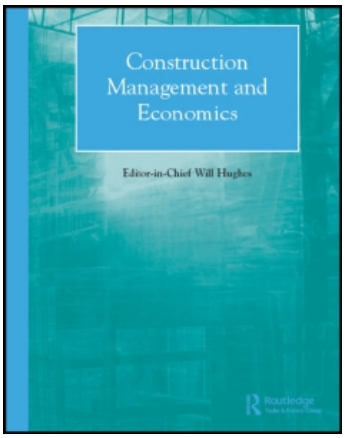

Construction Management and Economics
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713664979

Perspectives on experiences of innovation: the development of an assessment methodology appropriate to construction project organizations

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First Published on: 07 November 2007

To cite this Article Gray, Colin and Davies, Richard John(2007)'Perspectives on experiences of innovation: the development of an assessment methodology appropriate to construction project organizations',Construction Management and Economics,25:12,1251 — 1268
To link to this Article: DOI: 10.1080/01446190701573692
URL: http://dx.doi.org/10.1080/01446190701573692

Construction Management and Economics (December 2007) **25**, 1251–1268

Perspectives on experiences of innovation: the development of an assessment methodology appropriate to construction project organizations

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Received 11 December 2006; accepted 15 July 2007

The UK construction industry is in the process of trying to adopt a new culture based on the large-scale take up of innovative practices. Through the Demonstration Project process many organizations are implementing changed practices and learning from the experiences of others. This is probably the largest experiment in innovation in any industry in recent times. The long-term success will be measured by the effectiveness of embedding the new practices in the organization. As yet there is no recognized approach to measuring the receptivity of the organization to the innovation process as an indication of the likelihood of long-term development. The development of an appropriate approach is described here. Existing approaches to the measurement of the take up of innovation were reviewed and where appropriate used as the base for the development of a questionnaire. The questionnaire could be applicable to multi-organizational construction project situations such that the output could determine an individual organization's innovative practices via an innovation scorecard, a project team's approach or it could be used to survey a wide cross-section of the industry.

Keywords: Innovation, measurement, methodology

Introduction

The implementation of *Rethinking Construction* (Egan, 1998) and subsequently *Accelerating Change* (Strategic Forum for Construction, 2002) is being undertaken by the Strategic Forum and Constructing Excellence in probably the largest experiment in innovation in any industry. Over 375 Demonstration Projects worth over £7 billion (Rethinking Construction, 2003) are being used to realize the ambition of achieving change and the adoption of best practice through the involvement of a wide section of the construction industry. The dissemination of the lessons learnt is through a combination of individual experience, shared experience and by showing to others the change process in progress. The effectiveness of this approach depends upon the receptivity of the individual and their parent organization to embrace the experience and the ability to transfer it into established practice. Gann (2000) has identified the difficulties faced by project organizations in capturing knowledge from its variety of experiences on individual projects. The success or otherwise of the demonstration projects will be in whether this experiment achieves a wider take up of innovation than conventional approaches. To innovate is the introduction of technologically new products or processes that are new to the organization (OECD and Statistical Office of the European Communities, 1997). The nature of a project is that the participants will be placed in an innovative environment such that those involved have an opportunity to be innovative themselves or to take advantage of others' innovation. This is in addition to any technological innovation that may be used to satisfy the product development. The emphasis of the Demonstration Project process is predominantly process improvement, rather than product improvement. Each company is exposed to novel knowledge acquired on the project and the question is to what degree this exposure is welcomed and the company's processes and procedures geared to change via adoption? It is not just an issue for the Demonstration Projects, it is a general

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Construction Management and Economics
ISSN 0144-6193 print/ISSN 1466-433X online © 2007 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/01446190701573692

issue for the construction industry, but the opportunity presented by the Demonstration Projects brings innovation and transfer into ongoing operations to the forefront as it is their primary goal.

Innovation in the construction industry is multi-faceted with innovation activities ranging from the introduction of new products and processes to the introduction of new procurement and management strategies. However, given the prototypical nature of construction it would be a huge task to list all innovations in the UK construction industry and their take up. Even if it were possible it would serve little purpose as the innovative activities can be so customized to the firm's particular capabilities and market that direct comparison would be difficult. This is not to say that lessons cannot be learnt or knowledge transferred, it is merely to say that innovations are part of the normal business cycle (or should be!) and how effectively a firm absorbs and develops innovation is more the issue. In order to become a Demonstration Project each project team has to show to the monitoring team that it is introducing innovative practices. While this has the effect of placing the projects against a set of criteria there is limited robust evaluation of the criteria or of the outcomes.

The Demonstration Projects have as their objective 'to seek to innovate or employ best practice in working relationships, construction technique or process and development of components' (Egan, 1998). In a demonstration project the innovation is led by a project 'champion' who is tasked with dissemination of the outcomes. While it is hoped that the clusters, visits and knowledge exchange methodologies used by Constructing Excellence all contribute to dissemination, the key issue is whether the champions and their organizations are receptive to innovation and can implement any of the observed innovation long term and on other projects. To be successful, project-based organizations need to embed their experiences into their ongoing business (Gann, 2000). This brings in issues of the learning organization (Nonaka and Tackeuchi, 1995). However this paper concentrates on the development of an appropriate methodology of assessment for construction organizations' ability and willingness to embed the experience gained from the innovation process.

Approaches to evaluation of organizational innovation capability

As a significant economic variable, the measurement of innovation has attracted a lot of attention. Historically, organizations and public bodies have tended to measure innovation in terms of inputs (e.g. R&D expenditure) and outputs (e.g. patent or trademark applications) (Archibugi and Pianta, 1996). These indicators are useful for many types of research in that they offer publicly available time series data held across countries and industry sectors. What they neglect however are the organization level processes by which the inputs are transformed into outputs (Cordero, 1990). This omission is particularly problematic when applied to construction. Much construction innovation is project-based and unrelated to formal R&D expenditure and many innovations, particularly organizational or process innovations are neither patented nor trademarked (Slaughter, 1993). Modern construction companies largely function and innovate by the quality of their processes, the people operating them and the way in which they change and adapt to suit the changing business environment. Measuring these intra-firm processes require the use of specific firm-level surveys.

A range of innovation surveys exist in the literature. An important type of innovation survey in economic and policy work is generic innovation surveys designed for large-scale international and cross-sector comparison. As a consequence these often use general language, tend to be oriented towards traditional manufacturing firms and can be limited in the questions asked. Examples of these forms include the *Oslo Manual* (OECD and Statistical Office of the European Communities, 1997) and the *Frascati Manual* (OECD, 1994). However Reichstein *et al.* (2005) have pointed out the difficulties in using surveys based on the *Oslo Manual* (in that case the Innovation Survey by the UK's DTI) for understanding construction innovation because of these forms' traditional manufacturing heritage. Other forms of survey are more tightly focused, designed for specific research problems or as organization audit tools (e.g. Burgelman *et al.*, 1988; Chiesa *et al.*, 1996; Coombs *et al.*, 1998) again, usually in a manufacturing context. Within construction Kululanga and McCaffer (2001) adapted Burgelman *et al.* 's measure but this was a study of knowledge management specifically rather than innovation more broadly so is limited in scope. The measure reported in this study expands on this significantly, considering multiple dimensions of innovation capability.

Dimensions of organizational innovation capability

Our review of the literature identified eight important areas of capability and corresponding questions related to each area. These are:

(1) How was the innovation conceived?
(2) What was the product development innovation process?
(3) What are the production process innovation processes?
(4) What is the technology and knowledge acquisition process?
(5) How is the leadership for innovation provided?
(6) Are the resources capable of developing the innovations?
(7) Does the organization have suitable systems and tools for capturing the innovation? and
(8) Does the innovation lead to increasing competitiveness?

The following sections are a necessarily concise review and are intended to make explicit the links between the literature and the questions developed for the survey. The review is therefore organized around the eight areas identified and the questions used to assess specific aspects of each one.

Concept generation process

What policies for generating new process or product concepts do construction practitioners employ to develop innovations on Demonstration Projects?

In order to develop a new idea or concept the organizations within the construction industry need to systematically monitor market needs (Maidique, 1984). However, organizations need to match technological capabilities with the market needs (Johne, 1988; Cooper, 1994) although in a project-based environment knowledge gained from partners is likely to be invaluable. External sources of knowledge inside and outside the industry should be considered. Building long-term relationships with customers, especially repeat clients (Von Hippel, 1988), may provide sources of ideas for innovation. In addition the use of feedback from functions that relate to customer needs (Moenart and Souder, 1990; Moenart *et al.*, 1994) may also be of benefit as would putting up mechanisms for functional groups to meet the customer to discuss deficiencies and future requirements (Rochford and Rudelius, 1992).

What policies exist within the participants on the Demonstration Projects for product and process innovation planning?

The organizations innovating on the Demonstration Projects should have planned how their product or process concepts are best developed and implemented to produce the best returns to them and the project. Project-based returns require cooperation and trust of others involved in the project that is not always possible on a construction project, at least initially.

The Demonstration Projects should consider the planning implications for product and process innovations in both the short term and the long term. Linking the product innovation plan to the corporate plan is therefore essential (Utterback, 1982). Market-led planning processes and prioritizing parts of the product process or development process should be considered (Crawford and Rosenau, 1994). An innovation generation and phased delivery strategy may need to be sought in order to justify expenditure and resources. Establishing procedures for selecting new enhanced products and processes needs to be considered (Adler, 1992; Twiss, 1992; Wheelwright, 1992). Integrating processes for generating new product concepts, planning product innovation to realizing new products and process is vital (Adler, 1992).

What policies exist within Demonstration Project participants to promote innovation and creativity?

Innovativeness and creativity of its people is a vital ingredient to the successful organization. Rewarding entrepreneurial behaviour, supporting unplanned product initiatives and circulating new product ideas may also reinforce a culture that embraces change (Felberg and DeMarco, 1992; Twiss, 1992). How organizations structure themselves to favour creativity and inventiveness is an important issue (Kaplan, 1960; Twiss, 1992), as is choosing the appropriate people for critical innovation roles (Allen, 1976; Maidique, 1980; Felberg and DeMarco, 1992).

What explicit policies are there for exploiting innovation on the Demonstration Projects by participants?

Organizations do develop policies to exploit innovation routinely; however, it is not explicitly stated as part of Constructing Excellence's screening policy for new Demonstration Projects. It is observed that in some industrial sectors policies are developed and kept internally to protect their market position. It would appear that such an active policy is not evident on the production side of the construction industry or on the Demonstration Projects.

Exploitation of an innovation ideally should be planned early so that the returns are maximized and efforts directed. Weak ideas should be discarded early to avoid the wasting of time, effort and resource. The evaluation of alternatives in order to develop potential new business opportunities is of course vital (Maidique, 1980; Roberts, 1985; Burgelman *et al.*, 1988), but the selecting of new venture alternatives for entering into a new market or developing a market should be considered (Roberts, 1991). A related issue is being able to assess the relatedness of entrepreneurial

initiatives and what core competencies exist within the organization (Burgelman *et al.*, 1988).

Product development process

Do the Demonstration Projects have a product or process development process?

The development process for an innovation could be formalized so that procedures are made explicit on the Demonstration Projects to allow products to flow efficiently and without delay and to demonstrate to others the mechanics of the development process. Managing product projects from the concept to launch, establishing the scope of the process, phases, gates, reviews, sign-off procedures all could be considered (Cooper, 1990, 1994). Understanding the development process should permit informed judgement to be made permitting fast-tracking or quick-wins, something ironically sought out by most in the construction industry.

What policy do companies on Demonstration Projects have to create teams centred on innovations?

The Demonstration Projects should require the formation of a team to implement an agreed innovation. In practice the innovator is the originator of the idea and does not always receive the full support of others in the project team. This is also true of client-led innovation but to a lesser extent. Innovators may impose their innovations on those below them in the supply chain, something typical on client-led Demonstration Projects. Ideally, the availability of staff to organize a development project should be considered with multidisciplinary teams crossing organizational functions. This could increase the probability of successful innovation and a successful project (Cooper, 1990; Thamhain, 1990; Clark and Fujimoto, 1991). Early involvement of the key internal functions and external organizations should also be sought to improve cooperation and develop trust and a degree of ownership (Clark and Fujimoto, 1991).

Communication among different groups involved in the development process needs facilitating with the degree of parallelism, integration of steps and task interdependence built into the process. This would also include establishing the role and priority of project progress reviews (Clark and Fujimoto, 1993).

Production process innovation process

How has the organization used the Demonstration Project to transfer innovation to manufacture, production and distribution departments?

How an innovation involves production and the manufacturing strategy should be considered. The innovation may need ancillary changes to be made to accommodate it into a new product or process. This may be part of a continuous improvement strategy, but more likely will expose the weak link between design and production particularly in the construction industry. Strategies should exist to link design and engineering to manufacture and production with planned loops to deal with manufacturing and production changes (Wheelwright, 1992).

On what basis does your company/organization create development teams for innovations on the Demonstration Projects?

Cross-functional innovation requires that teams are developed from capable groups of individuals who can manage the development process of the new ideas and products. This is something which a personnel department could consider in order to match skills with given circumstances. The use of cross-functional teams to improve the range of skills of the team as well as defining the status of project managers in the organization will also strengthen commitment (Hise *et al.*, 1990). The use of organizational integration mechanisms at the initial stages of a project may help (Ciccantelli and Magidson, 1993) in complex project situations.

What policies exist on the Demonstration Projects for organizations to form a coherent manufacturing and production strategy?

Within the existing production processes is there a formal procedure for the development of a product development strategy or method statement for process innovation (Hill, 1993)? Allocating resources for developing new process technologies will become an issue as will reviewing and monitoring sources of process innovations at the project level (Hayes and Wheelwright, 1984).

What policies exist within the organizations on the Demonstration Projects for the managed implementation of new innovations?

Frequently the development and the implementation process on the Demonstration Projects are one and the same. For example, matching the accompanying production process innovations with the appropriate changes to the organization or modifying performance measures to reflect the capabilities of new processes (Drazin and Kazanjian, 1986; Tyre, 1991; Adler, 1992; Voss, 1992). Matching the technological complexity to the capability of the organization to adapt is vital (Gerwin, 1988; Leonard-Barton, 1988; Voss, 1992; Lissoni, 2000) as is managing the links with suppliers in the development and implementation (Tyre, 1991; Adler, 1992; Voss, 1992).

Does the originator of the innovation on the Demonstration Project have a company policy of continuous improvement?

Continuous improvement is the current mantra and implies that there is a continuous process to look for improvements in the whole of the activities of the firm. This could include identifying opportunities for improvement in existing processes (Hayes and Clarke, 1985; Bessant and Buckingham, 1993), integrating process improvement with quality control (Deming, 1982a) or benchmarking production process performance to establish competitive position in the sector (Camp, 1989).

The process could be formalized to establish an atmosphere conducive to ideas, a suggestion which does not penalize but rewards the originator, which could include involving production staff in improvement after installation (Wood and Elgie, 1976).

A strategy of continuous improvement is often talked of in the construction industry, but business as usual may be more accurate as formal strategies are rare.

Technology and knowledge acquisition process

Are there policies within organizations on the Demonstration Projects for knowledge and technology acquisition?

Knowledge and technological know-how are vital ingredients for any organization because they expand the core competencies of the staff and increase the flexibility of the organization to respond to a changing market. The systematic monitoring of new trends in existing and future technologies is seen by many as a prerequisite for survival of the organization (Mitchell, 1986; Hax and Majluf, 1991). The issue of intermediate and emerging technology is one which must be examined seriously. Developing competencies around an intermediate and emerging technology is certainly cheaper, so long as the knowledge and technology are available (Lissoni, 2000). It is often more appropriate to assess competitors' technical capabilities and begin to understand what the core competencies of one's own organization are currently (Papas, 1984; Foster, 1986; Pahalad and Hamel, 1986; Burgelman *et al.*, 1988; Roussel *et al.*, 1991). Building the required core competencies based upon technological capabilities should be the aim of most developing firms (Hax and Majluf, 1991) and (Pahalad and Hamel, 1986) as should the ability to relate technology to business objectives and strategies (Mitchell, 1986; Roussel *et al.*, 1991).

What policy exists in organizations for selecting, generating and sourcing new knowledge and technology?

When it has been established that the core competencies of an organization need updating, sources need to be found to supplement what currently exists. Organizations can choose to source technologies and knowledge in any number of ways. This could include: in-house developments, R&D, licensing, partnering or external alliances. The use of both quantitative and qualitative methods to evaluate how to use technology and knowledge and initiate development projects needs careful consideration (Twiss, 1992). An organization could develop procedures for selecting the most appropriate type of development projects. This could include balancing risk and reward, evaluating project timescales and identifying the key issues in the organization to support the firm's technology and knowledge policy. Issues relating to communication, structural interfaces of development projects with other functions and optimizing resources across the organization are of course considerations also (Roussel *et al.*, 1991).

Do policies exist for organizations to undertake market planning and review exercises?

As well as policies to capture knowledge and technology, knowledge created has a value. Protecting intellectual property rights (patenting, trade secrets) and exploiting intellectual property rights (licensing out) can be very profitable (Roberts, 1985; Twiss, 1992).

Leadership process

What human resources policy exists within organizations on the Demonstration Projects to promote innovation?

Organizations need to have individuals who can champion innovation and relate knowledge and technology to corporate strategies (Adler, 1992). Individuals need to build innovative strategies and develop these plans in corporate strategies and execution plans (Quinn, 1985; Burgelman *et al.*, 1988; Burgelman *et al.*, 2001).

The individuals selected must have the distinctive core competencies and have a representation of innovation and technical functions on the board (Pahalad and Hamel, 1986).

What is the management involvement in the innovation process within Demonstration Project organizations?

All organizations need to evaluate their processes for generating and implementing innovations periodically (Quinn, 1985) in order to benchmark their processes for innovation against what is best practice (Camp, 1989). Falling behind reduces competitiveness but not normally in the short term. It is advisable that innovation processes are visible to top management so that their strategies can incorporate the innovation or instigate a catch-up programme (Van de Ven, 1986; Burger, 1989; Van de Ven, 1999).

How do organizations on Demonstration Projects create a climate for innovation?

It is demonstrated frequently that innovation is an organizational trait that creates new directions and new opportunities for the organization to grow and expand. It therefore seems a reasonable expectation that innovation is promoted. This could include encouraging new developments, risk taking and entrepreneurship (Tushman and Nadler, 1986; Thamhain, 1990; Tushman and O'Reilly, 1997). Making innovation policies shared and understood in the organization (Tushman and Nadler, 1986) and defining a performance measurement system encourages innovation (Tushman and Nadler, 1986; Van de Ven, 1986, 1999).

Resource provision process

How do organizations set resources?

When starting and managing an innovation process it is essential that the key individuals have the competencies to deliver upon the expectations. It is therefore essential to identify the key roles needed for managing the innovation process. This may involve recruiting people with the necessary skills or developing core skills from within the organization. In addition, to instil commitment the individual associated with innovation should be evaluated and rewarded. Establishing career development paths for technical staff improves the quality of future development projects. Career development may take the form of dual ladder development, international development or cross-functional developments (Allen, 1976; Tushman and Nadler, 1986; Van de Ven, 1986; Adler, 1992).

What policy do organizations have for funding innovation?

Organizations need to fund innovation and this funding will relate to the strategic direction (vision) selected; this is most likely at board level. Innovation can in some cases turn into an open ended commitment and sharing risks and reducing the costs of innovation through alliance networks may be considered (Pahalad and Hamel, 1986). An important consideration for those involved in innovations and development projects is the stability of funding and the continued activities associated with knowledge and technological acquisition. Flexibility of funding of products and process development may need to considered (Twiss, 1992; Wheelwright, 1992).

Systems and tools provision process

What systems do organizations have in place to support innovation?

Innovation requires communication between associated parties to succeed and there need to be information systems that can be used to support the process for product and process development and information systems to enhance communication in the innovation process (Orlando, 1991).

What tools are used to aid innovation?

Innovation needs tools and techniques to assist in the development process and they may include the use of tools for capturing customer needs or the use of tools for design of new products (Adler, 1992; Rosenthal and Tatikonda, 1992). Tools also exist to promote creativity and generate the next generation of innovation (Richards, 1991).

What quality assurance policy exists within organizations on the Demonstration Projects?

The use of methods to analyse and improve the quality of innovation processes and integrating these process improvements and product innovations with the wider quality management strategies (Hauser and Clausing, 1988; Clausing, 1994) is an activity to consider when undertaking any project, regardless of whether it is a development project involving new innovations.

Competitiveness

How do organizations on Demonstration Projects measure innovation against targets?

The Movement for Innovation is keen to measure performance of the Demonstration Projects as a whole organizational gain rather than assessing the results of their innovations. It is this sort of information which has most value to second generation innovations. However, the measurement is expensive and evidence may not be readily measurable. The innovation maybe a supporting process or a health and safety issue which may present problems when determining the change in overall performance.

What management innovation performance is measured?

Organizational change resulting from the innovation take up needs to be measured to assess the variance from the predicted improvement resulting from the innovation. How this is done relates to the type of innovation, but a success criterion is essential.

Method

Participants and procedure

The participants in this study were the named Project Champions identified for each Demonstration Project. Ten initial interviews were held to understand their approach and to explore the type of questions that

would reveal their approach to innovation. What was clear was that while they were enthusiastic for their stage of development there was a range of experience and performance objectives within which each project was positioned. From these interviews a questionnaire was developed, a pilot undertaken and some questions revised for clarity before use in the survey of Demonstration Projects. This was a cross-sectional survey of all of the Project Champions from the total of 110 completed and published demonstration projects. The project champions were identified from the Demonstration Project file on the Constructing Excellence website. Initial contact and request for participation was by e-mail and followed up by phone call. The questionnaires were sent by e-mail in Microsoft Word format. Participants who had received questionnaires were followed up and supported by subsequent phone calls to ensure that they understood the questions and the method of completing the form.

Measures

Organizational innovation capability

In the initial interviews it became apparent that the champions were not clear, when asked about the level of innovation capability or performance, where they or their organizations were positioned compared to best practice. Respondents tended to rate their performance highly but without knowledge of potential for improvement. Because of this it was judged that a simple numerical scale would be unlikely to adequately position construction organizations in a normative range or adequately capture variation between projects and organizations. To address this, a more structured guide was developed. A four-step scale was developed with each scale point anchored to a specific description of innovation capability taken from the literature review described above (see Table 1). Specifically anchoring the scale in this way should mitigate the problem of respondents being unaware of gaps between their current capability and that of the most innovative companies. The full set of questions derived from the literature reviews above is set out in Table 2.

Satisfaction with level of organizational innovation capability

In addition to the capability measure, two exploratory attitudinal measures were included in the form. Satisfaction was measured to further explore some observations from the initial interviews that some Project Champions were disappointed with their organization's overall innovation performance compared to that they believed they had achieved on the Demonstration Project. Project Champions' satisfaction with their organization's score on the innovation capability measure was assessed using a five-point numerical scale. Satisfaction was operationalized as the perceived urgency of action required to improve the current performance level to an implicit desired performance level ('no action required' to 'urgent action required'). The scale was scored so that a high result indicates high respondent satisfaction with the current level of organizational performance.

Importance of each dimension of organizational innovation capability

Project Champions' perception of the importance of each dimensions of innovation capability measure was assessed using a five-point numerical scale. This was measured as an attempt to explore which of the various capability dimensions was judged as more significant. It was operationalized as Project Champions' perception of the importance to the company of each element for the success of the organization's overall innovation management policy ('unimportant' to 'most important'). The scale was scored so that a high result indicates high perceived importance for that element.

Comments

An additional blank column was provided for respondents to add any further comments for each capability element. This was not completed by any of the respondents.

Results

From the 110 Project Champions contacted, 24 completed questionnaires were received giving a disappointing response rate of 22%. This sample size is too small for meaningful inferential statistics or significance testing so a more exploratory form of *post-hoc* analysis effectively 'eyeballing' the data (Coolican, 1994) is presented.

The distribution of scores for organizational innovation capability showed a trend for the responses to be towards the higher end of the scale (see Table 3). The highest mean score obtained was for Q11 'Continuous improvement' and the lowest for Q19 'Funding innovation'. As with any attempt to measure organizational phenomena, it is possible that the results obtained were partly caused by the measurement instrument and the social elements of the measurement process. For this scale we judge that because of the explicit anchoring of each scale point it is unlikely that simple positive response bias contributed significantly to the pattern of results. A plausible social explanation could be hypothesized based on the sampling of Project Champions on public Demonstration Projects that have a marketing function for the sponsoring

Table 1 Examples of the question and alternatives to select
Question: What is your company's policy for generating new process of product?

Observed practices				Satisfaction	Importance	Comments
Basic advanced				Low–high	Low–high	
1	2	3	4	1 2 3 4 5	1 2 3 4 5	
Ad hoc development of new product or process concepts.	Product and process concepts developed within single functions and there is limited customer or client contact.	New product and process ideas sought in the marketplace and research into customer and client needs, or involvement of marketing and technical functions in developing and screening new product and process concepts.	Direct links with customers, clients and lead users to identify expressed and latent needs, or a broad range of functions involved in concept development and screening opportunities, or early analysis of new concepts			

organizations. This could have predisposed respondents to present their performance in a favourable light.

As with capability, the scores for satisfaction were all towards the higher end of the scale with no mean scores below the mid-point. Also repeated were the highest and lowest scoring elements: 'Continuous improvement' and 'Funding innovation' respectively. The lack of explicit scale-point anchors for this and the importance scale makes it more difficult to rule out the impact of positive response set as a partial explanation for the results obtained. The measure is new in this study and as such scoring norms are not available for comparison. The conservative approach to interpreting the data is not to draw normative conclusions such as 'respondents were highly satisfied' but to treat the results as a range of responses albeit over a restricted range given the negatively-skewed distribution. The exploratory analysis presented below takes this approach, thus making the most of what variability there is within the results.

Table 5 shows the mean scores for the importance to the company of each capability element. Generally, importance scored a little lower than satisfaction on each element. The two scales are not directly comparable though, as satisfaction and importance are different concepts. Also the first measured the *respondent's* satisfaction with current performance whereas the second measured the respondent's perception of the importance attached to the element by the *company*.

Analysis

Patterns in the data were explored by ranking the mean scale scores for capability, satisfaction, and importance and highlighting the upper- and lower-quartiles. This was then used to identify apparent relationships across the different scales. Some possible relationships that could be identified in this way included elements that scored highly on all three scales, elements that scored high on one or more scales but low on another and elements with a high score on one scale but middling scores on the others.

Questions for which the mean scores ranked high across the three scales (performance, satisfaction, importance) were Q11 'Continuous improvement' (1st, 1st, 2nd), Q6 'Teamwork' (4th, 3rd, 3rd) and Q8 'Developing teams' (2nd, 4th, 6th). Perhaps the simplest interpretation of these findings, and that most consistent with the innovation management literature reviewed, is that the organizations surveyed attached a high importance to these elements and they have, therefore, achieved a high level of performance. Also that the Project Champions are satisfied with the level of performance as a consequence. Consistently low-ranking questions were Q2 'Planning innovation' (23rd, 19th, 21st), Q4 'Exploiting innovation' (22nd, 20th, 19th) and Q19 'Funding innovation' (24th, 24th, 17th) These appear to be those to which the company attaches little importance and as such performance and satisfaction with performance is low. Given the nature of the current research (a cross-sectional survey using a common method for measuring each variable) causal interpretations of this kind must remain speculative and we are unable to rule out alternative hypotheses. For example, respondents may have believed that where a high level of performance has been achieved, their organizations must believe them to be important—how else could this high performance have been achieved? Similarly, the Project Champions may have defensively

Table 2 Processes and sub-process elements of innovation

Innovation processes	Possible steps from basic to advanced innovation process and practice				Satisfaction with step	Importance to organization	Comment
	Basic			Advanced	Low–high	Low–high	
Concept generation	1	2	3	4	1 2 3 4 5	1 2 3 4 5	
Generating new processes or product concepts.	Ad hoc development of new product or process concepts.	Product and process concepts developed within single functions and there is limited customer or client contact.	New product and process ideas sought in the marketplace and research into customer and client needs, or involvement of marketing and technical functions in developing and screening new product and process concepts.	Direct links with customers, clients and lead users to identify expressed and latent needs, or a broad range of functions involved in concept development and screening opportunities, or early analysis of new concepts			
Planning for product and process innovation	No product or process planning.	Planning for the next generation of products and processes.	Planning for up to two generations of products and processes.	Long-term planning for three or more generations of products or processes over a 5–15 year horizon.			
Encouragement of innovativeness and creativity	Control systems and organization discourage creativity.	New ideas encouraged, but risk avoided.	Risk taking encouraged and champions for new ideas sought and supported.	Employees' innovative and entrepreneurial behaviour encouraged and rewarded with mechanisms available to fund unplanned activities.			
Exploitation	No plan in place to exploit innovations.	Simple plans in place to apply to all suitable projects.	Detailed implementation plans developed, or major customers and clients identified.	Markets researched and identified, or patents and trademarks applied for, or major customers and client introduced to new products and processes.			
Product development	1	2	3	4			
Product development process	No product or process development procedures.	Simple procedures applied to all projects, to capture innovations.	Product and process development on major projects planned with phased reviews.	Established processes and objectives with flexibility to allow small developments to move through quickly.			

Table 2 Continued.

Innovation processes	Possible steps from basic to advanced innovation process and practice				Satisfaction with step	Importance to organization	Comment
	Basic			Advanced	Low–high	Low–high	
Teamwork for innovation	No teamwork and little communication between functions.	Some use of functionally based teams, but with weak project management and no involvement of other functions prior to start up.	Widespread use of multidisciplinary teams with clear project authority and internal cross-functional review prior to development, but limited involvement from the supply chain.	Wide use of multidisciplinary teams with early involvement by all and there is strong team leadership with the team leader empowered to make decisions.			
Innovation of production processes	1	2	3	4			
Integrated information transfer to manufacture and construction	No integrated transfer process—designs passed over to the next department.	Design to engineering communication prior to transfer to construction.	Strong links between engineering, design and construction.	Construction has effective capability to test prototypes and there is effective handling of design and engineering changes.			
Organization design for teamwork	Project team based on available staff.	The company collects information on the skills of its staff.	The company holds information on skills of all staff and is able to match individuals to projects.	The company is able to identify individual team members for projects quickly from an appropriately trained and skilled staff.			
Production design	No consideration of production design.	Design introduced at a late stage in the process.	Use of internal designers or external design consultancies.	Production designers involved as core part of project team from concept stage.			
Implementation of new processes	No attention to implementation.	Implementation seen as installation.	Cross-functional implementation teams.	Implementation teams stay together into full deployment across the company to ensure learning and improvement.			

Table 2 Continued.

Innovation processes	Possible steps from basic to advanced innovation process and practice				Satisfaction with step	Importance to organization	Comment
	Basic			Advanced	Low–high	Low–high	
Continuous improvement	If it works don't touch it mentality.	Focus on maintenance of the process not improvement.	Need for continuous improvement of processes recognized—primarily the responsibility of process engineering function.	Work teams encouraged to identify opportunities for improvement and there is use of wide range of internal and external data to support improvement.			
Technology and knowledge acquisition processes	1	2	3	4			
Formulation of a technology strategy	No technology strategy and no mechanisms for understanding technology.	Inward looking technology strategy identifies needs on a project-by-project basis.	Understanding of technical needs in each function with monitoring of trends and product-driven joint ventures and technical alliances.	The company understands its core competencies in technology and innovation and has policies for allocating resources to build and strengthen them.			
Selecting, generation and sourcing of new technology	Not invented here syndrome.	Participation in industry technical associations, but little dissemination internally.	Ongoing contacts with universities, government agencies, industry consortia, etc. and close relationships with the supply chain and the customer.	Explicit policies for sourcing new technologies, including funding R&D.			
Market planning and review	No policies or control——get away with what you can.	Formal policies and procedures to deal with environmental and regulatory issues but passive general management.	Active management to promote compliance and improvement from external initiatives.	Proactive, anticipating trends with line responsibility for compliance.			
Leadership processes	1	2	3	4			

Table 2 Continued.

Innovation processes	Possible steps from basic to advanced innovation process and practice				Satisfaction with step	Importance to organization	Comment
	Basic			Advanced	Low–high	Low–high	
Human resources policy	No requirement on staff to change or develop.	Technical functions not represented at board level.	Flexible approaches by the workforce encouraged.	Whole workforce encouraged to improve and to foster improvement in the organization.			
Management of the process for innovation	Management not concerned with project experiences.	Management encourages good practice in innovation management.	Innovation management, product realization and technology acquisition presented to and discussed at board level.	Management is proactive in ensuring best practices in innovation and product realization.			
Climate for innovation	Management focused on short term profitability and risk minimization.	General encouragement for innovation, but no measure or reward.	Performance measures for innovation reviewed regularly by board with a customer-led climate encouraged.	Management ensures that risk taking is encouraged rather than penalized and new ideas are rewarded. It ensures that the technology mission of the company is shared and understood throughout the company.			
Resource provision processes	1	2	3	4			
Resources for innovation	No human resources planning for innovation; key skills missing.	The human resources needed for innovation generally known and available, but usually slow to be applied.	The skills required for innovation are identified and are fully resourced through recruitment and training.	Career structures support innovation through development in all functions.			
Funding of innovation	Last year spend adjusted up for inflation and down for cash availability.	Industry average levels. R&D and innovation budgets subject to sharp fluctuations from year to year.	Policies on how R&D should be funded. There are some mechanisms to ensure that capacity is available in suppliers, manufacturing and support functions.	Related to potential business contribution over short and long-term with minimal fluctuations despite cash flow variation.			

Table 2 Continued.

Innovation processes	Possible steps from basic to advanced innovation process and practice				Satisfaction with step	Importance to organization	Comment
	Basic			Advanced	Low–high	Low–high	
Systems and tools provision processes	1	2	3	4			
The systems to support innovation	Limited use of information systems.	Information system usage without functions.	Widespread information system usage, primarily for one-way information flow including CAD and process simulation on a functional basis to improve design effectiveness.	Systems geared to improving design effectiveness and to shortening product development lead times with integrated links to suppliers and customers.			
The tools to support innovation	No significant usage of management and design tools.	Ad hoc tool usage, with no clear objectives.	Some use of design tools to improve product and process design effectiveness and/or creativity.	Widespread use of appropriate tools to capture customer needs and to ensure the effectiveness of product and process design.			
Quality assurance to support innovation	Limited use of formal quality management approaches.	Quality control in manufacturing, but little involvement in engineering, ISO 9000 possibly in place but focus on the procedure only.	Quality practices and procedures in place for quality assurance of products and processes.	TQM programme in place including a focus on achieving improved innovation performance			
Competitiveness	1	2	3	4			
Measurement and goals for innovation	No measurement of innovation performance or customer satisfaction.	Measures of financial and sales performance of new products and measures of product quality.	Operational targets are set for some aspects of innovation at departmental level.	Customer satisfaction feedback surveys initiated with feedback into the innovation process.			
Innovation performance	Anecdotal evidence only.	Positive improvement trends in most areas.	Good-to-excellent results in major areas with evidence that results are caused by active management of innovation.	Excellent sustained results in major areas caused by active management of innovation.			

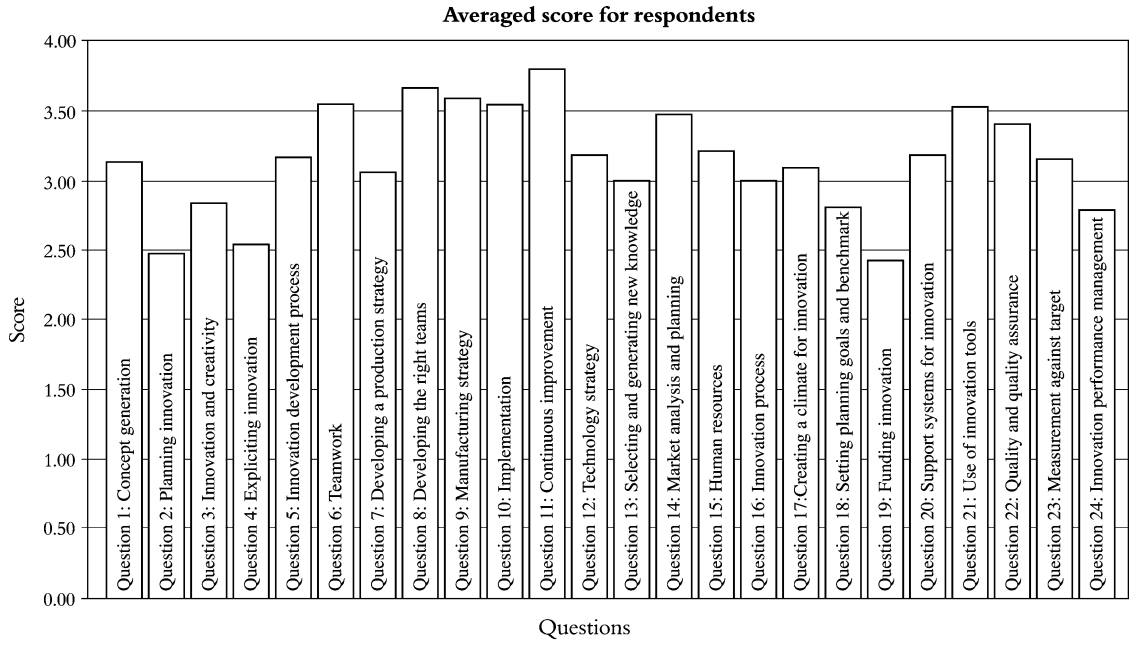

Table 3 Level at which innovation is being implemented

attributed poor performance to a lack of company support rather than to themselves or their project. Further development of the survey with multiple and independent data sources could help to shed further light on these relationships.

Elements with high importance and one or more low performance or satisfaction rankings were Q23 'Measurement against targets' (15th, 12th, 1st), Q24 'Innovation performance measurement' (21st, 9th, 4th) and Q13 'Selecting and generating new knowledge' (18th, 22nd, 5th). High perceived importance, but relatively low achievement or satisfaction ratings, imply that these elements are those where there is both need for improvement and also recognition of that need and

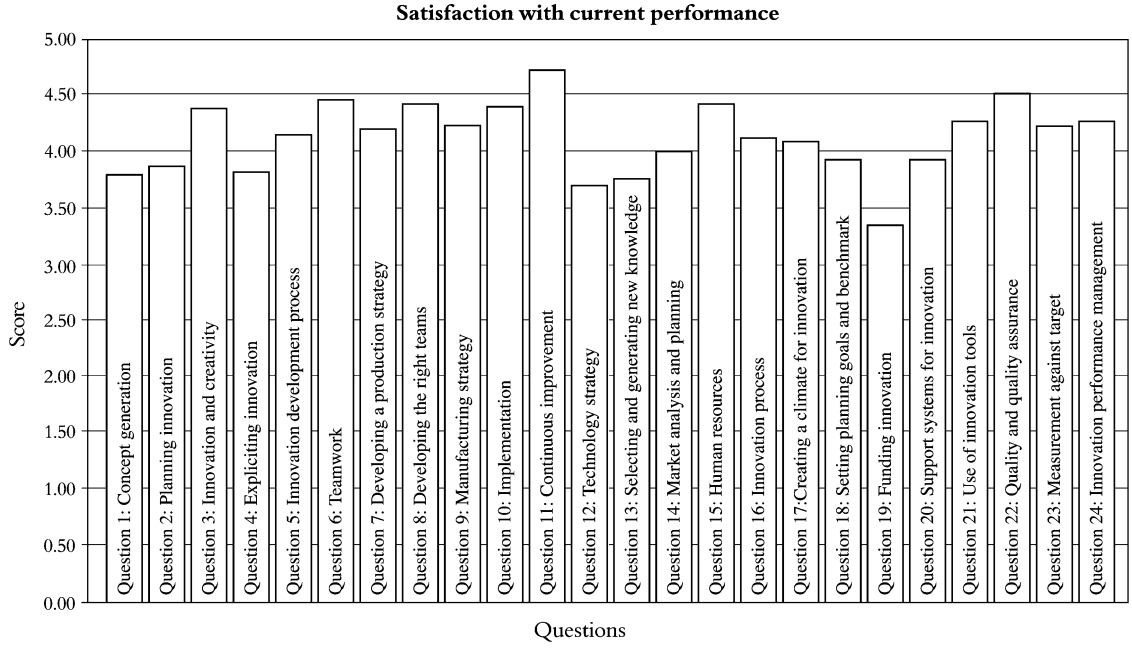

Table 4 Satisfaction with the company's position on the level of innovation

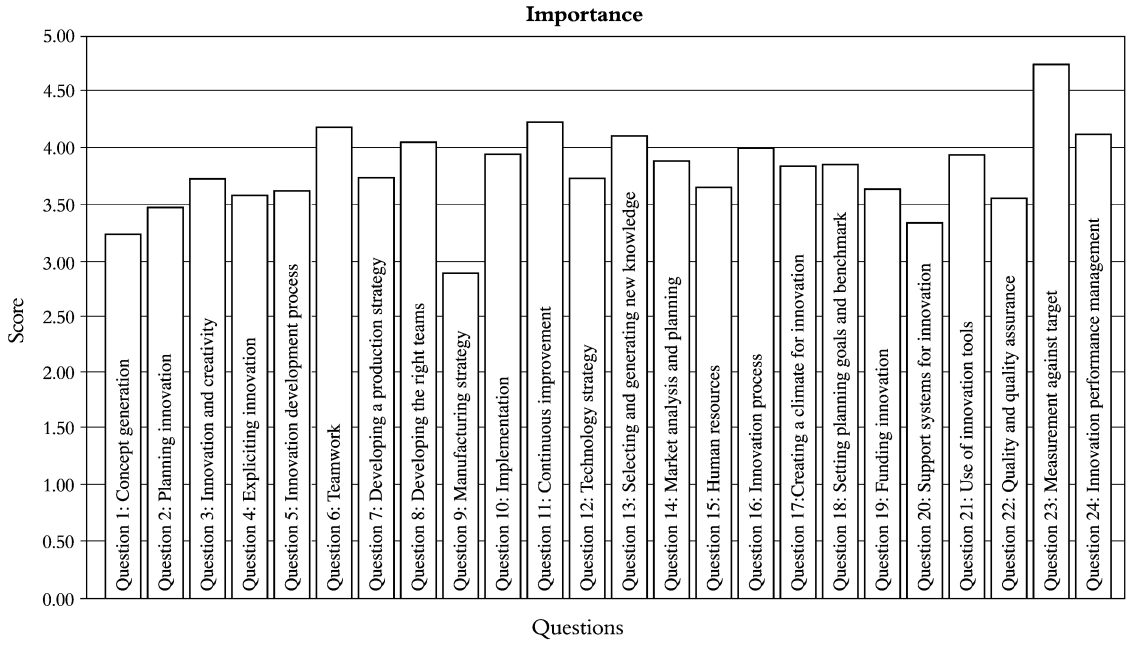

Table 5 Relative importance attached by the company to the adoption of the innovation

potential for improvement. The implications of these and the previous findings are discussed in the following section.

Finally, one question had a low importance ranking but high satisfaction ranking. 'Q9 'Manufacturing strategy' was the lowest ranked for importance (24th) but ranked third for performance (satisfaction ranking was 10th). This was probably due to a significant amount of missing data (*n=15)* where respondents were unwilling or unable to conceive of their activities in terms of production or design. This would account for the low importance and the high performance rating for the sub-sample who did supply a rating.

Discussion

The highest performance ratings were for the areas of continuous improvement, teamwork and developing teams. These are aspects of construction work that are well developed in the industry owing to its history of project-based work and devolved control. The preponderance of site-based rather than centrally coordinated innovation in construction has long been recognized (Slaughter, 1993) and this was also reflected in the results with low scores for planning, exploiting and funding innovation. Although intended for application to construction projects and organizations the items chosen were taken from a broader innovation management literature. Some of the items therefore may be more or less relevant to construction (see the analysis of 'Manufacturing strategy' for an example). Applying a 'universal' set of dimensions of innovation performance and capability does however offer the potential of comparing across as well as within sectors. These results suggest that the construction organizations surveyed were good at forming project teams but poor at planning innovation—it would be easy to imagine that for a traditional manufacturing firm these relative strengths and weaknesses could be reversed. This in turn raises the interesting question of whether combining performance on these separate elements is additive (so that low scores on some elements can be compensated for by high scores on others) or multiplicative (so that high performance is needed on all for 'overall' performance). The scoring also carried with it the implicit assumption that high scores on all items would be desirable but improving any of the dimensions would not be without cost, so it would be necessary to know which areas would be most likely to deliver benefits from increased investment. The answer to these questions would have serious implications for both measurement and management of innovation.

The areas with low ratings for performance and satisfaction, but where perceived importance is high, would seem on the face of it to be those where there would be the most potential, motivation and likelihood of improvement. Particularly interesting in this category is the issue of target setting and performance measurement of innovation. Targets and measurements are well established in construction and as such

it would seem relatively easy to apply this culture to the management of innovation as well as output and costs. This could also go some way to addressing the anecdotal finding that many of the Project Champions believed that their companies were not sufficiently supportive. Project Champions expressed frustration with their companies' lack of ambition and support for the innovations they were attempting. Although not possible with the current dataset, it would be worth investigating further whether the lower scores for perception of the company's view of importance reflect this.

The limitations of the current survey have already been discussed but are worth summarizing here. Most successful was the development of an explicitly anchored performance scale for a comprehensive set of innovation management elements. In addition, measuring satisfaction and importance alongside performance allows further exploration of the relationships between these differing aspects. This did make the questionnaire more complex however. Respondents were not asked how satisfied they were with their performance but how satisfied they were that performance was at the level that it was. This meant that performance and satisfaction were interacting in possibly quite complex ways. Comparison with alternative ways of assessing satisfaction would be useful to better understand this (for example by asking respondents about current and ideal levels of performance and inferring satisfaction from the difference). Another source of complexity was requiring the respondents to consider their perception of the company's perception of the importance of each dimension.

In general, further work on the design of the questionnaire and construct validation of the measures would be useful. A larger sample with multiple and independent sources of data would also be valuable to allow statistical testing of the results and a more systematic item analysis. Data could also be usefully gathered from a wider range of companies than those in the current survey who were presumably above average owing to their participation in an industry initiative to promote innovation. Alternatively, this complexity, and the considerable amount of support that was required for the Project Champions to complete the questionnaire may mean that it should be administered in an interview context to allow fuller explanation and checking of responses.

Conclusions

In the projects and organizations surveyed the innovation management strengths were continuous improvement, teamwork and team formation. Planning, exploiting and funding of innovation were less well developed. Areas of poor performance that were nevertheless viewed as important were innovation target setting and measurement and acquiring and generating new knowledge. Incidental findings suggested that the largely project-based respondents expressed frustration with the support received and ambition of their companies although this was not directly measured through the survey. The questionnaire developed could provide a good base for measuring innovation management capability and performance in the future for academic research purposes or in directing business strategy for future development of innovation potential.

References

Adler, P.S. (1992) Managing DFM: learning to coordinate product and process design, in Susman, G.I. (ed.) *Integrating Design and Manufacturing for Competitive Advantage*, Oxford University Press, New York, pp. 140–56.

Allen, T. (1976) *Managing the Flow of Technology*, MIT Press, Cambridge, MA.

Archibugi, D. and Pianta, M. (1996) Measuring technological change through patents and innovation surveys. *Technovation*, **16**(9), 451–68.

Bessant, J. and Buckingham, J. (1993) Innovation and organisation learning: the case of the computer-aided production management. *British Journal of Management*, **4**(4), 219–34.

Burgelman, R.A., Kosnik, T.J. and Van den Poel, M. (1988) Towards an innovation capability audit framework, in Burgelman, R.A. and Maidique, M.A. (eds) *Strategic Management of Technology and Innovation*, Irwin, Homewood, IL, pp. 31–4.

Burgelman, R.A., Maidique, M.A. and Wheelwright, S.C. (2001) *Strategic Management of Technology and Innovation*, 3rd edn, McGraw-Hill/Irwin, Boston.

Burger, P.C. (1989) A report on the development of a research agenda for product development and managerial association. *Journal of Product Innovation Management*, **6**(1), 51–60.

Camp, R.C. (1989) *Benchmarking*, Quality Press, Milwaukee, WI.

Chiesa, V., Coughlan, P. and Voss, C.A. (1996) Development of a technical innovation audit. *Product Innovation Management*, **13**, 105–36.

Ciccantelli, S. and Magidson, J. (1993) Customer idealized design: involving customers in the product development process. *Product Innovation Management*, **10**(4), 341–7.

Clark, K.B. and Fujimoto, T. (1993) *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry*, Harvard Business School Press, Boston.

Clausing, D.P. (1994) *Total Quality Development*, ASME Press, New York.

Coolican, H. (1994) *Research Methods and Statistics in Psychology*, Hodder & Stoughton, London.

Coombs, R., Hull, R. and Petlu, M. (1998) *Knowledge Management Practices for Innovation: An Audit Tool for Improvement*, Centre for Research on Innovation and Competition, Manchester.

Coombs, R., McMeekin, A. and Pybus, R. (1998) Towards the development of benchmarking tools for R&D project management. *R&D Management*, **28**(3), 175–86.

Cooper, R.G. (1990) Winning at new products. *Journal of the Operational Research Society*, **41**(2), 181.

Cooper, R.G. (1994) Third generation new product processes. *Journal of Product Innovation Management*, **11**, 3–14.

Cordero, R. (1990) The measurement of innovation performance in the form: an overview. *Research Policy*, **19**(2), 185–92.

Crawford, C.M. and Rosenau, M.D. (1994) Significant issues for the future of product innovation. *Journal of Product Innovation Management*, **11**(3), 253–8.

Deming, W.E. (1982b) *Quality, Productivity and Competitive Position*, Massachusetts Institute of Technology Centre for Advanced Engineering Study, Cambridge, MA.

Drazin, R. and Kazanjian, R.K. (1986) Implementing manufacturing innovations: critical choices of structure and staffing roles. *Human Resource Management*, **25**(3), 385–403.

Egan, J. (1998) *Rethinking Construction*, Construction Task Force Report for Department of the Environment, Transport and the Regions, HMSO, London.

Felberg, J.D. and DeMarco, D.A. (1992) New idea enhancement at AMOCO chemical: an early report from a new system. *Journal of Product Innovation Management*, **9**, 278–86.

Foster, R.N. (1986) Timing technology transitions, in Horwitch, M. (ed.) *Technology in the Modern Corporation*, Pergamon Press, New York, pp. 127–141.

Gann, D.M. (2000) *Building Innovations, Complex Constructs in a Changing World*, Thomas Telford, London.

Gann, D.M. and Salter, A.J. (2000) Innovation in project-based, service-enhanced firms: the construction of complex products and systems. *Research Policy*, **29**(7), 18.

Gerwin, D. (1988) A theory of innovation process for CAM technology. *IEEE Transactions on Engineering Management*, **36**(3), 90–100.

Hauser, J.R. and Clausing, D. (1988) The house of quality. *Harvard Business Review*, **66**(3), 63–73.

Hax, A.C. and Majluf, N.S. (1991) *The Strategy Concept and Process: A Pragmatic Approach*, Prentice Hall, Englewood Cliffs, NJ.

Hayes, R.H. and Clarke, K.B. (1985) Exploring the sources of productivity differences at factory level, in Clark, K.B., Hayes, R.H. and Lorenz, C. (eds) *The Uneasy Alliance: Managing the Productivity–Technology Dilemma*, HBS Press, Boston, MA, pp. 151–188.

Hayes, R.H. and Wheelwright, S.C. (1984) *Restoring Our Competitive Edge*, Wiley, New York.

Hill, T.J. (1993) *Manufacturing Strategy: The Strategic Management of the Manufacturing Function*, 2nd edn, Macmillan, London.

Hise, R.T., Parasuraman, A. and McNeal, J.U. (1990) Marketing/R&D interaction in new product development: implications for new product success rates. *Journal of Product Innovation Management*, **7**(2), 142–55.

Johne, A.F. (1988) Success factors in product innovation. *Journal of Product Innovation Management*, **5**, 114–28.

Kaplan, N. (1960) Some organisational factors affecting creativity. *IEEE Transactions on Engineering Management*, **EM-7**, 43–47.

Kululanga, G.K. and McCaffer, R. (2001) Measuring knowledge management for construction organisations. *Engineering Construction and Architectural Management*, **5/6**, 346–54.

Leonard-Barton, D. (1998) *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*, Harvard Business School Press, Boston, MA.

Lissoni, F. (2000) Technological expectations and the diffusion of the intermediate technologies. *Economics of Innovation and New Technologies*, **9**.

Maidique, M.A. (1980) Entrepreneurs, champions and technological innovation. *Sloan Management Review*, **21**(2), 59–76.

Maidique, M.A. (1984) A case study of success and failure in product innovation. *IEEE Transactions on Engineering Management*, **31**(4), 192–203.

Mitchell, G.R. (1986) New approaches for the strategic management of technology, in Horwitch, M. (ed.) *Technology in the Modern Corporation: A Strategic Perspective*, Pergamon Press, New York.

Moenart, R.K. and Souder, W.E. (1990) An analysis of the use of extra functional information by R&D and marketing personnel: review and model. *Journal of Product Innovation Management*, **7**(3), 213–29.

Moenart, R.K.S., De Meyer, A. and Deschoolmaster, D. (1994) R&D–marketing integration mechanisms, communication flows and innovation success. *Journal of Product Innovation Management*, **7**(3), 31–45.

Nonaka, I. and Takeuchi, H. (1995) *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, Oxford.

OECD (1994) *The Measurement of Scientific and Technological Activities: Proposed Standard Practice for Surveys of Research and Experimental Development (Frascati Manual 1993)*, OECD, Paris and Washington, DC.

OECD and Statistical Office of the European Communities (1997) *Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*, OECD, Paris and Washington, DC.

Orlando, B. (1991) CALS/EDI intergrating speed and product delivery. *Manufacturing Systems*, **12**(10), 56–8.

Pahalad, C.K. and Hamel, G. (1986) The core competencies of the corporation. *Harvard Business Review*, **68**(3), 79–91.

Papas, C. (1984) Strategic management of technology. *Journal of Product Innovation Management*, **1**, 30–5.

Pinto, M.B. (1990) Project team communication and cross-functional cooperation in new program development. *Journal of Product Innovation Management*, **7**(3), 200–12.

Quinn, J.B. (1985) Managing innovation: controlled chaos, *Harvard Business Review*, **31**(3), 73–84.

Reichstein, S., Salter, A.J. and Gann, D.M. (2005) Last among equals: a comparison of innovation in construction, services and manufacturing in the UK. *Construction Management and Economics*, **23**, 631–44.

Rethinking Construction (2003) *Rethinking Construction Demonstrations Report*, Constructing Excellence, London.

Richards, A. (1991) Innovation and creativity, trees and pathways. *R&D Management*, **21**(2), 97–108.

Roberts, E.B. (1985) Entering new businesses: selecting strategies for success. *Sloan Management Review*, **26**(3), 3–17.

Roberts, E.B. (1991) *Entrepreneurs in High Technology*, Oxford University Press, New York.

Rochford, L. and Rudelius, W. (1992) How involving more functional areas within a firm affect the new product process. *Journal of Product Innovation Management*, **9**(4), 287–99.

Rosenthal, S.R. and Tatikonda, M.V. (1992) Competitive advantage through design tools and practice, in Susman, G.I. (ed.) *Integrating Design and Manufacturing for Competitive Advantage*, Oxford University Press, New York, pp. 15–35.

Roussel, P.A., Saad, K.N. and Erickson, T.J. (1991) *Third Generation R&D*, HBS Press, Boston, MA.

Slaughter, S.E. (1993) Innovation and learning during implementation: a comparison of user and manufacturer innovations. *Research Policy*, **22**(1), 81–95.

Strategic Forum for Construction (2002) *Accelerating Change*, A Report by the Strategic Forum for Construction, Rethinking Construction (c/o Construction Industry Council), London.

Thamhain, H.J. (1990) Managing technologically innovative team efforts towards new product success. *Journal of Product Innovation Management*, **7**(1), 5–18.

Tushman, M.L. and Nadler, D. (1986) Organizing for innovation. *California Management Review*, **28**(3), 74–92.

Tushman, M. and O'Reilly, C.A. (1997) *Winning through Innovation: A Practical Guide to Leading Organizational Change and Renewal*, Harvard Business School Press, Boston, MA.

Twiss, B.C. (1992) *Managing Technological Innovation*, 4th edn, Pitman, London.

Tyre, M.J. (1991) Managing the introduction of new process technology: international differences in a multi-plant network. *Research Policy*, **20**, 57–76.

Utterback, J.M. (1982) Environmental analysis and forecasting, in Tushman, M.L. and Moore, W.L. (eds) *Readings in the Management of Innovation*, Harper Business, Cambridge, Mass, pp. 299–310.

Van de Ven, A.H. (1986) Central problems in the management of innovation. *Management Science*, **32**(5), 590–607.

Van de Ven, A.H. (1999) *The Innovation Journey*, Oxford University Press, New York.

Von Hippel, E. (1988) *The Sources of Innovation*, Oxford University Press, New York, Oxford.

Voss, C.A. (1992) Measurement of innovation and design performance in services. *Design Management Journal*, **31**(1), 40–6.

Wheelwright, C. (1992) *Revolutionising Product Development*, The Free Press, New York.

Wood, A.R. and Elgie, R.J. (1976) *Early Adoption of Manufacturing Innovation*, Research Report, University of Western Ontario, Canada.