3.12	2.79	3.45
c11	2.34	2.14	2.53	1.95	1.83	2.07	2.30	2.02	2.57
c12	3.67	3.49	3.85	3.41	3.30	3.52	2.84	2.54	3.13
c13	4.36	4.24	4.48	4.55	4.47	4.62	4.41	4.24	4.57
c14	4.37	4.25	4.49	4.21	4.13	4.29	3.77	3.53	4.02
c15	3.64	3.47	3.80	3.14	3.02	3.27	2.95	2.63	3.27
c16	3.70	3.53	3.86	3.27	3.15	3.39	3.34	3.08	3.61
c17	2.92	2.70	3.13	2.55	2.40	2.69	2.97	2.68	3.26
c18	3.32	3.13	3.51	2.81	2.66	2.95	3.19	2.94	3.45
c19	3.26	3.07	3.44	2.83	2.70	2.97	3.43	3.19	3.68
c20	1.88	1.72	2.03	1.46	1.34	1.58	1.91	1.66	2.15
c21	3.44	3.28	3.59	3.90	3.78	4.02	3.82	3.61	4.03
c22	2.68	2.50	2.87	2.95	2.81	3.09	2.30	2.02	2.59
c23	2.79	2.59	3.00	2.21	2.06	2.36	2.52	2.23	2.82
c24	3.15	2.96	3.35	2.56	2.41	2.71	2.67	2.36	2.98
c25	2.30	2.09	2.50	1.38	1.26	1.50	1.97	1.69	2.25
c26	1.91	1.72	2.09	1.23	1.11	1.35	1.51	1.21	1.81
c27	3.43	3.24	3.63	3.03	2.88	3.17	2.95	2.69	3.22
c28	3.17	2.97	3.37	2.89	2.76	3.03	2.75	2.48	3.02

Table A-4b. Descriptive statistics and 95% confidence intervals., Firm-weighted
By industry sector - contractors.

	Contractors, engineering			Contractors, residential			Contractors, non-residential		
Var.	Mean	[95% C.I.]		Mean	[95% C.I.]		Mean	[95% C.I.]	
‘# observ	227			108			153		
c1	3.16	3.04	3.28	3.47	3.34	3.61	3.26	3.1	3.43
c2	3.72	3.58	3.85	4.32	4.13	4.50	3.40	3.24	3.57
c3	3.01	2.86	3.15	3.19	3.03	3.34	2.87	2.72	3.02
c4	3.43	3.26	3.60	3.75	3.49	4.00	3.50	3.33	3.68
c5	3.28	3.14	3.42	3.95	3.70	4.20	3.21	3.01	3.41
c6	2.19	2.06	2.31	2.48	2.27	2.69	2.81	2.67	2.96
c7	3.62	3.50	3.74	2.77	2.51	3.03	3.76	3.60	3.92
c8	3.15	3.06	3.24	2.94	2.63	3.26	3.18	3.00	3.37
c9	2.82	2.56	3.08	2.28	1.91	2.66	2.54	2.21	2.87
c10	3.71	3.52	3.90	2.15	1.80	2.49	2.52	2.20	2.85
c11	2.10	1.91	2.29	1.27	1.01	1.53	2.16	1.89	2.42
c12	3.49	3.33	3.66	2.06	1.72	2.39	2.97	2.68	3.26
c13	4.46	4.35	4.57	4.01	3.79	4.24	4.58	4.46	4.69
c14	3.90	3.74	4.06	4.08	3.85	4.30	4.44	4.30	4.59
c15	2.96	2.73	3.19	3.21	2.93	3.50	3.59	3.44	3.75
c16	3.80	3.64	3.97	3.69	3.39	4.00	3.55	3.38	3.73
c17	3.44	3.24	3.64	1.79	1.47	2.12	3.11	2.89	3.34
c18	3.69	3.51	3.86	2.79	2.46	3.13	2.95	2.70	3.20
c19	3.81	3.66	3.95	2.81	2.47	3.16	2.98	2.74	3.21
c20	2.52	2.32	2.72	1.48	1.27	1.70	2.54	2.30	2.78
c21	4.08	3.96	4.19	4.03	3.78	4.29	4.10	3.91	4.28
c22	3.17	2.94	3.40	2.20	1.91	2.48	3.34	3.08	3.61
c23	2.82	2.60	3.03	1.49	1.20	1.79	2.27	1.96	2.58
c24	2.83	2.64	3.03	1.76	1.45	2.08	3.05	2.86	3.24
c25	2.00	1.83	2.18	0.80	0.60	1	1.56	1.35	1.77
c26	1.28	1.06	1.50	0.49	0.33	0.66	0.96	0.72	1.20
c27	3.75	3.58	3.92	1.95	1.60	2.30	3.10	2.88	3.31
c28	2.75	2.58	2.93	2.02	1.67	2.36	2.56	2.30	2.83

Table A5. Factor means by firm size, all sectors combined, firm-weighted This table is provided without commentary for information.					
	Total	**SIZE 1: Small**	**SIZE 2: Medium**	**SIZE 3:Large**	**Sheffe**
Sample size	**1739**	**633**	**839**	**267**	**tests**
Population (weights)	**90731**	**74846**	**15030**	**855**	****=p<0.05**
Section 1: Perceived characteristics of the Environment					
Rapid technological change	0.00	-0.03	0.12	0.17	M=L
Competitive threats	0.00	0.05	-0.22	-0.08	S<>M
Consumer/competitor predictability	0.00	0.04	-0.16	-0.20	M=L
Many suppliers	0.00	-0.02	0.08	0.07	S=M=L
Materials obsolescence	0.00	0.01	-0.03	-0.26	S=M
Section 2: Perception of the importance of the following on firm success:					
2-1: marketing strategy					
Market share expansion	0.00	-0.07	0.31	0.41	M=L
Client retention	0.00	-0.04	0.18	0.12	S<>M
Expanded product range	0.00	0.04	-0.17	-0.19	M=L
Geographic expansion	0.00	-0.07	0.32	0.42	M=L
Awareness of clients operating costs	0.00	0.01	-0.08	0.08	S=M=L
2-2: human resources strategy					
Employees skills and knowledge development	0.00	-0.03	0.12	0.20	M=L
Hiring experienced employees	0.00	-0.02	0.10	-0.07	S=M=L
Hiring well trained new graduates	0.00	-0.05	0.24	0.45	all different
Multi-advanced skilled teamsTeams	0.00	-0.05	0.20	0.40	all different
2-3: technology strategy					
Improving your technology practices and capabilities	0.00	-0.05	0.22	0.41	all different
NOT developing proprietary technologies	0.00	0.00	0.01	-0.01	S=M=L
Developing industry standards and practices	0.00	-0.04	0.18	0.36	all different

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Appendix B -- Copy of the Innovation Survey Instrument

Science and Technology Redesign Project

Innovation, Advanced Technologies and Practices in the Construction and Related Industries

Confidential when completed

Si vous préférez ce questionnaire en français, veuillez cocher ☐

Please correct name and address if necessary

Information for Respondents

Survey Purpose
The objective of this survey is to provide information on innovation, advanced technology and advanced practices being used in the construction and related industries. The information in the survey can be used by businesses for market analysis, by trade associations to study performance and other characteristics of their industries, and by government to develop national and regional economic policies.

Authority
This survey is conducted under the authority of the Statistics Act, Revised Statutes of Canada, Chapter S19. Completion of this questionnaire is a legal requirement under the Statistics Act.

Confidentiality
Statistics Canada is prohibited by law from publishing any statistics which would divulge information obtained from this survey that relates to any identifiable business without the previous consent of that business. The data reported in this questionnaire will be treated in strict confidence, used for statistical purposes and published in aggregate form only. Statistics Canada will create a data base combining individual survey responses with existing Statistics Canada data records. The confidentiality provisions of the Statistics Act are not affected by either the Access to Information Act or any other legislation.

Assistance

If you require assistance in the completion of this form or have any questions regarding this survey, please contact:

Heather Prieur
Phone: (613) 951-7683
Fax: (613) 951-9920
E-Mail: prieur@statcan.ca

Certification

Please indicate the name of the person completing this form so we know who to contact should we have questions about this report.

Name *(please print)*	Official position:	
Internet address:	Telephone No. ( )	Fax No. ( )

5-4900-486.1: 1999-02-23 STC/SAT-465-75152

Business Environment and Success Factors

1. For <u>your business</u>, please indicate how strongly you agree or disagree with the following statements.

Please indicate your opinion by using the following scale where 1 is strongly disagree and 5 is strongly agree.

	1 Strongly Disagree	2	3 Neutral	4	5 Strongly Agree
My clients' needs are easy to predict	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯
My clients can easily find a substitute for my services	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯
My competitors' actions are easy to predict	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯
My business can easily substitute among suppliers	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯
The arrival of new competitors is a constant threat	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯
Materials and supplies quickly become obsolete	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯
Technologies in the office are changing rapidly	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯
Technologies on the construction/building site are changing rapidly	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯

2. Please rate the importance of each of the following factors for the success of <u>your business</u>.

Please indicate your opinion by using the following scale where 1 is low importance and 5 is high importance. Indicate 0 if not relevant to your business.

	Importance: Low 1	2	3	4	High 5	Not Relevant 0
Strategy within <u>your business</u>						
Developing unique expertise or a unique market	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Delivering products or services which reduce the client's operating costs	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Seeking business outside of your present geographical region of activity	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Increasing your market share	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Building and enhancing relationships with existing clients	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Attracting new clients	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Providing a broader range of services to your clients	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Ensuring employees are aware of business issues	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Human Resources within <u>your business</u>						
Encouraging and rewarding your employees to seek out technological improvements	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Encouraging and rewarding your employees to seek out organizational improvements	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Providing or supporting training programs for employees	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Hiring new graduates from colleges and universities	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Hiring experienced employees	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Participating in apprenticeship programs	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Using teams which bring together people with different skills	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Technology within <u>your business</u>						
Introducing new user-friendly technologies	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Investing in research and development	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Protecting intellectual property (patents, trademarks, copyrights, etc.)	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Enhancing your technical capabilities	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯
Participating in the development of industry standards and practices	1 ◯	2 ◯	3 ◯	4 ◯	5 ◯	0 ◯

List of Definitions

Advanced Technologies

Communications

E-mail: Refers to electronic mail.

Digital photography for progress reporting: The use of digital photography to record progress on a work-site so it can be transmitted by electronic means.

Office-to-site video links or video conferencing: The use of video cameras to communicate between the site and other locations. Can be used to solve problems on the site without bringing people to the site.

Company computer network: LAN (local area network) for communications within a building or WAN (wide area network) for communications within a business extending beyond a single building or site.

On-site plant and equipment

Laser-guided equipment: Equipment which incorporates a laser. An example is a bulldozer or a grader with on-board computerized grade information and a laser sensor which assists the operator in excavating/grading to a precise level.

Automated systems and/or programmable machines: Automated systems and programmable machines incorporate computer technologies to carry out specific tasks. Examples include bar code readers and automated welding machines.

GPS (Global Positioning Systems): Surveying equipment that determines the exact position with the aid of satellites. Other applications include the use of GPS to determine the location of delivery trucks or other vehicles.

Materials and systems

High performance concrete: Concrete that has been modified to achieve superior performance in terms of strength or other desired characteristics.

Composite materials (e.g. fiber reinforced plastics) : A synthetic material reinforced with other materials to achieve superior performance characteristics.

Recycled plastics components: Products that incorporate plastics that have already been used and are used to make another product.

Systems

Remote sensing and monitoring systems (e.g. "smart" detection systems): Systems incorporating sensors for monitoring.

Bio-remediation clean-up: Bio-remediation involves the use of microorganisms to clean up contaminated soil.

Preassembled air, water, power distribution systems (e.g. “drop-in” systems): Systems that are produced off-site and transported to the construction site where they are easily installed.

“Clean room” technology: Technology that assures that rooms are super-clean (hospital operating rooms, computer chip fabrication, etc.). Clean rooms require special sub-systems and special materials.

Deconstruction and reuse systems: Taking a building or structure apart in such a manner that materials used can be reused and recycled.

Design

Computer Aided Design (CAD): Use of computer-based software to carry out design. CAD allows engineers, architects, or designers to produce complete designs on the computer screen and to visualize the implications of design changes on other aspects of the design.

Modeling or simulating technologies: Used to provide a computer-based visualization of the performance of a computer aided design. Modeling involves the approximation, representation or idealization of selected aspects of the structure, behavior, operation and characteristics of a real-world process, concept or system. Simulation is a model that behaves or operates like a given system when provided with a set of controlled input.

Electronic exchange of CAD files: Refers to the transfer of computer aided design files. If the exchange is outside of a company, then conversion or translation of the software files may be required because of incompatible software.

Advanced Technologies

3. Please check which of the following advanced technologies <u>your business</u> either:

- **currently uses**
- **plans to use within two years; or**
- **has no plans to use within two years or is not applicable to your business**

	Currently uses	Plans to use within 2 years	No plans/Not applicable
Communications			
E-mail			
Digital photography for progress reporting			
Office-to-site video links or video conferencing			
Company computer networks (LAN or WAN)			
On-site plant and equipment			
Laser-guided equipment			
Automated systems and programmable machines			
GPS (Global Positioning System)			
Materials			
High performance concrete			
Composite materials (e.g. fiber reinforced plastics)			
Recycled plastic components			
Systems			
Remote sensing and monitoring systems (e.g. "smart" detection systems)			
Bio-remediation clean-up			
Preassembled air, water, power distribution systems (e.g. "drop-in" systems)			
"Clean room" technology			
Deconstruction and reuse systems			
Design			
Computer aided design			
Modeling or simulation technologies			
Electronic exchange of CAD files			
Other advanced technologies (*please specify*)			
______________________________			
______________________________			

List of Definitions

Business Practices

Computerization

Computerized inventory control: Use of computers to manage a company's inventory.

Computerized estimating software: The use of computer software programs to estimate costs.

Computerized project management and/or scheduling software: The use of computer software to manage and/or schedule projects.

Quality

Quality certification (e.g. ISO 9000, R2000, etc.) : Quality systems that are introduced by a firm and which receive third-party validation. ISO 9000 for example is an internationally recognized series of quality system standards and guidelines used to certify the consistency of the way a business produces and delivers its products and services.

Organization

Written market analysis report to evaluate needs and opportunities of your business: A formal and structured analysis of the market carried out by the business or by a consultant hired by the business. A market analysis would lead to a market plan for the business.

Written documentation of technological improvements developed by your business: A formal and structured process to record and document all technological improvements that are developed by the business.

Written evaluation of new ideas in order to develop options for your business: Formal studies and reports prepared by the business or by consultants hired by a business to assess new ideas that are of interest to the business.

Written strategic plan: A formal and structured process carried out by the business or by a consultant hired by the business which leads to a strategic plan.

Business

Design-build contracts: With design-build contracts, owners specify the time lines and performance criteria sought for a project. In response, design-build teams comprising architects, engineers, contractors and in many cases building materials suppliers submit project proposals that indicate the project's design, cost and completion date. The owner then evaluates the submissions and selects the winning proposals. Significant savings often result from this approach.

Build-operate-transfer (BOT) contracts: An arrangement where the builders of a structure or building operate it for a specified length of time and at the end of the time transfer the building to the original financers.

Post-commissioning inspection and maintenance contracts: Builders obtain an on-going contract to inspect and maintain the structure or building they built.

Long-term working arrangements with other businesses to work together on joint projects : Agreements between different businesses to work together jointly on projects. These working arrangements can be based on a formal contract or on an informal agreement.

Advanced Practices

4. Please check which of the following business practices <u>your business</u> either:

- **currently uses**
- **plans to use within two years; or**
- **has no plans to use within two years or is not applicable to your business**

	Currently uses	Plans to use within 2 years	No plans/Not applicable
Computerization			
Computerized inventory control			
Computerized estimating software			
Computerized project management and/or scheduling systems			
Quality			
Quality certification (e.g. ISO 9000, R2000, etc.)			
Organization			
Written market analysis report to evaluate needs and opportunities of your business			
Written documentation of technological improvements developed by your business			
Written evaluation of new ideas in order to develop options for your business			
Written strategic plan			
Business			
Design-build contracts			
Build-operate-transfer (BOT) contracts			
Post-commissioning inspection or maintenance contracts			
Long-term working arrangements with other businesses to work together on joint projects			
Other advanced practices (*please specify*)			
______			
______			
______			

5. In the past three years has your business:

Please check all that apply.

- Been involved in a merger ☐
- Acquired another business ☐
- Set up a new line of business or a new division ☐

Sources of information

6. Please indicate your sources of information on advanced technologies and advanced practices, such as those listed in Questions 3 and 4.

Please check all that apply.

- Trade shows and conferences ☐
- Trade journals and newsletters ☐
- Trade associations ☐
- Computer based information networks (including internet) ☐
- Suppliers of materials, supplies, machinery and equipment ☐
- Clients ☐
- General contractors ☐
- Specialty trades ☐
- Consulting engineers ☐
- Architects ☐
- Government facility owners or managers ☐
- Non-government facility owners or managers ☐
- Federal information programs ☐
- Federal research organizations ☐
- Provincial research organizations ☐
- Universities and colleges ☐
- Regulatory and standards organizations ☐
- Testing and evaluation service firms ☐
- Business consultants ☐

Other sources of information *(please specify)*

____

____

Please list the most important source of information on advanced technologies and advanced practices for your business:

____

____

____

____

Obstacles

7. Please check the major obstacles for <u>your business</u> to using new and improved building products, building systems and construction equipment.

Please check all that apply

Market:

- High cost of products, systems and equipment ☐
- Lack of interest by clients ☐
- Resistance to change by businesses with which your business has joint projects ☐
- Risk of legal liability ☐
- Restrictive codes and standards ☐

Human resources:

- Shortage of skilled workers ☐
- Lack of in-house expertise ☐
- Inability to train workers within the required time ☐
- Worker resistance to change ☐

External support services:

- Lack of technical support from vendors ☐
- Lack of technical support from consultants ☐
- Inability to evaluate new products and equipment ☐

Other obstacles (*please specify*)

____

____

____

Please list the <u>most important obstacle</u> to using new and improved building products, building systems and construction equipment <u>for your business</u>:

____

____

____

Impact

8. Please provide a brief description of the technological or business practice change or improvement which had the biggest impact on your business during the last three years.

____

____

____

____

____

____

____

____

Did this technological or business practice change or improvement provide your business with a significant advantage over your competitors?

Yes ☐ **No** ☐

Comments

____

____

____

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____

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Thank you for your co-operation

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