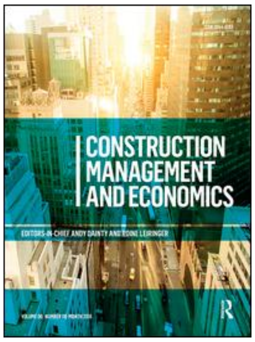

Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

Strategic decisions and innovation in construction firms

George Seaden , Michael Guolla , Jerome Doutriaux & John Nash

Construction Management and Economics (September 2003) **21**, 603–612

Spon Press
Taylor & Francis Group

Strategic decisions and innovation in construction firms

GEORGE SEADEN*, MICHAEL GUOLLA, JEROME DOUTRIAUX and JOHN NASH

School of Management, University of Ottawa, 136 Jean-Jacques Lussier Private, PO Box 450, Ottawa, Ontario, K1N 6N5, Canada

Received 1 September 2001; accepted 20 June 2002

Current research on the process of innovation has focused attention on the crucial role of the business firm as the place where new ideas are developed and then implemented in the marketplace. Based on current knowledge, a model was developed which attempts to replicate the strategic decision-making process in a construction firm. It links perceived business environment variables to various business strategy variables (i.e. marketing, human resources and technology). These two sets of variables are linked to the innovativeness of the firm, measured by the number of advanced technologies and/or business practices currently used. Innovativeness is subsequently linked to outcomes (i.e. profitability, competitive advantage) to assess overall effectiveness. The model was tested empirically, using data from the Survey on Innovation, Advanced Technologies and Practices in the Construction and Related Industries carried out by Statistics Canada in 1999 with 1739 usable responses. The results generally support the proposed model; certain perceived business environment and business strategy variables are significantly related to firm innovativeness, however the link between innovativeness and outcomes requires further confirmation. Many construction firms introduce new approaches in information and construction technologies as well as in business practices. A large number of these were found to provide significant competitive advantage. In general, innovative behaviour varies with the size of the firm.

Keywords: Innovation, construction, business model, quantitative data

Introduction

As literature and the discussion cited below attests, it is generally accepted that innovation is the implementation in a firm of significantly new processes, products or management approaches in order to increase its efficiency (i.e. improved quality, lower production costs) and/or effectiveness (i.e. greater market share, client satisfaction). It is also agreed that innovation is risky, requires significant investments and is often resisted within the firm. To innovate is to change and that is never easy. Over the years there has been mounting evidence of client dissatisfaction with the construction industry's inability to deliver quality products and services on time, at a reasonable price (*The Economist*, 2000). In response to this challenge, changes are taking place in the delivery of construction goods and services around the world.

The recent International Symposium on Construction Innovation in Ottawa (National Research Council of Canada, 2001) heard from senior managers of large organizations of many successful innovative approaches in contractual/institutional arrangements, service delivery, technology, regulation and other related fields. There was also indication that larger global firms are emerging (e.g. through mergers, acquisition and alliances), offering greater range of services. The consensus of the Symposium was that innovation is becoming the principal competitive tool to achieve greater market penetration and increased profitability. This view is also echoed in a recent study of the construction industry in Chile, where innovation is

*Author for correspondence. E-mail: george.seaden@rogers.com

Construction Management and Economics
ISSN 0144-6193 print/ISSN 1466-433X online © 2003 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/0144619032000134138

driven by increasing clients' requirements, greater market competition and globalization (Serpell and Ocaranza, 2001).

One explanation for this recent trend is that construction firms may be simply late arrivals to this global competition game. Porter (1998) and others suggest that, during the last 20 years, companies have been increasingly responding to the 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 become parts of companies' efforts to remain/become competitive in the global market-place.

Innovation is not only of great importance to individual firms but, on the aggregate, it is linked to regional and national economic growth. Hence, there is great interest in understanding and measuring the processes and variables believed to be associated with it. However, collecting and interpreting statistical data on innovation is a new field and as such is still experimental (OECD, 1997a). Along with other agencies (CERF, 1993; Technopolis, 1995; Lundvall and Christensen, 1999), Statistics Canada recently undertook several studies to measure innovation in various sectors of Canadian economy. While construction is a large economic sector in Canada (6–8% of GDP), there are indications that it is under-performing with respect to innovation (ARA Consulting Group, 1997). Thus, the 1999 *Survey on Innovation, Advanced Technologies and Practices in the Construction and Related Industries* (Seaden *et al.*, 2001), which is the source document for this paper, is a relatively new approach in studies on innovation. This comprehensive report examines the industry in a quantitative manner with a large, representative sample rather than using anecdotal or case study evidence based on a few, select firms. This paper highlights the principal findings and extends the analysis of strategic management process regarding innovation in construction firms. Additional survey results, methodological details and the survey questionnaire can be found in said report at http://www.statcan.ca/english/IPS/Data/88F0017MIE01010.htm

The survey was sponsored by the National Research Council of Canada and Statistics Canada, and conducted under the Science, Innovation and Electronic Information Division of the latter agency. 'Construction', for the purpose of the survey, comprised contractors and sub-trades. Land developers who were included in the 'Construction' statistical classification group were excluded from the analysis. Professional service providers (architects, consultants, surveyors) were not part of the survey sample. The survey design was based on ideas outlined by Anderson and Manseau (1999) following the principles defined in the Oslo Manual (OECD, 1997a). In summary, the locus of innovation is considered to be the business firm since that is where the benefits of the investment can be observed and measured.

Both the survey and this research adopt the concept of 'systems of innovation' (OECD, 1997b) whereby innovation is part of an overall system of organizational dynamics suggesting causes and effects. Innovative firms have a strong sense of strategic intent (OECD, 1997a, 1997b) by responding quickly to market changes and thinking of future opportunities. Based on this, we investigate the reaction of firms to their business environment. Indeed, a major question addressed by our analysis concerns competitive drivers in the industry and how they relate to a firm's strategic decisions. Furthermore, do typical Canadian construction firms behave according to the current competitive advantage business model? In other words, are firms seeking innovative approaches in response to threats or opportunities observed in their business environment? Innovative firms are also known to be receptors and users of knowledge, to employ highly skilled people and to link with sources of information. Our study therefore examines how various business strategies influence innovation. Overall, a systems view of innovation is put forth in our conceptual model that is now discussed.

A conceptual model of innovation for construction industry data

Figure 1 illustrates our conceptual model to describe the linkages between the business environment, business strategy, innovative practices and business outcomes. Our model is consistent with previous OECD reports (OECD, 1997a, 1997b) and existing innovation studies in the construction literature. Such research has shown the important effect of the environment on innovation (Pries and Janszen, 1995; Toole, 1998) and the critical role of strategic decision-making on innovation (Nam and Tatum, 1992). A recent study of innovation in small construction firms in the UK (Barrett and Miozzo, 2000) links such elements as business strategy, processes and structure to the implementation of new ideas thus offering more support to our model. Finally, the model also appears consistent with the practice in product innovation (Cooper, 1998) and a logical interpretation of the variables present in the survey.

A central part of the model is that innovation will lead to improved competitive advantage and of greater profitability. Both of these factors are paramount

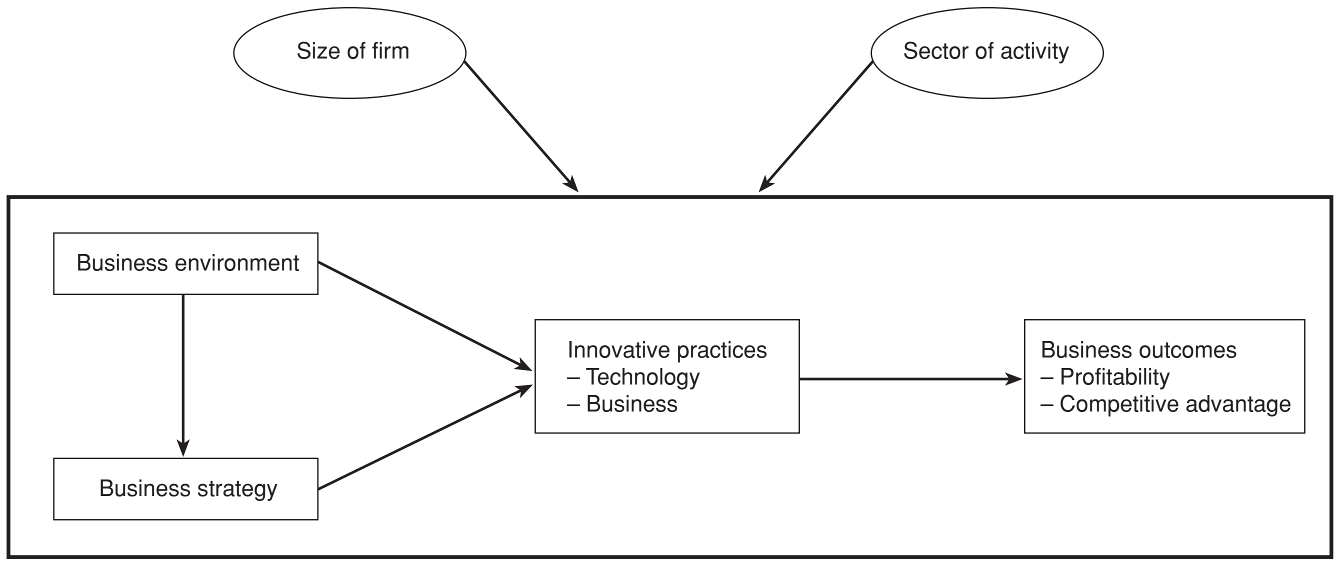

Figure 1 Conceptual model for analysis of innovation in construction

objectives that managers expect to achieve when investing resources in innovative practices. The model also illustrates two sets 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 business environment, 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 (e.g. competitive pressure) could lead to higher levels of innovation since managers need to innovate to attain competitive advantages.

Second, variables pertaining to managers' attitudes toward their business strategy (marketing strategy, human resources strategy and technology strategy) are related to innovative practices. In the case of marketing strategy, we expect pro-active attitudes toward markets or customers will lead managers to changes and higher levels of introducing 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 towards innovation that would lead to actual innovative practices (i.e. tangible behaviour). Our model also suggests that business environment variables provide an impetus to understand what external pressures managers perceive when determining their business strategies for marketing, human resources and technology.

Our model would not be complete if it did not account for the influence of two key business characteristics of size and sector. It illustrates the effect of the size of the firm (large, medium, small). The motivation here is predicated on the possibility that larger firms may have greater levels of resource allowing them to engage in more or a wider variety of innovations. The model also illustrates the effect of the industry sub-sectors of specialty (i.e. residential, non-residential, engineering), and the role (i.e. contractors vs. sub-trades). The results presented in this paper will focus on firm size due to space limitations. A comparative analysis of the Canadian construction industry sub-sectors did show significant differences between individual specialties and between roles, confirming heterogeneity in the sector (Seaden *et al.*, 2001).

Methodology and descriptive statistics

Our model was tested empirically using data from the *Survey on Innovation, Advanced Technologies and Practices in the Construction and Related Industries* carried out by Statistics Canada in 1999 under the authority of the Statistics Act of Canada. Respondents had a legal obligation to complete the questionnaire and there was an extensive follow up to ensure high response rate. Information from a significant sample of 1739 firms allowed analysis from the perspective of firm's revenue as a proxy for size (i.e. large, medium, small), specialty (i.e. residential, non-residential and engineering construction) and role (i.e. general contractor, trade).

The questionnaire for the survey had eight sections. The first two sections comprised questions of perceptions of business environment and business strategy recorded on one to five scales. The third and fourth sections recorded the use of advanced technology and business practices with three categories (i.e. used, planned to use within two years, no plans/not applicable). The next three sections (not the focus of the model presented in this paper) concerned mergers and acquisitions, sources of information and major obstacles to advanced practices.

To assess profitability, the survey data was linked to partial data already available at Statistics Canada on the financial performance of construction firms. We used a coded form of the pre-tax operating margin, that is, the ratio of total operating revenue minus total operating expenses. The combination of this information with data from the survey provided a method to assess the relationship between innovative practices and business outcomes.

The nature of innovative practices proposed in the questionnaire requires elaboration since it is the primary focus of the study. Because construction is an assembly industry, it was assumed that innovation would occur primarily in the processes carried out. As such, it would be measured indirectly since the product is essentially the same whether produced by a novel or traditional process. This approach contrasts with the usual indicators of innovation in industrial surveys such as the number of new products or services introduced, the percentage of sales derived from such product/services, the acquisition of new production machinery or technology or expenditures on R&D. Instead, based on case studies of successful firms in the manufacturing sector (Cooper, 1998), the survey used proxy measures and assumed that firms using a greater number of advanced technological and business practices are likely to be more innovative. The word 'innovation' was not used in the questionnaire.

The survey instrument investigated the current or planned use of 18 advanced technologies (i.e., communications (4), plant and equipment (3), materials (3), systems (5), design (3)) and 12 business practices (i.e., computers (3), quality (1), organization (4), processes (4)). Table 1 shows innovative practices listed in the survey and the percentage current use by all firms and by firm's size, by order of interest. It should be noted that these practices ranged from those that are simple and inexpensive (e-mail, computerized estimating software) to truly advanced technologies such as Global Positioning System or ISO certification. To differentiate business practices that were more formally managed from those casually used, the modifier 'written' was used in the survey. We counted the number of these as aggregates to measure the use or planned use of technology or business practices. This approach of counting the number of innovations is consistent with past innovation measures in the construction literature. For example, innovation has been previously measured as the total number of new products adopted (Toole, 1998) and the total number of adaptations to a product (Slaughter 1993).

Table 2 reports the (statistical) population estimates (firm weighted) of the number of innovative practices, along with their 95% confidence intervals, for technology, business and combined technology and business. The innovative practices are also demarcated in terms of those that a firm 'currently used' and the sum 'currently used' and 'planned to use within two years'. Results are given by firm size, where 'small' firms have revenues from C$50 000 to below C$1 million, 'medium' firms revenues from C$1 million to C$10 million, and large above C$10 million.

The total sample data reveals that the average firm used or planned to use almost seven of a possible 30 innovative practices. Furthermore, the technology and business innovative practices are at approximately the same level. While these levels may appear somewhat low, they are tempered with the knowledge that some innovative practices proposed in the survey were not applicable to all forms of construction and that significant differences are observed for different business sectors. Technology and business innovativeness increases with size: larger firms tend to use three times as many advanced technology or business practices as small firms. Noteworthy is the fact that there is a strong association between advanced technology practices and business practices: an innovative firm is generally innovative in technology and in business at the same time suggesting innovativeness may be a culture that permeates all the activities of the firm.

To complement the quantitative measures of firm profitability, the survey qualitatively investigated the competitive advantage results of innovation. The final question involved an open-ended question that asked respondents to give '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'. Respondents also indicated (i.e. yes/no) whether this practice led to 'a significant advantage over your competitors'.

Analysis of the conceptual model of innovation

Creation of business environment and business strategy variables

Perceived business environment variables and views of business strategy variables are psychological variables

Table 1 Percentage of firms currently using each innovative practice

Technology practices	Total firms (%)	Small (%)	Medium (%)	Large (%)
E-mail	37.80	33.50	56.90	75.20
Company computer networks (LAN or WAN)	22.20	16.30	48.60	76.80
Computer-aided design (CAD)	20.50	17.60	32.70	55.90
Laser-guided equipment	14.50	11.30	29.10	39.40
Remote sensing and monitoring systems (e.g., 'smart' detection systems)	12.90	11.90	17.20	23.70
Automated systems and programmable machines	12.50	11.20	18.10	27.10
High performance concrete	12.00	10.80	16.50	39.10
Composite materials (e.g. fibre reinforced plastics)	11.30	9.80	17.70	36.40
Deconstruction and reuse systems	9.50	10.00	6.80	14.60
Pre-assembled air, water, power distribution systems (e.g. 'drop-in systems')	8.20	8.20	7.40	16.50
Electronic exchange of CAD files	7.40	4.20	21.60	42.70
Recycled plastic components	7.30	6.80	9.20	19.80
Modelling or simulation technologies	4.50	4.10	6.20	13.70
Digital photography for progress reporting	3.30	1.90	9.30	19.60
'Clean room' technology	3.20	3.20	3.10	10.60
Bio-remediation clean-up	2.80	2.40	4.70	10.60
Global Positioning System (GPS)	1.50	1.20	2.50	7.30
Office-to-site video links or video conferencing	1.40	1.30	1.70	3.60

Business practices	Total firms (%)	Small (%)	Medium (%)	Large (%)
Design-build contracts	30.80	28.40	41.10	65.50
Computerized project management systems and/or scheduling systems	28.10	23.40	48.90	69.70
Computerized estimating software	27.00	22.90	45.00	72.50
Long-term working arrangements with other businesses	23.80	21.40	34.20	45.80
Written strategic plan	17.10	15.80	21.90	41.20
Post-commissioning inspection or maintenance	16.30	14.40	24.60	34.60
Written evaluation of new ideas in order to develop options for your business	13.90	13.90	13.20	30.30
Written documentation of technological improvements developed by your business	11.60	12.00	9.10	22.40
Computerized inventory control	10.60	5.70	33.10	36.40
Written market analysis report to evaluate needs and opportunities of your business	8.20	6.30	16.20	26.30
Build–operate–transfer (BOT) contracts	5.00	4.50	7.10	13.30
Quality control certification (e.g. ISO 9000, R2000, etc.)	4.90	3.40	11.40	22.50

since they reflect the perceptions and beliefs of managers. As such they are amenable to factor analysis to reduce the dimensionality of this data. This 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 that are linear combinations of the original variables.

The factor analysis of the eight available business environment variables produced a five-factor solution that explained 81% of the variation. The five factors were named based on their correlations with the original variables: rapid technological change, competitive threats, consumer/competitor predictability, many suppliers and materials obsolescence.

The factor analysis of seven marketing strategy variables produced a five-factor solution that explained 89% of the variation. These factors were identified as market share expansion, client retention, expanded product range, geographic expansion and awareness of clients operating costs. Eight human resource strategy variables produced a four-factor solution that explained 83% of the variation. These were identified as employees skills/ knowledge development, hiring experienced workers, hiring well-trained new graduates and multi-skilled teams. The technological strategy

Table 2 Number of innovative (technology, business, total) practices currently used or planned to use with two years

Innovative practices	Total (*n*=1739)			Small (*n*=633)			Medium (*n*=839)			Large (*n*=267)		
	Mean	[95% C.I.]		Mean	[95% C.I.]		Mean	[95% C.I.]		Mean	[95% C.I.]	
Technology (used)	1.93	1.82	2.04	1.66	1.49	1.82	3.09	2.92	3.27	5.32	4.92	5.73
Technology (used & planned)	3.35	3.19	3.50	3.03	2.78	3.28	4.71	4.49	4.93	7.17	6.73	7.62
Business (used)	1.97	1.86	2.09	1.72	1.54	1.91	3.06	2.88	3.24	4.80	4.47	5.14
Business (used & planned)	3.31	3.16	3.46	2.99	2.75	3.24	4.69	4.49	4.90	6.50	6.12	6.88
Total (used)	3.90	3.70	4.11	3.38	3.06	3.70	6.15	5.84	6.47	10.13	9.47	10.78
Total (used & planned)	6.66	6.37	6.94	6.02	5.55	6.50	9.40	9.03	9.77	13.67	12.96	14.39

variables produced a three-factor solution that explained 86% of the variation. These variables were identified as improving technology practices/capabilities, developing proprietary technologies and developing industry standards/practices.

Relationship of business environment and business strategy

Regression analysis was used to test the relationship between the five perceived business environment factors and the 12 business strategy factors. Due to space limitations, we summarize the results without providing detailed tables. The analysis shows that rapid technological change appears to be a clear impetus for engaging in all 12 business strategies. The only exception is a 'negative' effect of rapid technological change on the hiring of experienced workers indicating that firms may delay hiring or substitute hiring for technological change.

The remaining four perceived environment factors present mixed effects (i.e. positive, negative and no relationships) on the 12 business strategies. For example, competitive threats is positively associated with the hiring of experienced employees and negatively associated with the hiring of well-trained new graduates, indicating that firms tend to consider experienced employees as a competitive tool but that this is not the case for well-trained new graduates. Despite inconsistencies, each of these four factors predict eight to 10 business strategies suggesting that the business strategies implemented for innovation are not done in isolation but rather with considered strategic intent resulting from environmental scanning.

Relationship of business environment and innovative practices

Regression analysis was used to test the relationship between the five perceived business environment factors and the total number of advanced technology and business practices currently used (Table 3). Here and for the rest of the paper, we focus on actual advanced technology and business practices currently used as an indicator of innovativeness since it is an actual self-report of organizational activity. As could have been expected, there is a strong linkage between the respondents' perception of the environment and their use of innovative practices, thus supporting a key relationship in our model. We find more innovative practices in environments perceived to be subject to rapid technological change for all firms. We also observe fewer innovative practices in environments with perceived competitive threats, especially for small and medium firms. This seems to indicate that innovation is considered an added risk rather than a competitive advantage. And large firms with many suppliers tend to be more innovative while small firms with many suppliers tend to be less innovative.

Table 3 Relationship between business environment and total of currently used innovative practices

Business environment	Total (*n*=1739)	Small (*n*=633)	Medium (*n*=839)	Large (*n*=267)
Rapid technological change	1.52	1.50	0.58	1.13
Competitive threats	–0.49	–0.34	–0.82	
Consumer/competitor predictability		0.28		
Many suppliers	–0.88	–1.07		1.92
Material obsolescence				
R2	0.17	0.23	0.04	0.12

All regression equations were significant ($p < 0.001$); coefficients shown were significant ($p < 0.05$).

Relationship of business strategy and innovative practices

The relationships between the 12 business strategy factors and business and technology innovative practices currently used were investigated using regression analysis (Table 4). These regressions were done in blocks: five marketing strategy factors, four human resources factors and three technology factors, all on same dependent variable. For the overall data, we found that most of the business strategies are positively related to innovative practices.

The variable *expanded product range* has no effect, while *hiring experienced employees* has a negative effect; both variables exhibit a size effect. The most innovative large and medium firms have product range expansion strategies in comparison to small firms who have none. Similarly, only small firms exhibit a negative effect of hiring experienced employees. The analysis also shows that the most innovative small and medium-size firms have strong growth strategies (i.e. market share expansion, geographic expansion) and are involved with developing industry standard/practices as compared to large firms who do not exhibit such relationships.

Many strategies (i.e. awareness of clients operating costs, hiring well-trained new graduates, developing the skills/knowledge of the employees, using multi-skilled teams, improving technology practices/capabilities, developing proprietary technologies) are shared by the most innovative firms of all sizes with varying degrees of strength.

Relationship of innovative practices and outcomes

The next step in the conceptual model is to investigate whether innovation is profitable or leads to significant competitive advantage. The former is addressed with quantitative analysis while the latter is addressed qualitatively.

Profitability

We examined the profitability question with two analyses. First, we present correlations between the pre-tax operating margin and the three measures of innovation (i.e. technology, business, total) currently used (see Table 5). Next, we compare the average of each innovation variable above and below the median pre-tax operating margin (Table 6). In some instances, the tests on the correlations and the above/below median measures appear inconsistent. We remind the reader that the tests are founded on distributional and other assumptions that may not be fully supportable and that the sample is drawn from a single year of financial data.

Table 5 Relationship between currently used innovative practices and pretax operating margin

Innovative practices	Total (n=1739)	Small (n=633)	Medium (n=822)	Large (n=261)
Technology	0.02	0.00	0.08	–0.03
Business	–0.09	–0.12	–0.01	0.08
Total	–0.04	–0.07	0.04	0.02

Correlations shown in bold were significant ($p < 0.05$).

Table 4 Relationship between business strategy and total of currently used innovative practices

Business strategies	Total (n=1739)	Small (n=633)	Medium (n=839)	Large (n=267)
Marketing strategy				
Market share expansion	1.30	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
Human resources strategy				
Employees skills/knowledge development	1.00	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	0.94	2.26
R2	0.27	0.30	0.11	0.14
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

All regression equations were significant ($p < 0.001$); coefficients shown were significant ($p < 0.05$).

Table 6 Relationship between currently used innovative practices and pretax operating margin (mean value of innovative practices below (column 1) and above (column 2) median pretax operating margin (POM))

Innovative practices	Total (n = 1739)		Small (n=633)		Medium (n=822)		Large (n=261)	
	< POM median	> POM median	< POM median	> POM median	< POM. median	> POM median	< POM median	> POM median
Technology	1.79	2.08	1.60	1.72	2.83	3.36	5.34	5.47
Business	2.07	1.86	1.90	1.51	2.98	3.13	4.56	5.15
Total	3.86	3.95	3.50	3.24	5.81	6.50	9.90	10.60

Differences shown in bold were significant ($p < 0.05$).

The correlation for total 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. Examining this relationship by size indicates that the negative coefficient is due to the pronounced effect for small firms whereas there is no real effect for medium and large firms.

Individually, technology and business innovation provide an interesting result when looking at the effects by size. Profitability and business innovation shows a negative relationship for small firms and a positive relationship for large firms. Note the correlation for large firms is not significant but one of the highest in all of the results. Furthermore, we find a positive relationship for medium firms with technology innovation and profitability. This initial test suggests that different types of innovation have differing effects for varying sizes of firms.

Our second test of the innovation to profitability relationship presents similar results. Higher levels of technology innovation appear for medium firms that have a pre-tax operating margin above the median. Lower levels and higher levels of business innovation emerge for small and large firms, respectively, that have pre-tax operating margin above the median. Note the difference for large firms ($p = 0.08$) does not have the customary level of significance ($p < 0.05$) but it does have a consistent trend.

Synthesizing the results of both tests, we find that technology and business innovation may have different effect on profits in the construction industry. We offer one interpretation of these findings, but recognize that other hypotheses may be relevant. Small firms (some of firms in this category are likely to be very small) tend to be focussed on day-to-day operations and may not perceive investment in even relatively inexpensive technology or management tools as a source of competitive advantage. As medium firms grow, they have established business practices but must invest in information technology to remain competitive with large firms. In contrast, established large firms engage in more complex business practices (i.e. partnerships, design build, joint ventures). Overall, these results are quite realistic. They are robust too, being similar for both firm-weighted analysis, presented in this paper, which gives more importance to small firms which are a large part of the sample, and wage-weighted analysis where a firm's importance is determined by its size (Seaden *et al.*, 2001). An alternative interpretation, suggested by one of the anonymous referees is that 'data could be saying that big firms need more complex technologies and management processes as a response to the complexity implicit in the large projects and internal organizational issues confronted. And it might be that they are inappropriate for small firms that are simpler and to invest in these "innovations" does not show a good business return'.

Competitive advantage

Almost half of the firms answered the open-ended question on 'the technological or business practice change or improvement which had the biggest impact on your business during the last three years'. This question was used to qualitatively assess the effect of innovative practices on outcomes. We interpret this response level quite favourably as it was the last question of the survey and it required respondents to describe a specific technology or business improvement.

The practices were coded into 13 distinct categories plus 'other' for a total of 14. For our analysis and to be reasonably consistent with the quantitative analysis (i.e. business and technology practices) we regrouped the categories into meaningful assemblies of 'information technology' (i.e. software and hardware applications), 'business' (i.e. strategies, contractual arrangements) and 'construction technology' (i.e. material, processes). As might be expected, most assemblies (86%) concern information technology (39%), business practices (28%) and technology practices (18%) and these vary by size (Table 7). Regulations and ISO certifications are shown separately because of particular interest in the industry with new approaches in these areas.

Small firms report that they engage in more business practices that result in a significant competitive

Table 7 Relationship between innovative practices with biggest impact on business and perceived competitive advantage (firm weighted)

Innovative practices	Total (n = 1739)		Small (n=633)		Medium (n=822)		Large (n=261)	
	Frequency	Significance	Frequency	Significance	Frequency	Significance	Frequency	Significance
Information technology	39.2%	45.8%	35.0%	40.5%	55.0%	59.7%	56.1%	36.7%
Business	28.4%	77.7%	30.2%	80.5%	22.5%	63.1%	10.9%	69.1%
Construction technology	18.4%	53.0%	19.6%	51.3%	13.9%	63.4%	14.5%	35.0%
Regulations	5.2%	2.5%	6.0%	1.1%	2.4%	12.5%	2.7%	52.4%
ISO	0.4%	68.3%	0.0%	0.0%	1.6%	68.6%	3.9%	66.4%
Weighted % of responding firms indicating perceived competitive advantage		50.4		48.8		57.8		38.1
Weighted % of firms responding	45.6		43.7		54.3		65.4	

Frequency of practices reported and its significance (percentage of respondents who judged that it produced significant advantage).

advantage than medium or larger firms. In fact, there is a decreasing trend through all three sizes. Information technology exhibits a slightly different trend where medium and large firms engage in many more practices than small firms do. Interestingly construction technology practices are generally the same across all three sizes.

Another trend emerges based on the self-report of whether the firm perceived that the practice provided a significant competitive advantage. Overall, 50% of the respondents or 25% of the total sample report that the innovation provided a significant competitive advantage and ten percent did not answer this question. While we cannot say for certain, it is possible that much of the remaining 40% could be attributed to maintaining a competitive position.

Business practices provided substantially more competitive advantage (i.e. 3:2 ratio) than construction or information technology. However, there is a pronounced effect based on size. We observe an inverted-U relationship of significant advantage for information and construction technologies going across firms from small to large. As for business practices, once again we see the importance of business practices for small firms as 80% report these innovations as having a significant advantage.

The remaining two practices, regulations and ISO, are included since each represents an interesting finding despite their small incidence. Large firms perceive significant competitive advantage with regulations and ISO both of which may be proxies for the degree large construction firms are engaging in the global economy or taking advantage of more open regulatory regime.

Synthesis and summary

Numerous overview studies of Canadian construction during the last 50 years (Keys and Caskie, 1975; Construction Industry Development Board, 1984; Industry Canada, 1998) 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, reported elsewhere (Seaden *et al.*, 2001). It also shows significant differences between large, medium and small firms. All action that may be contemplated to encourage innovation needs to take this diversity into consideration.

Surveying the use of innovative technology and business practices appears to be a useful proxy of innovation intensity of construction firms, however, greater consultation with the industry is required to obtain the appropriate array of relevant advanced practices. The relatively low uptake of practices proposed in the survey may underestimate the actual level of introduction of new ideas given the more positive view shown by the number of self-reported practices introduced with a significant impact on the firm and on its competitive advantage. Information technology practices clearly dominate new ways of doing business and need to be analysed separately from construction technology or other business arrangements.

There is an overall consistency in the survey results. Quantitative analysis shows smaller firms being more risk averse, with lower intensity of use of innovative practices and negative correlation of innovativeness to profitability when compared to larger firms. At the same time, a greater percentage of larger firms reported adopting technological or business changes with significant impact on their business. Yet, smaller and particularly medium size firms indicate that such changes provided them with bigger competitive advantage when compared to large firms. Available survey data does not allow us more detailed analysis of this apparent contradiction in the small and medium size enterprise (SME) competitive behaviour.

There are, of course, limitations to the validity of our findings and of the model. In particular, the survey was not designed with our model in mind. In addition, the financial data was made available in a codified form for confidentiality purposes and was measured at a single time point, thus we cannot easily infer long-term relationships.

In general, findings of this study support the proposed conceptual model of business environment scanning leading to strategic decisions regarding investment in innovation. Construction in Canada does appear to undertake innovative practices in order to gain competitive advantage and/or to maintain its competitiveness 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 slower in coming to terms with the new reality of intense global competition based on knowledge and innovation. Larger firms are likely to be more exposed to these forces and there is evidence of greater innovation activity among them.

It is suggested that future surveys of innovation in construction also include a greater variety of measurable business success factors (financial results, changes in market share, rate of growth, repeat orders) that would enable a richer analysis of data relationships.

References

Anderson, F. and Manseau, A. (1999) A systematic approach to the generation/transmission/use of innovation in construction activities. *Third International Conference on Policy and Innovation*, August 1999, Austin, Texas, USA.

ARA Consulting Group (1997) *Nature of Innovation in the Canadian Construction Industry,* Institute for Research in Construction, National Research Council of Canada.

Barrett, P. and Miozzo, M. (2000) Innovation in Small Construction Firms, LINK/IMI/EPSRC Project, Interim Report, August 2000, University of Salford, UK, working document.

Civil Engineering Research Foundation (CERF) (1993) *A Nationwide Survey of Civil Engineering-related R&D*, American Society of Civil Engineers, Washington.

Construction Industry Development Board (1984) *Canada Constructs*, Construction Industry Development Board, Ottawa.

Cooper, R. G. (1998) *Product Leadership: Creating and Launching Superior New Products*, Addison-Wesley, Reading.

Industry Canada (1998) *Service Industries and Capital Projects Branch. Sector Competitiveness Frameworks, Construction, Part 1- Overview and Prospects,* Industry Canada, Ottawa.

Keys, B. A. and Caskie, D. M. (1975) *The Structure and Operation of the Construction Industry in Canada*, Economic Council of Canada, Ottawa.

Lundvall, B.-A. and Christensen, J. L. (1999) Extending and deepening the analysis of innovation systems-with empirical illustrations from the DISKO-project. Aalborg University, Aalborg, Denmark, unpublished paper.

Nam, C. H. and Tatum, C. B. (1992) Strategies for Technology Push: Lessons from Construction Innovations. *Journal of Construction Engineering and Management*, **118**(3).

National Research Council of Canada (2001) Construction innovation – opportunities for better value and profitability. *International Symposium*, Preliminary Proceedings, June, National Research Council of Canada, Ottawa.

OECD (1997a) *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data – Oslo Manual,* OECD, Paris.

OECD (1997b) *National Innovation Systems*, OECD, Paris.

Porter, M. (1998) *On Competition*, Harvard Business Review Book Series, Cambridge, MA

Pries, F. and Janszen, F. (1995) Innovation in the construction industry: the dominant role of the environment. *Construction Management and Economics*, **13**(1).

Seaden, G., Guolla, M., Doutriaux, J. and Nash, J. (2001) *Analysis of the Survey on Innovation, Advanced Technologies and Practices in the Construction and Related Industries, 1999.* Science, Innovation and Electronic Information Division, Statistics Canada, Ottawa. Document no. 88F0017 MIE01010. Available online http://www.statcan.ca/english/IPS/Data/88F0017MIE01010.htm

Serpell, A. and Ocaranza, R. (2001) Technology innovation in the Chilean construction industry: a diagnosis of the current situation. *Proceedings of the First International Conference on Innovation in Architecture, Engineering and Construction*, Loughborough University, July, pp. 299–308.

Slaughter, S. E. (1993) Builders as sources of innovation. *Journal of Construction Engineering and Management*, **119**(3).

Technopolis, IPRA (1995) UK National Technology Foresight Programme, Digest of Statistical Indicators for the Construction Panel, Construction Panel and the Department of the Environment, working document.

The Economist (2000) Construction and the Internet. *The Economist*, 15 January.

Toole, M. T. (1998) Uncertainty and home builder's adoption of technological innovations. *Journal of Construction Engineering and Management*, **124**(4).