Innovation management measurement: A review

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Measurement of the process of innovation is critical for both practitioners and academics, yet the literature is characterized by a diversity of approaches, prescriptions and practices that can be confusing and contradictory. Conceptualized as a process, innovation measurement lends itself to disaggregation into a series of separate studies. The consequence of this is the absence of a holistic framework covering the range of activities required to turn ideas into useful and marketable products. We attempt to address this gap by reviewing the literature pertaining to the measurement of innovation management at the level of the firm. Drawing on a wide body of literature, we first develop a synthesized framework of the innovation management process consisting of seven categories: inputs management, knowledge management, innovation strategy, organizational culture and structure, portfolio management, project management and commercialization. Second, we populate each category of the framework with factors empirically demonstrated to be significant in the innovation process, and illustrative measures to map the territory of innovation management measurement. The review makes two important contributions. First, it takes the difficult step of incorporating a vastly diverse literature into a single framework. Second, it provides a framework against which managers can evaluate their own innovation activity, explore the extent to which their organization is nominally innovative or whether or not innovation is embedded throughout their organization, and identify areas for improvement.

Measuring the Management of Innovation

A considerable literature has accumulated on the subject of innovation, which is widely seen as the basis of a competitive economy (Porter and Ketels 2003). This literature includes evidence that competitive success is dependent upon an organization's management of the innovation process and proposes factors that relate to successful management of the innovation process (cf. *inter alia* Balachandra and Friar 1997; Cooper 1979a,b; de Brentani 1991; Di Benedetto 1996; Ernst 2002; Globe *et al*. 1973; Griffin 1997; Rothwell 1992).

Quantifying, evaluating and benchmarking innovation competence and practice is a significant and complex issue for many contemporary organizations (Frenkel *et al*. 2000). An important challenge is to measure the complex processes that influence the organization's innovation capability, in order that they can be optimally managed (Cordero 1990). The measurement of innovation is also important from an academic research perspective. Unless constructs relating to the phenomenon are measurable using commonly accepted methods, there is a risk that different operationalizations of the same effect will produce conflicting findings, and that theoretical advances become lost in the different terminologies that resist the accumulation of knowledge.

Within the literature on the management of innovation, measures of aspects of innovation management are frequently proposed, responding to the needs of both firms and academics to understand the effectiveness of innovation actions (Barclay 1992; Kim and Oh 2002). However, their treatment is fragmented. It is possibly a consequence of this fragmentation that empirical studies have found many organizations tend to focus only on the measurement of innovation inputs and outputs in terms of spend, speed to market and numbers of new products, and ignore the processes in-between (Cordero 1990). A generalized measurement framework specified at the level of the organization would provide a useful basis for managers to monitor and evaluate their innovation processes, diagnose limitations and prescribe remedies (Cebon and Newton 1999). In an attempt to extend measurement theory and practice beyond a focus on output performance, this paper reviews the literature as it relates to the measurement of innovation management in the context of a conceptual framework of process that provides the basis for a general measurement framework. We bring together disparate suggestions for innovation management measurement made in various parts of the literature and summarize commonly used measures at different stages of innovation management. We identify gaps in measurement theory and practice and point the way toward the development of a comprehensive set of innovation management measures.

Developing an Analytic Framework for Innovation Management Measurement

The innovation literature is a fragmented corpus, and scholars from a diversity of disciplinary backgrounds adopt a variety of ontological and epistemological positions to investigate, analyse and report on a phenomenon that is complex and multidimensional (Wolfe 1994). More specifically, this diversity is reflected in the multitude of approaches to measurement and the number of different measures that can be found. It is difficult to identify a bounded body of literature in which a comprehensive discussion of innovation measurement issues might be located. Representing this diversity within a synthesized framework is a challenging task.

Indeed, the term 'innovation' is notoriously ambiguous and lacks either a single definition or measure. We chose to adopt the UK Department of Trade and Industry's (DTI 1998) broad definition of innovation, 'the successful exploitation of new ideas', to guide our review, because it accommodates the range of innovation types (product/service, process, administrative, technological, etc.) that one might reasonably expect to encounter in an organization. This holistic approach is clearly important from the practitioner's perspective, as it obviates the need to collate measures on a piecemeal basis from a diverse literature. So, while this review is broadly specified, its breadth presents a number of methodological challenges. We address these challenges by employing the approach of an adapted systematic review.

The notion of systematic review has recently gained currency in the management literature (Denyer and Neely 2004), and the strategy for this review followed, in many respects, the methodology detailed by Tranfield *et al.* (2003). They state that systematic reviews include: development of clear and precise aims and objectives; pre-planned methods; comprehensive search of all potentially relevant articles; use of explicit, reproducible criteria in the selection of articles for review; appraisal of the quality of the research and the strength of the findings; synthesis of individual studies using an explicit analytic framework; and balanced, impartial and comprehensible presentation of the results. Our review strategy broadly adopted this model, but with some changes to suit the exigencies of our question and data sources, notably: first, the inclusion of a Delphi study and, second, a relaxation of the requirement for reproducible criteria for document selection and appraisal.

The authors formed a review panel consisting of domain-relevant experts from a range of disciplines with an interest in both innovation and measurement. Time was spent outlining the research project, which was articulated in terms of the fragmented world of competing and contradictory measures addressing the issue of the management of innovation. Rather than attempting to generate an exhaustive list, our objectives were defined in terms of the collation and synthesis of measures, better reflecting the needs of academics and practitioners: we ask 'What are the measures that have been used, and to what extent do they adequately populate and dimensionalize a comprehensive analytic framework?'

McManus *et al*. (1998), reflecting upon systematic review, identified the limitations of searching electronic databases as sometimes uncovering only half the relevant studies. They attribute this in part to a lack of sensitivity of electronic databases. Indeed, this may account for the disappointing outcome in terms of breadth that Leseure *et al*. (2004) report from their search of electronic databases for literature relating to the adoption of promising practices. Compensating strategies include either hand searching of journals (which we had to discount on the grounds of time and cost) or consultation with appropriate experts (McManus *et al.* 1998). The latter are particularly important when 'performing a systematic review in a developing field that does not have a clearly defined specialist literature' (McManus *et al.* 1998, 1563). Using the Delphi method, a process consisting of structured design for group communication relating to complex problems (Linstone and Turoff 2002), we extended our consultation process to incorporate the input of external experts.

A list of global experts in innovation and measurement (n = 100) based on the knowledge of the review panel was developed. Potential respondents were contacted by e-mail and asked to respond to a series of questions relating to innovation metrics at the level of management practice, particularly addressing aspects of measuring the existence and effectiveness of the innovation management process. There was a high degree of consensus in the 28 responses received. All respondents recognized the existence of a plethora of extant measures, obviating the need for *new* measures to be developed. Specifically, an absence of measures well aligned to the activities of the innovation process was noted. Further, our attention was drawn to the absence of devices to help identify the appropriate metrics to apply.

Systematic review stresses the importance of an audit trail in the review process to ensure clarity and replicability. Significant to this is the use of explicit, reproducible criteria in the selection of articles for review and, an appraisal of the quality of the research and the strength of the findings (Tranfield *et al.* 2003). However, regardless of a study's methodology or generalizability, it might still incorporate measures of innovation management that could contribute to the construction of a measurement framework, and so grey literature is included in this review. As we were not reviewing an evidence base in the normally accepted use of the term, quality criteria as used in previously published systematic reviews in the management literature (e.g. Leseure *et al*. 2004; Pittaway *et al*. 2004), in which the value of the evidence base is determined by assessed levels of theory robustness, methodology, implications for practice, generalizability and contribution, were felt not to be wholly relevant in this case. We instead adopted a position akin to Glaser and Strauss's (1967) notion of 'theoretical saturation' which is achieved when

> no additional data are being found whereby the researcher can develop properties of the category. As he sees similar instances over and over again, the researcher becomes empirically confident that a category is saturated … when one category is

Table 1. Review strategy

Step 1	Establish review team and scope and nature of the question and search strings
Step 2	Undertake Delphi investigation
Step 3	Preliminary search of electronic databases
Step 4	Develop analytic framework
Step 5	Secondary search of electronic databases and Delphi study
Step 6	Content analysis of data set, sorting of measures into first order categories defined by the analytic framework
Step 7	Review measures against framework for gaps

> saturated, nothing remains but to go on to new groups for data on other categories, and attempt to saturate these categories also. (Glaser and Strauss 1967, 65)

That is, the incremental contribution of further sampling is marginal and fails to add significant value. The steps of our review are presented in Table 1.

A plethora of studies operationalize measures of aspects of innovation management; however, to provide some synthesis and identify gaps, agreement regarding the nature of innovation management is needed. The literature lacks such consensus. The concept is frequently disaggregated into component parts, and scholars adopt their own partial views. As a result, the operationalization of measures is frequently idiosyncratic, owing more to the predilections of the researcher and the exigencies of the data than to the overarching objectives of synthesis or cumulation. To organize, compare and contrast such measures, we propose a typology of elements of the innovation management process.

Many scholars have sought to identify the key activities of the innovation management process (Wolfe 1994), some of which are presented as linear models (e.g. Daft 1978), and others that are dynamic and recursive characterized by feedback and feed-forward loops (e.g. Schroeder *et al*. 1989). While useful, these models are limited from a measurement perspective: first, there are many competing models with consensus only evident at abstract levels; second, models have principally been generated in the context of technology, and so generalizability is constrained; third, with a focus on activities, models fail to take account of the organizational pervasiveness of innovation and its socio-technical connectedness with all aspects of the organization, or the levels of integration envisaged in Rothwell's (1992) fifth-generation process model. Finally, while the range and sequence of activities may vary across organizations and projects, their successful management is affected by a number of factors. Cebon and Newton (1999) call this the 'capacity to make change', about which the literature generally is relatively silent (Neely and Hii 1998). Based on a review of models, we propose a seven-factor framework of meaningful categories specified in terms of the requisite organizational capabilities to make and manage change (see Table 2).

In a review of the factors associated with new product development (NPD) success, Ernst (2002) echoes Cooper and Kleinschmidt's (1995) influential five techno-centric factors for new product performance: NPD process, NPD strategy, organization, culture and management commitment. This model, though, overlooks innovation in non-technical contexts and other important factors such as the role of knowledge (Leonard and Sensniper 1998).

In their technical innovation audit tool, Chiesa *et al*. (1996) describe process and performance as the two foci of innovation management measures. They overlay 'core processes' with a set of 'enabling processes', the latter describing the deployment of resources, and the effective use of appropriate systems and tools governed by top management leadership and direction. Finding this applicable only to 'hard' innovations, Verhaeghe and Kfir (2002) extended the audit tool to an investigation of the processes that support and enable both 'hard' and 'soft' (e.g. a research or consultancy project) innovation. The changes they made may appear semantic, for instance relabelling 'process innovation' as 'technology transfer'. However, the important implication is that the study extends the application of the instrument to service contexts.

Table 2. Innovation management models and organizing framework

	Cooper and Kleinschmidt (1995)	Chiesa *et al.* (1996)	Cormican and O'Sullivan (2004)	Goffin and Pfeiffer (1999)	Burgelman *et al.* (2004)	Verhaeghe and Kfir (2002)
Inputs				Creativity and human resources	Resource availability	Idea generation Technology acquisition
Knowledge management		Resource provision			Understand relevant technological developments and competitor strategies	Networking
Strategy	NPD strategy		Strategy and leadership	Innovation strategy	Strategic management	
Organization and culture	Organizational culture Management commitment	Leadership	Culture and climate		Structural and cultural context of the organization	
Portfolio management	NPD process	Systems and tools	Planning and selection	Portfolio management		
Project management			Communication and collaboration	Project management		Development
Commercialization			Structure and performance			Commercialization

Furthermore, they explicitly bounded their model with notions of inputs and commercialized outputs.

Cormican and O'Sullivan (2004, 820), reflecting earlier studies' coverage of the organization of innovation, conceive of product innovation as a continuous and cross-functional process 'involving and integrating a growing number of different competencies [inside the organization]'. So, effective management of the process requires successful adoption and adaption of a socio-technical systems approach to all aspects of the organization, critically including people and process as well as technology-related issues.

While there are areas of commonality across these innovation management models, no one model covers every dimension. This suggests a need for a synthetic and integrative framework to promote comparability and to enable future work to build on results found in previous studies. In column 1 of Table 2, we present such a framework derived from a synthesis of the studies presented in the other columns of the table. The framework consists of seven categories: inputs, knowledge management, strategy, organization and culture, portfolio management, project management and commercialization.

In the following sections, we use these seven inductively derived categories as the organizing framework for a discussion of innovation management measurement. For each of these categories, we review the diverse literature relevant to the measurement of that typological category. Within each category, a series of subdimensions of measurement focus are identified, reflecting the distinctions and emphases in the literature (see Table 3).

Table 3. Innovation management measurement areas

Framework category	Measurement areas
Inputs	People
	Physical and financial resources
	Tools
Knowledge management	Idea generation
	Knowledge repository
	Information flows
Innovation strategy	Strategic orientation
	Strategic leadership
Organization and culture	Culture
	Structure
Portfolio management	Risk/return balance
	Optimization tool use
Project management	Project efficiency
	Tools
	Communications
	Collaboration
Commercialization	Market research
	Market testing
	Marketing and sales

Measures of Innovation Management

Inputs Management

Inputs management is concerned with the resourcing of innovation activities and includes factors ranging from finance, to human and physical resources, to generating new ideas. The construct research and development (R&D) intensity has frequently been used as a global measure of input. Typically, it is expressed as a ratio between expenditure (e.g. Parthasarthy and Hammond 2002) or numbers employed in R&D roles (Kivimäki *et al*. 2000) and some expression of output. The relationship between R&D intensity and firm or innovation performance has been empirically demonstrated in several studies (e.g. Deeds 2001; Greve 2003; Parthasarthy and Hammond 2002). However, there is some equivocality in the literature. Stock *et al*. (2001) note an inverted-U relationship between R&D intensity and NPD performance, and Bougrain and Haudeville (2002) point out that it does not influence the future prospects of a project and is, indeed, an imperfect measure of innovation activity. Further, R&D is only one of several inputs into the innovation process and, therefore, cannot be regarded as an adequate proxy; it also does not appear to be a very useful measure for small and medium-sized enterprises (SMEs), which may not have formal R&D activities or may not record them (Kleinknecht 1987), or, indeed, for service industries, which tend to have low R&D intensity (Hipp and Grupp 2005).

High levels of R&D intensity are therefore not necessarily evidence of good innovation practice: they may simply mask process inefficiencies (Cebon and Newton 1999; Dodgson and Hinze 2000). However, adequate funding is clearly a critical input into the innovation process. Expenditure data have long been a popular proxy measure of innovation input, largely because of their ready availability. Several different approaches, both qualitative and quantitative, to measuring funding can be identified: total expenditure, expenditure expressed as a proportion of sales or revenues, and expenditure by item (organizational department, patent, innovation or scientist) (Geisler 1995; Oliver *et al.* 1999). Also, there is a series of perceptual measures that attempt to determine the adequacy of funding (Atuahene-Gima 1995). Measures, though, tend principally to be quantitative and express little other than funding level; in particular, few measures attempt to determine the adequacy of funding for the innovation project. Kerssens-van Drongelen and de Weerd-Nederhof (1999) point to a lack of measurement procedures to help managers diagnose poor innovation performance or support improvement.

A more helpful measure of inputs may therefore be obtained by disaggregating inputs into different types and measuring each independently, before aggregating back to a measure of overall inputs management. Brown and Svenson (1988, 30) define the inputs into the R&D system as 'the raw materials or stimuli a system receives and processes', including people, equipment, facilities and funds. This fundamental distinction between people, tools and physical and financial resources is widely mirrored in the literature.

People factors have been measured as the number of people committed to the innovation task (absolute numbers and relative to total employees), in terms of the mix of types of people regarding cosmopolitanism and propensity to innovate and, in terms of skills, experience and education. Damanpour (1991) argues that a diversity of skills and experience permits more differentiated units from which collaborative relationships can emerge and add significant value to innovation outcomes. Although Baldridge and Burnham (1975) argue that demographic characteristics (sex, age, cosmopolitanism, education) do not appear to influence innovative behaviour among individuals, more recent research suggests that innovating groups should comprise individuals with a mix of these characteristics (Amabile 1998). Members with high levels of education and self-esteem increase the effectiveness of R&D project teams (Kessler and Chakrabarti 1996), and individuals of greater educational attainment with diverse backgrounds have been associated with more innovative teams (Bantel and Jackson 1989).

The propensity of an individual to innovate has received considerable attention, though it is difficult to measure. Kirton (1976) developed a 32-item questionnaire designed to establish an individual's position on an 'adaptor–innovator' continuum. Scott and Bruce (1994) operationalized an 'innovative behaviour measure' consisting of six items against which subordinates are measured by hierarchical superiors. Finally, the Innovation Potential Indicator (Patterson 2003) provides a framework for investigating individual behaviours that might promote or inhibit innovation in the workplace. This measure is constructed around four dimensions: an individual's motivation to change, challenging behaviour, preferred approach to work, and preference for tried and trusted methods of work as opposed to doing things differently.

Facilities, or physical resources, is a broad category that captures a range of inputs from buildings to computer equipment. Physical resources can be counted or measured in dollar terms. However, one important general measure of facilities, which cannot be so readily measured, is slack. Slack resources or unused capacity can be regarded as an important catalyst for innovation. Slack allows failures to be absorbed, provides the opportunity for diversification, and fosters a culture of experimentation and protects against the uncertainty of project failure (Kimberly 1981). An alternative view, however, suggests a negative relationship: slack can become synonymous with waste and represents a cost that should be eliminated (Nohria and Gulati 1996). Typically, financial measures of slack are used (Damanpour 1991), although Miller and Friesen (1982) use both financial and human measures of slack.

Use of systems and tools is an important input to the innovation process (Bessant and Francis 1997; Cooper *et al.* 2004). Measures identified tend to relate to whether or not the organization has or makes use of formal systems and tools in support of innovation. These can be of various sorts, such as the availability and use of tools and techniques for promoting creativity (Amabile 1998; Rickards 1991; Rochford 1991; Thompson 2003) or the availability and use of systems of quality control ranging from informal methods to specific techniques such as total quality management (TQM) (Souitaris 2002). While tool use can be evaluated on a binary or degree of use scale, there is little other than Chiesa *et al.*'s (1996) technical innovation audit that attempts to measure whether or not tool use is consistent with a firm's innovation requirements and is integrated into its processes.

We conclude that, while there has been a concentration on financial measurement of inputs, there is less emphasis on measuring other aspects of the category. Even within financial measures, there are few that attempt to determine the adequacy of funding for the innovation project. Further, most measures reflect a preoccupation with R&D and NPD rather than other forms of innovation (e.g. process, business model). In particular, the softer inputs of skills and knowledge are poorly represented by measurement instruments. Tacit knowledge input appears not to be well captured by extant measures, and no measures of appropriate skill levels have been developed. This is an imbalance that needs to be addressed by further work to develop a balanced set of measures covering all sub-dimensions of the input category.

Knowledge Management

Knowledge absorption, an organization's ability to identify, acquire and utilize external knowledge, can be critical to a firm's successful operation (Zahra and George 2002). The concept of knowledge has received much attention in recent years (e.g. Blackler 1995; McAdam 1999; Nonaka 1991) and has been asserted to play a critical role in the innovation process (Hull *et al.* 2000). Knowledge management is concerned with obtaining and communicating ideas and information that underlie innovation competencies, and includes idea generation, absorptive capacity and networking. Knowledge management covers the management of explicit and implicit knowledge held by the organization (Davis 1998; Nonaka 1991) as well as the processes of gathering and using information. The three areas within knowledge management of importance for innovation management identified in the literature are: idea generation, knowledge repository (including the management of implicit and explicit knowledge) and information flows (including information gathering and networking).

The importance of generating sufficient numbers of ideas has been well established in the literature. Ideas are the raw materials for innovation; it is relatively inexpensive to generate and screen ideas, yet this can have significant impact on ultimate success or failure (Cooper 1988). Several authors have conceptualized the early stages of the innovation process as a somewhat fuzzy period (Kim and Wilemon 2002; Moenaert *et al.* 1995; Verworn 2002), including opportunity identification, opportunity analysis, idea genesis, idea selection and concept development (Koen *et al.* 2001).

At the commencement of the innovation process, when ideas are generated and explored, measures tend mostly to be quantitative, inexpensive and rapid. As the process progresses and uncertainties with regard to appropriateness, feasibility and business case are reduced, measurement approaches become increasingly qualitative and possibly more costly and time-consuming to deploy. Measures imply an assumption that the objective is to generate as many ideas as possible through the use of generative tools. Several measures attempt to count the number of ideas generated in a period (cf. Chiesa *et al*. 1996; Lee *et al*. 1996), while others probe the extent to which organizations are using different generative tools and techniques (cf. Cebon and Newton 1999; Chiesa *et al*. 1996; Loch *et al*. 1996; Rochford 1991; Szakonyi 1994; Thompson 2003).

If knowledge is fundamental to innovation, then it should be possible to measure the accumulated knowledge of the firm, its knowledge repository. One aspect of innovation relates to combinations of new and existing knowledge, which privileges the contribution of internal and external knowledge and the mechanisms by which it flows into and within an organization (Galunic and Rodan 1998; Nonaka and Takeuchi 1995; Pitt and Clarke 1999). Central to this perspective is the idea of 'absorptive capacity', the firm's ability to absorb and put to use new knowledge, and involving 'an ability to recognize the value of new, external knowledge, assimilate it, and apply it to commercial ends' (Cohen and Levinthal 1990, 128). Absorptive capacity results from a prolonged process of investment and knowledge accumulation within the firm, and its development is path dependent. Firms with strong absorptive capabilities are more likely to acquire knowledge and learn effectively from outside. Higher levels of absorptive capacity appear to be positively related to innovation and performance (Chen 2004; Tsai 2001), but it is impossible to predict what is the 'right' level of investment in absorptive capacity for any individual firm (Cohen and Levinthal 1990), meaning that it is not readily amenable to international benchmarking. However, the conceptual development and empirical studies infer or imply a range of organizational knowledge states.

Several quantitative approaches have been developed for the measurement of imported tangible knowledge. The most frequently used approach counts numbers or value of patents brought in. However, this restricts its application to contexts in which patents are significant, and overlooks those industries where they do not feature. For a while, patent data was widely accepted as a proxy measure for innovation. More recently, however, the validity of patent statistics has been questioned: patents vary in their utility for organizations, and so their input value to the innovation cannot adequately be judged in terms of a cash price (Griliches 1990; Pakes and Griliches 1980). Only a few studies have attempted to devise measures for other contexts. For example, Kleinknecht (1987) constructed a question designed to capture the informal hours of R&D work that are hypothesized to be hidden within other activities or to take place outside formal working hours.

Patents represent codified knowledge, but the importance of tacit knowledge to organizational innovation is underscored in the resource-based approach (Barney 1991; Galunic and Rodan 1998; Grant 1991; Leonard and Sensiper 1998). Tacit knowledge is an important resource when it is has value for the organization, is difficult for competitors to imitate, is rare, and can be operationalized by the organization. Of particular importance is its acquisition and use (Bess 1998). It can be acquired opportunistically or by a deliberate policy of search.

Tacit knowledge is notoriously difficult to measure in organizational research, and methodologies for its investigation and measurement can be complex. Ambrosini and Bowman (2001), for example, propose an approach that consists of causal mapping facilitated by story-telling and the use of metaphor. Other attempts to capture tacit knowledge and group memory have been reported by Oliver *et al.* (1999). At the level of the organization, Sveiby (1997) suggests the difference between market value and net book value as an indicator of the value to an organization of intangible knowledge assets. The first method is resource intensive, while in the second it is not clear how much of the identified value can be attributed to inputs into innovation. Tacit knowledge input appears not to be well captured by extant measures.

Information flows into and within the firm are important in sparking ideas and in allowing the development of innovative concepts. Three measurement approaches to information flows can be identified: first, measures of the linkages that the innovating group maintains with external organizations and sources; second, measures of internal information gathering processes. Third, measures of customer information contacts.

Linkage measures determine whether or not the organization has and maintains external linkages with other organizations or sources of information, e.g. through participation in research projects, university links or attendance at trade shows (Atuahene-Gima 1995; Tipping and Zeffren 1995). These are principally dichotomous measures, only infrequently is there a measure that implies some sort of qualitative assessment of the nature of the linkages. Cebon and Newton's (1999) measures suggest that quality and diversity of linkage might be an important factor, for example, visits to exemplary projects.

Statistics on the use of formal methods of information gathering such as project reviews and the use of technical reports (Oliver *et al.* 1999) provide a frequently used approach to the measurement of information gathering. Cebon and Newton (1999) suggest benchmarking information gathering against competitors' activities, to gauge how well the activity is performed. Another important area about which a firm needs understanding and information is customers; Atuahene-Gima (1995) lists a series of measures specifically aimed at examining the extent to which organizations make use of customers as a source of information, and include measures assessing the adequacy of information and customer contact time (Lee *et al.* 1996; Miller and Friesen 1982).

Innovation Strategy

Ramanujam and Mensch (1985) define innovation strategy as a timed sequence of internally consistent and conditional resource allocation decisions that are designed to fulfil an organization's objectives. Activities must be consistent with an overarching organizational strategy that implies that management must take conscious decisions regarding innovation goals (Sundbo 1997). Innovation strategy is generally understood to describe an organization's innovation posture with regard to its competitive environment in terms of its new product and market development plans (Dyer and Song 1998). This techno-centric view predominates in the literature and overlooks those innovative initiatives that are internally focused (for example, the adoption of new management techniques and practices). In the conceptualization of innovation strategy as an articulation of the organization's commitment to the development of products that are new to itself and/or to its markets, and because strategy does not operate in a vacuum, but requires a structural context, two complementary approaches to its measurement, which have been described as objective and subjective (Li and Atuahene-Gima 2001), can be identified.

In the literature, scholars principally have adapted measures from strategic management research to explore the existence, nature and extent of innovation strategy. Richard *et al.* (2003) use three scale items drawn from the strategic posture scale devised by Covin and Slevin (1989), who, in turn, draw on Miles and Snow's (1978) 'prospectors' and Mintzberg's (1978) 'entrepreneurial' organizations, for their assessment of bank innovativeness. These studies classify organizations based on their approach to innovation using classifications that are ontologically grounded in the assumption that innovation orientation can be deciphered from quantitative interpretations of new product and market activity.

Other objective evidence of an organization's innovation strategic posture may include many of the input measures (such as level of R&D expenditure) that we have already discussed. It is argued that it is not their absolute magnitude but their magnitude relative to industry rivals that is significant. As has been noted, although these may be useful indicators of commitment or intent, they could mask process inefficiencies. However, O'Brien's (2003) observation that an interaction between *intended* strategy and slack will influence performance suggests that process inefficiencies are less likely to occur where an innovation strategy is not merely nominally adopted, but is embedded in the culture, behaviours and actions of the organization.

In Li and Atuahene-Gima's (2001) terms, the evidence for an embedded innovation strategy is subjective and may include evaluations of an organization's emphasis on NPD, such as resource allocation. Saleh and Wang (1993) describe this as consisting of three main components: risk-taking, proactiveness and persistent commitment to innovation. These include top management responsibility for innovation within the organization, including specifying and communicating a direction for innovation. Cooper (1984) demonstrated that new product performance is largely decided by the strategy that top management adopts. The key components are the link between innovation strategy and overall business goals (strategic orientation) and the provision of leadership to make innovation happen via a strong vision (Pinto and Prescott 1988) for innovation, a long-term commitment to innovation and a clear allocation of resources (Cooper *et al*. 2004). This distinction between strategic planning or orientation and strategic vision or leadership is frequently replicated in the literature.

Two distinct types of strategic orientation measures can be identified in the literature. First, those that measure whether the organization has an innovation strategy; this can be evaluated in several ways, such as commitment to differentiated funding (White 2002), explicit expression (does the organization have an innovation strategy?) (Miller and Friesen 1982) and identifiable roles for new products and services (Cooper and Kleinschmidt 1990; Geisler 1995; Hauser and Zettelmeyer 1997; Tipping and Zeffren 1995). The second type of measure regards strategy as a dynamic instrument that shapes and guides innovation in the organization. These measures assume that strategy exists and asks questions about how effective it is in shaping and guiding: 'are structures and systems aligned' (Bessant 2003), 'do innovation goals match strategic objectives' (Tipping and Zeffren 1995) and further similar measures of strategic fit (Bessant 2003).

From a strategic leadership perspective, Dougherty and Cohen (1995) found the behaviour of senior managers to be influential. Those chief executives most likely to make innovation happen are those with a clear vision of the future operation and direction of organizational change and creativity (Shin and McClomb 1998). Senior management are responsible for developing and communicating a vision for innovation, being supportive and adopting an attitude tolerant to change and championing the notion of innovation within the organization. Managerial tolerance to change creates the right climate for the implementation stage of innovation, where conflict resolution might be necessary (Damanpour 1991).

Managerial attitude is also reflected in norms or support for innovation. These are the expectation, approval and practical support of attempts to introduce new and improved ways of doing things in the work environment. Measures are mostly qualitative in nature and explore perceptions, mostly about the extent to which respondents recognize factors to be present (or absent).

Relatively few measures of championing and leadership have been uncovered in this review other than those that simply ask the question whether or not one or other exists, perhaps through evidence of signs of commitment in annual reports (Chiesa *et al*. 1996) or levels of concern of top management (Coughlan *et al*. 1994) or whether or not an individual has been physically assigned to a particular role (Souitaris 2002). Shane *et al.* (1995) provide a series of reflective questions designed to allow organizations to determine for themselves their expectations and understanding of the role of champion. For example, 'to what extent should the organization make it possible for the people working on an innovation to bend the rules of the organization to develop the innovation, or be allowed to bypass certain personnel procedures to get people committed to an innovation?'

It must be emphasized that the dominant perspective on strategy in the literature is one that examines the relationship between strategy and performance. However, a small number of studies have examined the nature of the transitions of these states as organizations adopt and embed an innovation strategy. This sub-section of the literature is underpinned by the assumption that firms that follow innovation strategies differ from other firms in several respects. It is apparent that more innovative firms adopt different operational strategies to accommodate flexibility and quality capabilities (Alegre-Vidal *et al.* 2004), have different capital management practices to facilitate slack resources (O'Brien 2003), are more tolerant of internal conflict in support of creativity (Dyer and Song 1998), and maintain organizational structures that are in the 'intermediate zone between order and disorder' (Brown and Eisenhardt 1997, 22). What is clear from this literature is that any transition towards an innovation strategy will necessarily take several years because of the resources and energy that are necessary before such a transformation can even be triggered (Hope Hailey 2001).

Organizational Culture and Structure

Burns and Stalker (1961) described a contingency approach to innovation management, later developed to include concepts of functional differentiation, specialization and integration (Lawrence and Lorsch 1967), which suggests that environmental change prompts a realignment of the fit between strategy and structure. That is, to perform effectively, an organization must be appropriately differentiated, specialized and integrated. Pugh *et al.* (1969) argued that the structure of an organization is strongly related to the context within which it functions. Our closing discussion in the previous section, that the characteristics of organizations following an innovation-focused strategy will differ from those that do not, is consistent with this contingency approach and, in the following, we focus on those dimensions of culture and structure that have been identified to differentiate between innovative and non-innovative organizations.

Organizational culture and structure concern the way staff are grouped and the organizational culture within which they work. There has been considerable work on the situational and psychological factors supportive of innovation in organizations. Indeed, it has been widely demonstrated that the perceived work environment (comprising both structural and cultural elements) does make a difference to the level of innovation in organizations (Amabile *et al.* 1996; Ekvall 1996). Creative and innovative behaviours appear to be promoted by work environment factors (Mathisen and Einarsen 2004). Indeed, it is clear that organizations can create environments in which innovation can be encouraged or hampered (Dougherty and Cohen 1995; Tidd *et al.* 1997). A common theme is that of the polychronic organization – one with the capacity to be in two states at once (Becker and Whisler 1973). Shepard (1967) describes this as a two-state organization manoeuvreing between loose and tight, and Mitroff (1987) as business-as-usual versus business-not-as-usual. More prosaically, this means organizations need to be able, for example, to provide sufficient freedom to allow for the exploration of creative possibilities, but sufficient control to manage innovation in an effective and efficient fashion.

Ernst (2002) specifies a range of generic characteristics for the dedicated project group assigned the innovation task: multidisciplinarity, dedicated project leader, inter-functional communication and co-operation, qualifications and know-how of the project leader, team autonomy and responsibility for the process. And these factors are echoed throughout the literature. Rothwell (1992) refers to them as 'corporate conditions', Chiesa *et al*. (1996) 'enabling processes' and O'Reilly and Tushman (1997) 'norms for innovation and change'. However, despite their perceived importance, there is little guidance on how to measure them.

Volberda (1996) developed a conceptual model of alternative flexible organizational forms that are argued to initiate or respond better to different types of competition. Yet, in spite of its importance, there is relatively little evidence of extant measures of flexibility in the literature. Rothwell (1992) and Ekvall (1996) propose a range of foci for measures of organizational and production flexibility, such as 'corporate flexibility and responsiveness to change'; Coughlan (1994) considers the flexibility of resource allocation. Several measures of personnel flexibility are evident, such as 'the adaptiveness of R&D personnel to technology changes' (Lee *et al*. 1996) and 'the willingness to try new procedures and to experiment with change, so as to improve a situation or a process' (Abbey and Dickson 1983). At the level of the firm, Liao *et al*. (2003) introduce a similar construct – 'organizational responsiveness'.

Organizational complexity, the amount of specialization and task differentiation reportedly have a positive relationship (Damanpour 1996), though Wolfe (1994) argues that it may favour initiation at the expense of implementation. Administrative intensity, that is the ratio of managers to total employees, favours administrative innovation (Damanpour 1991, 1996), but possibly at the cost of other product or technological innovations (Dougherty and Hardy 1996). Centralization, the concentration of decision-making authority at the top of the organizational hierarchy, and formalization, the degree of emphasis on following rules and procedures in role performance, have both been shown to have a negative impact on organizational innovation (Burns and Stalker 1961; Damanpour 1991). Indeed, rigidity in rules and procedures may prohibit organizational decision-makers from seeking new sources of information (Vyakarnam and Adams 2001).

Underlying the concept of the workplace environment are issues related to the management of human resources and the creation of a culture or climate in which individuals perceive innovation to be a desired and supported organizational objective. There has been considerable empirical work on organizational climates supportive of the innovation process, and several measurement instruments have been developed, which Mathisen and Einarsen (2004) review. The Team Climate Inventory (TCI) (Anderson and West 1996, 1998) and the KEYS instrument for assessing the work environment for creativity (Amabile *et al.* 1996) have been found to be robust and rigorous.

The TCI has been applied and validated in several studies (Agrell and Gustafson 1994; Anderson and West 1998; Kivimäki *et al.* 1997; West and Anderson 1996). Replication studies using the TCI have found it can explain a large part of the variance in teams' innovative performance (Agrell and Gustafson 1994). The TCI is based around four main factors: participative safety (how participative is the team in decision-making procedures, and how psychologically secure do team members feel about proposing new and improved ways of doing things), support for innovation (the degree of practical support for innovation attempts contrasted with the rhetoric of professed support by senior management), vision (how clearly, defined, shared, attainable and valued are the team's objectives and vision) and task orientation (the commitment of the team to achieve the highest possible standards of task performance, including the use of constructive progress monitoring procedures) (Anderson and West 1996). Kivimäki *et al*. (1997) suggested a fifth factor, 'interaction frequency' relating to the regularity of contact and communication within the project team.

There is general agreement about the importance of individual and group autonomy in the innovation process (Amabile 1998). Zien and Buckler (1997) emphasize the need for freedom to experiment and the creation of safe havens, without which innovation outcome might be constrained. Measures of autonomy mix both qualitative and quantitative approaches. For example, 'the degree of freedom personnel have in day-to-day operating decisions such as when to work and how to solve job problems, including freedom from constant evaluation and close supervision' (Abbey and Dickson 1983) or 'percentage of R&D portfolio with explicit business unit and/or corporate business management sign-off' (Tipping and Zeffren 1995). Additionally, several authors have proposed general measures of autonomy such as 'freedom to make operating decisions' (Abbey and Dickson 1983) or 'degree of empowerment' (de Leede *et al.* 1999; Tipping and Zeffren 1995).

Morale and motivation are dimensions of the innovative organization that can be measured as they pertain to individuals – 'the extent to which personnel are well rewarded' (Abbey and Dickson 1983); to groups – 'our reward system is more group-based than individual-based' (Parthasarthy and Hammond 2002); and to the organization as a whole – 'the degree to which the organization attempts to excel' (Abbey and Dickson 1983). Aspects of morale and motivation that have been measured include trust (Miller and Friesen 1982) and job satisfaction, which has been measured by Keller (1986) on a 20-item scale.

Organizational culture may include a shared vision, and it has been argued that, the clearer the vision, the more effective it is as a facilitator of innovation, as it enables focused development of new ideas that can be assessed more precisely (West 1990). Pinto and Prescott (1988) found that the only factor to have predictive power in terms of potential for success at all stages of the innovation process (conception, planning, execution and termination) was having a clearly stated mission/vision, while West (1990) contends that the quality of innovation is partly a function of vision. Keller (1986) adopts Kirton's (1976) 32-item adopter–innovator inventory to determine individual and team orientation to innovation. Vision is operationalized in the team climate inventory (cf. Agrell and Gustafson 1994; Anderson and West 1996, 1998; West and Anderson 1996) and is deconstructed into a series of sub-dimensions such as clarity, sharedness, attainability and value with regard to team objectives.

Another aspect of culture is the propensity to take risks. Saleh and Wang (1993) describe this as a willingness to confront risky opportunities and tolerate failure, and learn from doing so rather than recklessly gambling. Similarly, West (1990) demonstrated that higher levels of participative safety facilitate innovation. Participative safety is non-judgmental, supportive and characterized by socio-emotional cohesiveness. The attractiveness of the organization as a place to work and undertake innovative activities is used by Geisler (1995) as an indicator of the climate for innovation, measured by numbers of candidates applying for positions, and the age profile of scientists and engineers. Keller (1986) offers a slightly different perspective on participative safety with the construct 'group cohesiveness', which he operationalizes using an established five-item measure.

This review has described a wide variety of measures proposed for organizational culture and structure. Unlike some other aspects of innovation management, this area has received extensive measurement attention. However, Holbek (1988) argues that innovating organizations must adopt contrasting structures and climates as they move from the initiation to the implementation stages of innovation. Chesborough and Teece (1996) and Burns and Stalker (1961) argue that there is a relationship between organizational design and type of innovation. It is a significant gap in innovation measurement that there appears to be no measures that adequately capture or articulate this sense of structural shift.

Portfolio Management

The importance of portfolio management to successful product innovation has recently emerged as a key theme in the literature. It is important because of the rapidity at which resources are consumed in the innovation process and the need for these to be managed (Cebon and Newton 1999). The effectiveness with which an organization manages its R&D portfolio is often a key determinant of its competitive advantage (Bard *et al.* 1988). The focus of portfolio management is on making strategic, technological and resource choices that govern project selection and the future shape of the organization (Cooper *et al.* 1999). The problems of allocation of resources, evaluation, selection and termination of projects in achieving the optimal portfolio have been extensively investigated. The models all have the objective of devising means to allocate resources to projects to obtain the optimal balance in the product development portfolio, that is, arriving at a portfolio that optimizes the trade-off between returns and risks.

The process of selecting innovation projects requires evaluation and resource allocation under uncertain conditions. It is argued that a systematic process guided by clear selection criteria can help optimize the use of limited resources and enhance an organization's competitive position (Hall and Nauda 1990). The earliest models used return on investment as the primary decision criteria (Bard *et al.* 1988). Following this, increasingly sophisticated mathematical tools were developed to resolve what Schmidt and Freeland (1992) describe as the constrained optimization problem, that is, to maximize the output (according to specified criteria) from a subset of available inputs. These project selection models 'have been virtually ignored by industry' (Schmidt and Freeland 1992, 190). Part of the reason for this is the inherent complexity of some of these models, but also that they fail to take into account organizational decision and communication processes. More recently, models have tried to take account of these more qualitative factors involved in decision processes.

Scoring models require respondents to specify the merit of any project proposal according to a set of a priori criteria which may be objective or subjective (Hall and Nauda 1990). Economic and benefit models attempt to compute the cost/benefit or financial risk of pursuing a specific project, while mathematical programming approaches seek to optimize some objective function(s) subject to specified resource constraints. Algorithms of varying complexity exist, requiring monitoring and significant data entry, and, while many are conceptually attractive, surveys do not show widespread utilization of these techniques (Hall and Nauda 1990). These approaches are all based on financial measures such as internal rate of return, net present value and return on investment. At the other end of the spectrum, qualitative approaches such as peer review and mental checklists rely on subjective perceptions and measures of portfolio balance (Cooper *et al.* 2001; Henriksen and Traynor 1999).

Cooper *et al.* (1999) find that best performers use explicit formalized tools and consistently apply them to all projects considered to belong to a portfolio. A series of measures can be identified that evaluate the whole portfolio of innovation projects to answer questions such as 'is it balanced in terms of quantity of short- and long term-projects?' and 'is there a balance between high and low risk projects and large and small projects?' (Brenner 1994; Cooper *et al.* 2001). Another set seeks to identify the extent to which portfolio evaluation measures are formalized within the organization's processes (Cebon and Newton 1999; Chiesa *et al.* 1996; Farrukh *et al.* 2000; Miller and Friesen 1982). Yet another approach is to view project evaluation and selection as an organizational capability and attempt to determine a level of proficiency (Szakonyi 1994). Finally, there is a series of post hoc measures of the appropriateness of project selections in the light of results and alignment with business objectives (Lee *et al.* 1996).

Project Management

Project management is concerned with the processes that turn the inputs into a marketable innovation. The innovation process is complex, comprising a myriad of events and activities some of which can be identified as a sequence and some of which occur concurrently, and it is clearly possible that innovation processes will differ to some degree, across organizations and even within organizations on a project-by-project basis. Having an efficient process that is able to manage the ambiguity of the innovation is universally agreed to be critical to innovation (Globe *et al*. 1973).

Various approaches have been taken to modelling innovation processes: as a series of events (Zaltman *et al*. 1973), as a social interaction (Voss *et al*. 1999), as a series of transactions (Nelson and Winter 1982) and as a process of communication (Farrukh *et al*. 2000). The history of project management research is partly characterized by a debate regarding the extent to which events and activities within the process occur in linearly sequential, discrete, identifiable stages (Zaltman *et al*. 1973) or whether events are more disorganized (King 1992) or even chaotic (Koput 1997). However, despite these different viewpoints, there are a number of common elements that can be summarized as the major components of the innovation project management. These are project efficiency, tools, communications and collaboration.

Several studies make efforts to measure project management efficiency, mostly in the form of comparisons between budget and actual (project costs, project duration, revenue forecasting). Another measure of project management success is speed. Innovation speed has been positively correlated with product quality or the degree to which it satisfies customer requirements; measures include speed (Hauser and Zettelmeyer 1997), performance against schedule (Chiesa and Masella 1994), and duration of the process (Cebon and Newton 1999).

To achieve efficiency, it is widely recommended that organizations seeking to innovate should establish formal processes for innovating and make use of tools and techniques that may facilitate innovative endeavours. The stage-gate process (Cooper 1990) is possibly the most familiar of these, but other methodologies for innovation project management exist, including Phased Development, Product and Cycle-time Excellence and Total Design (see Jenkins *et al*. (1997) for a discussion). These methodologies have in common the separation of the product development process into structured and discrete stages, which each have milestones in the form of quality control checkpoints at which stop/go decisions are made with regard to the progress of the project. These highly structured approaches to the management of the innovation process began to emerge in the 1990s (Veryzer 1998). The use of structured tools and processes can be measured by project process evaluations, for example the use of a formal problem-finding/problem-solving cycle (Bessant 2003), the use of formal post-launch evaluation procedures (Atuahene-Gima 1995) or the use of certified processes (Chiesa *et al*. 1996). These rather general process measures have been supplemented by measures of the use of specific instruments and tools, such as interactive CAD or CAM (Maylor 2001) or the use of computer-integrated manufacturing processes (Parthasarthy and Hammond 2002), but we note that these measures betray the technological and NPD heritage that underpins many of the innovation measures identified in this review. Equivalents for service industry, public or not-for-profit sector innovations are somewhat lacking in the literature and constitute a research gap.

Communications are important in project management. Damanpour (1991) demonstrated the existence of a positive relationship between internal communication and innovation. Internal communication facilitates the dispersion of ideas within an organization, increases the diversity and also contributes to the team ‘climate’. Communication can be measured by various integration mechanisms, e.g. committees, numbers of meetings and contacts (Damanpour 1991). There are also measures of external communications, which tend to focus on whether communication is taking place, the level at which it occurs and with whom (Cebon and Newton 1999; Lee *et al*. 1996; Rothwell 1992; Souitaris 2002). These measures of internal and external communication in the literature are based on both subjective evaluations and objective frequency counts. Subjective measures include: 'we always consult suppliers/customers on new product ideas' (Parthasarthy and Hammond 2002) and 'degree of organization members involved and participating in extra-organizational professional activities' (Damanpour 1991). Objective counts include (Damanpour 1991) 'extent of communication amongst organizational units or groups measured by various integrating mechanisms such as numbers of committees and frequency of meetings', (Anderson and West 1998) 'frequency of formal meetings concerning new ideas', (Souitaris 2002; Szakonyi 1994) 'how well do the technical and finance people communicate with one another'.

It is widely recognized that collaborating with suppliers (Bessant 2003) and customers (von Hippel 1986) can also make a significant contribution to the innovation process. Measures of collaborative working include the use of guest engineers (Maylor 2001), the percentage of projects in co-operation with third parties (Kerssens-van Drongelen and Bilderbeek 1999) and the extent to which decision-making at top levels is characterized by cross-functional discussions (Miller and Friesen 1982). In addition, Jassawalla and Sashittal (1999) identify some characteristics of internal collaboration, i.e. that teams are characterized by their mindfulness, levels of at-stakeness, synergy and transparency, but they do not suggest how these aspects might be measured, which constitutes a further research gap.

Commercialization

Commercialization can be considered to be the second of the two phases in Zaltman *et al*.'s (1973) conceptualization of the innovation process, that is, 'implementation'. This can mean taking an innovation to market (Chakravorti 2004), but may also include convincing production managers to adopt a series of new techniques available to them (Single and Spurgeon 1996). Indeed, the successful introduction of new products and services into markets is important for the survival and growth of organizations. Kelm *et al*. (1995) regard commercialization as a transitional phase in which the organization becomes less reliant on its technological capabilities (important during the activities of initiation), but more dependent on market dynamics. Commercialization is concerned with making the innovative process or product a commercial success; it includes issues such as marketing, sales, distribution and joint ventures. While technical capabilities are important for the early stages of the innovation process and development activities, for the launch and implementation stage it is marketing capabilities (market investigation, market testing, promotion etc.) that are significant (Calantone and di Benedetto 1988; Globe *et al*. 1973). Verhaeghe and Kfir (2002) consider aspects of commercialization under the headings of market analysis and monitoring, reaching the customer and market planning.

Firm-level measures of the launch or commercialization process appear to be relatively thin. In their description of the R&D process, Balachandra and Brockhoff (1995) characterize the commercialization stage as requiring 'big bucks', market reviews and organizational commitment. Most measures appear to be not much more sophisticated than this. Measures are frequently restricted to numbers of products launched in a given period (e.g. Yoon and Lilien 1985). There is, though, some focus on market analysis and monitoring (Verhaeghe and Kfir 2002). Song and Parry (1996) employ a set of measures of launch proficiency (salesforce, distributional and promotional support) that directly address the 'adequacy' of the organization's facilities in these areas, as do Avlonitis *et al*. (2001). And there is a limited mention of the commercial intentions of an organization's competitors (Calantone and di Benedetto 1988). The themes of proficiency of personnel in this area (e.g. Atuahene-Gima 1995; Cebon and Newton 1999), of adherence to a commercialization schedule (e.g. Griffin and Page 1993) and of formal post-launch reviews (Atuahene-Gima 1995; von Zedtwitz 2002) can also be found in the literature.

Even in the work that addresses post-project reviews, very little attention is directed towards measuring innovation launch or commercialization. However, this comes as little surprise, as Hultink *et al*. (2000) recently observed that little work has been done in the area, perhaps because, at least in the innovation literature, launch activities appear to be considered the domain of other specialists, particularly marketers, and the process is seen as separate from innovation. In their study, they investigated launch decisions associated with success for consumer and business-to-business products. Much of the literature that considers launch and commercialization does so from the viewpoint of the adopter, and assesses rates of adoption and diffusion of innovations over time across populations (Kessler and Chakrabarti 1996; Van Den Bulte 2000).

The area of commercialization appears to be the least developed of the issues involved in innovation management. This is a huge gap because, without this last step, the previous steps of assembling inputs, project management, etc. will not result in a commercially viable outcome for the firm. We believe that this area of innovation is in urgent need of further development, from both theory and measurement viewpoints.

Discussion

Innovation management measurement is a critical discipline for both academics and practitioners. The capacity of organizations to innovate is determined by multiple factors that relate both to their own internal organization and to their market environment (Rothwell *et al*. 1974) and the task of generating and then converting ideas into usable and marketable products requires high levels of inter-functional co-ordination and integration. This paper opened with the general observation that innovation measurement does not appear to take place routinely within management practice and that, where it does, it tends to focus on output measures. Further, from the relatively small number of empirical studies of measurement in practice, measurement of innovation management appears to be undertaken infrequently, in an ad hoc fashion, and relies on dated, unbalanced or under-specified models of the innovation management phenomenon. This suggests that a large part of the contemporary conceptualization of the innovation management phenomenon is overlooked in practitioners' measurement practices and, consequently, that opportunities for the more efficient and effective management of the innovation process are not realized. Some possible reasons for this state of affairs are: failure of academics to communicate adequately, inconsistency, inaccessibility and complexity of measures and poor synthesis and packaging.

Following a review and synthesis of the literature, we proposed a seven-dimensional conceptualization of the innovation management phenomenon and applied it to an examination of the measurement problem. Through the application of this framework to their own particular context, it is suggested that practitioners will be able to conduct an evaluation of their own innovation management activity, identify gaps, weaknesses or deficiencies, and also improvement potential. Further, it is hoped that organizations applying the framework will be able to tease out areas where innovation is only nominally adopted in their processes and identify areas where attention and resources might be focused.

From the perspective of its management, it is no longer sufficient to treat innovation as a linear process where resources are channelled at one end, from which emerges a new product or process. The measurement framework presented in Table 2 shows the breadth and variety of elements of innovation management that ideally need to be measured. There have been several studies that have investigated the limitations of various approaches to measurement (e.g. Werner and Souder 1997), and of specific measures (e.g. Trajtenberg 1990) as they relate to the practice of innovation. The choice of an appropriate R&D measurement metric depends on the user's needs in terms of comprehensiveness of measurement, type of R&D being measured, available data and amount of effort the user can afford to allocate to the exercise. Nonetheless, the common citing across various papers of the measures noted in the innovation management framework presented here suggests that a base set of innovation management measures is implicitly present in the literature, even though they may be fragmented in appearance and presentation. By pulling together the innovation management framework from diverse sources, this paper aims to bring such issues into the open and identify relevant research gaps. Table 2 can be viewed as the basis for a balanced scorecard (Kaplan and Norton 1992) for innovation management, that is, as a balanced set of areas that need to be measured in order to gain insight into an organization's holistic ability to manage innovation. Such multidimensional approaches to measurement have been found in other areas of management to be an improvement on simple one-dimensional measures and to be able to capture both short- and long-term aspects of value creation in the firm (Phelps 2004).

We have identified a large number of measures and approaches in a variety of innovation management areas, and we have constructed a generic set of innovation management measurement areas to act as a framework for balanced measurement. However, in several of these areas, measurement gaps have been identified. These gaps are of two types: validity gaps and omission gaps. Validity gaps arise where there is insufficient evidence that proposed measures actually do capture drivers or outputs of innovation management; for example, we have noted the objections to counts of patents or increasing expenditure on R&D being used as measures of innovative organizations. Similarly, there is an absence of evidence that the large number of subjective perceptions of innovation management practices proposed ('we do A', 'we are good at B') actually relate to innovation management performance.

Omission gaps occur where the importance of an aspect of innovation management is supported in the literature, but measures for this aspect are lacking. Omission gaps are particularly prevalent in the elements of innovation management such as knowledge management, innovation strategy and commercialization that do not feature strongly in the literature on technological and manufacturing-based innovation. Another area traditionally not given much emphasis in this literature is organization and culture, which, fortunately, is better treated by the organizational behaviour literature, where a number of measures have been developed. Much of the current state of measurement practice can be traced back to the discipline's early manufacturing, R&D and NPD focus. While product innovation is undoubtedly important, it is only one dimension of an organization's innovation agenda. Process and organizational innovations are recognized, too, as critical for competitiveness, yet these perspectives are inadequately represented in measurement terms.

General areas of omission in this field relate to an over-reliance on financial measures rather than process measures: for example, the use of financial measures of portfolio optimization, but an absence of portfolio capability measures; a similar reliance on codified knowledge such as patents to the exclusion of more intangible measures such as tacit knowledge; the measurement of levels of resources or activities with no indication of what an optimal level would be; the measurement of drivers of innovation without measures of whether these drivers are aligned with each other and with firm strategy; measures of presence that do not measure quality (e.g. the use of dichotomous (yes/no) measures that do not indicate how well an action is implemented, and measures of the presence of leadership (such as champions), but not of quality of leadership); a general absence of measures for important properties of organizational structures such as flexibility, and a lack of measures of the match between structure and environment; a technological and NPD bias to project management measures and a relative absence of measures for service sectors; a paucity of measures for internal communications; and a general lack of measures for commercialization management – in particular, around marketing and sales capabilities for innovative products and services. All these gaps provide the potential for further research in innovation management measurement.

The absence of an accepted framework of innovation management measures leads not only to the gaps identified above, but also to other problems in the literature. One is that it is frequently unclear whether or not the metrics used are of the researchers' own devising, drawn from the literature or are what are used by the organizations being studied. Nor is it always clear when metrics are devised or recommended, whether they are intended for use in a research capacity or for management tasks. Further, the measures proposed in the literature often seem to be proposed abstractly, with little consideration given to the use of measures as a management tool in the day-to-day context of managing innovation. In the absence of a comprehensive framework for innovation management measurement, organizations will inevitably resort to ad hoc and partial metrics, which can encourage wasteful practice (e.g. measuring innovation management capability according to annual R&D spend). We hope that the framework constructed in this paper will be useful in the construction of comprehensive measures of innovation management.

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Note

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References

Abbey, A. and Dickson, J. (1983). R&D work climate and innovation in semi-conductors. *Academy of Management Journal*, **26**, 362–368.

Agrell, A. and Gustafson, R. (1994). The team climate inventory (TCI) and group innovation: a psychometric test on a Swedish sample of work groups. *Journal of Occupational and Organizational Psychology*, **67**, 143–151.

Alegre-Vidal, J., Lapiedra-Alcami, R. and Chiva-Gomez, R. (2004). Linking operations strategy and product innovation: an empirical study of Spanish ceramic tile producers. *Research Policy*, **33**, 829–839.

Amabile, T.M. (1998). How to kill creativity. *Harvard Business Review*, September–October, 77–87.

Amabile, T.M., Conti, R., Coon, H., Lazenby, J. and Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal*, **39**, 1154–1184.

Ambrosini, V. and Bowman, C. (2001). Tacit knowledge: some suggestions for operationalisation. *Journal of Management Studies*, **38**, 811–829.

Anderson, N. and West, M.A. (1996). The team climate inventory: development of the TCI and its applications in teambuilding for innovativeness. *European Journal of Work and Organizational Psychology*, **5**, 53–66.

Anderson, N.R. and West, M.A. (1998). Measuring climate for work group innovation: development and validation of the team climate inventory. *Journal of Organizational Behavior*, **19**, 235–258.

Atuahene-Gima, K. (1995). An exploratory analysis of the input of market orientation on new product performance: a contingency approach. *Journal of Product Innovation Management*, **12**, 275–293.

Avlonitis, G.J., Papastathopoulou, P.G. and Gounaris, S.P. (2001). An empirically-based typology of product innovativeness for new financial services: success and failure scenarios. *Journal of Product Innovation Management*, **18**, 324–342.

Balachandra, R. and Brockhoff, K. (1995). Are R&D project termination factors universal? *Research-Technology Management*, **38**, 31–36.

Balachandra, R. and Friar, J. (1997). Factors for success in R&D projects and new product innovation: a contextual framework. *IEEE Transactions on Engineering Management*, **44**, 276–287.

Baldridge, J.V. and Burnham, R.A. (1975). Organizational innovation – individual, organizational and environmental impacts. *Administrative Science Quarterly*, **20**, 165–176.

Bantel, K.A. and Jackson, S.E. (1989). Top management and innovations in banking: does the composition of the top team make a difference? *Strategic Management Journal*, **10**, 107–124.

Barclay, I. (1992). The new product development process: part 2. Improving the process of new product development, *R&D Management*, **4**, 307–317.

Bard, J.F., Balachandra, R. and Kaufmann, P.E. (1988). An interactive approach to R&D project selection and termination. *IEEE Transactions on Engineering Management*, **35**, 139–146.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, **17**, 99–120.

Becker, S.W. and Whisler, T.L. (1973). The innovative organization: a selective view of current theory and research. In Wills, G., Hayhurst, R. and Midgley, D. (eds), *Creating and Marketing New Products*. London: Crosby Lockwood Staples.

Bess, G. (1998). A first stage organization life cycle study of six emerging nonprofit organizations in Los Angeles. *Administration in Social Work*, **22**, 35–52.

Bessant, J. (2003). *High Involvement Innovation: Building and Sustaining Competitive Advantage Through Continuous Change*. Chichester: John Wiley.

Bessant, J. and Francis, D. (1997). Implementing the new product development process. *Technovation*, **17**, 189–197.

Blackler, F. (1995). Knowledge, knowledge work and organizations: an overview and interpretation. *Organization Studies*, **16**, 1021–1046.

Bougrain, F. and Haudeville, B. (2002). Innovation collaboration and SMEs internal research capacities. *Research Policy*, **31**, 735–747.

Brenner, M.S. (1994). Practical R&D project prioritization. *Research Technology Management*, **37**, 38–43.

Brown, M.G. and Svenson, R.A. (1988). Measuring R&D productivity. *Research-Technology Management*, July–August, 11–15.

Brown, S.L. and Eisenhardt, K.M. (1997). The art of continuous change: linking complexity theory and time-paced evolution in relentlessly shifting organizations. *Administrative Science Quarterly*, **42**, 1–34.

Burgelman, R.A., Christensen, C.M. and Wheelwright, S.C. (2004). *Strategic Management of Technology and Innovation*, 4th edition. New York: McGraw Hill/Irwin.

Burns, T.R. and Stalker, G.M. (1961). *The Management of Innovation*. London: Tavistock.

Calantone, R.J. and di Benedetto, C.A. (1988). An integrative model of the new product development process: an empirical validation. *Journal of Product Innovation Management*, **5**, 201–215.

Cebon, P. and Newton, P. (1999). Innovation in firms: towards a framework for indicator development. Melbourne Business School Working Paper 99-9.

Chakravorti, B. (2004). The new rules for bringing innovations to market. *Harvard Business Review*, **82**, 58–67.

Chen, C.-J. (2004). The effects of knowledge attribute, alliance characteristics, and absorptive capacity on knowledge transfer performance. *R&D Management*, **34**, 311–321.

Chesborough, H.W. and Teece, D.J. (1996). When is virtual virtuous? Organizing for innovation. *Harvard Business Review*, January–February, 65–73.

Chiesa, V. and Masella, C. (1994). Searching for an effective measure of R&D performance. In *Proceedings, 2nd International Product Development Management Conference* Gothenburg, Sweden, 30–31 May. Brussels: European Institute for Advanced Studies in Management.

Chiesa, V., Coughlan, P. and Voss, A. (1996). Development of a technical innovation audit. *Journal of Product Innovation Management*, **13**, 105–136.

Cohen, W.M. and Levinthal, D.A. (1990). Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, **35**, 128–152.

Cooper, R.G. (1979a). The dimensions of industrial new product success and failure. *Journal of Marketing*, **43**, 93–103.

Cooper, R.G. (1979b). Identifying industrial new product success: Project NewProd. *Industrial Marketing Management*, **8**, 124–135.

Cooper, R.G. (1984). The strategy–performance link in product innovation. *R&D Management*, **14**, 247–259.

Cooper, R.G. (1990). Stage-gate systems: a new tool for managing new products. *Business Horizons*, **33**, 44–56.

Cooper, R.G. and Kleinschmidt, E.J. (1990). New product success factors: a comparison of 'kills' versus successes and failures. *R&D Management*, **20**, 47–64.

Cooper, R.G. and Kleinschmidt, E.J. (1995). Benchmarking the firm's critical success factors in new product development. *Journal of Product Innovation Management*, **12**, 374–391.

Cooper, R.G., Edgett, S.J. and Kleinschmidt, E.J. (1999). New product portfolio management: practices and performance. *Journal of Product Innovation Management*, **16**, 333–351.

Cooper, R.G., Edgett, S.J. and Kleinschmidt, E.J. (2001). *Portfolio Management for New Products*, 2nd edition. Cambridge, MA: Perseus.

Cooper, R.G., Edgett, S.J. and Kleinschmidt, E.J. (2004). Benchmarking best NPD practices. *Research-Technology Management*, **47**, 50–59.

Cordero, R. (1990). The measurement of innovation performance in the firm: an overview. *Research Policy*, **19**, 185–192.

Cormican, K. and O'Sullivan, D. (2004). Auditing best practice for effective product innovation management. *Technovation*, **24**, 819–829.

Coughlan, P., Chiesa, V. and Voss, C. (1994). Evaluating leadership as an enabler of innovation. In *Proceedings*, *2nd International Product Development Management Conference*, Gothenburg, Sweden, 30–31 May. Brussels: European Institute for Advanced Studies in Management.

Covin, J.G. and Slevin, D.P. (1989). Strategic management of small firms in hostile and benign environments. *Strategic Management Journal*, **10**, 75–87.

Daft, R. (1978). A dual-core model of organizational innovation. *Academy of Management Journal*, **21**, 193–210.

Damanpour, F. (1991). Organizational innovation: a meta-analysis of effects of determinants and moderators. *Academy of Management Journal*, **34**, 555–590.

Damanpour, F. (1996). Organizational complexity and innovation: developing and testing multiple contingency models. *Management Science*, **42**, 693–716.

Davis, M.C. (1998). Knowledge management. *Information Strategy: The Executive's Journal*, **15**, 11–22.

De Brentani, U. (1991). Success factors in developing new business services. *European Journal of Marketing*, **25**, 33–60.

De Leede, J., Nijhof, A.H. and Fisscher, O.A. (1999). The myth of self managing teams: a reflection on the allocation of responsibilities between individuals, teams and the organisation. *Journal of Business Ethics*, **21**, 203–215.

Deeds, D.L. (2001). The role of R&D intensity, technical development and absorptive capacity in creating entrepreneurial wealth in high technology start-ups. *Journal of Engineering and Technology Management*, **18**, 29–47.

Denyer, D. and Neely, A. (2004). Introduction to special issue: innovation and productivity performance in the UK. *International Journal of Management Reviews*, **4/5**, 131–135.

Di Benedetto, C.A. (1996). Identifying the key success factors in new product launch. *Journal of Product Innovation Management*, **16**, 530–544.

Dodgson, M. and Hinze, S. (2000). Indicators used to measure the innovation process: defects and possible remedies. *Research Evaluation*, **8**, 101–114.

Dougherty, D. and Cohen, M. (1995). Product innovation in mature firms. In Bowman, E. and Kogut, B. (eds), *Redesigning the Firm*. New York: Oxford University Press.

Dougherty, D. and Hardy, C. (1996). Sustained product innovation in large, mature organizations: overcoming innovation-to-organization problems. *Academy of Management Journal*, **39**, 1120–1153.

DTI (1998). *An Audience With Innovation: Innovation in Management*. London: Department of Trade and Industry.

Dyer, B. and Song, X.M. (1998). Innovation strategy and sanctioned conflict: a new edge in innovation? *Journal of Product Innovation Management*, **15**, 505–519.

Ekvall, G. (1996). Organizational climate for creativity and innovation. *European Journal of Work and Organizational Psychology*, **5**, 105–123.

Ernst, H. (2002). Success factors of new product development: a review of the empirical literature. *International Journal of Management Reviews*, **4**, 1–40.

Farrukh, C., Phaal, R., Probert, D., Gregory, M. and Wright, J. (2000). Developing a process for the relative valuation of R&D programmes. *R&D Management*, **30**, 43–53.

Frenkel, A., Maital, S. and Grupp, H. (2000). Measuring dynamic technical change: a technometric approach. *International Journal of Technology Management*, **20**, 429–441.

Galunic, D.C. and Rodan, S. (1998). Resource recombinations and the firm: knowledge structures and

the potential for Schumpeterian innovation. *Strategic Management Journal*, **19**, 1193–1201.
Geisler, E. (1995). An integrated cost–performance model of research-and-development evaluation. *Omega – International Journal of Management Science*, **23**, 281–294.
Glaser, B.G. and Strauss, A.L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. London: Aldine.
Globe, S., Levy, G.W. and Schwartz, C.M. (1973). Key factors and events in the innovation process. *Research Management*, **16**, 8–15.
Goffin, K. and Pfeiffer, R. (1999). *Innovation Management in UK and German Manufacturing Companies*. London: Anglo-German Foundation for the Study of Industrial Society.
Grant, R.M. (1991). The resource-based theory of competitive advantage: implications for strategy formulation. *California Management Review*, **33**, 114–135.
Greve, H.R. (2003). A behavioral theory of R&D expenditures and innovations: evidence from shipbuilding. *Academy of Management Journal*, **46**, 685–702.
Griffin, A. (1997). PDMA research on new product development practices: updating trends and benchmarking best practices. *Journal of Product Innovation Management*, **14**, 429–458.
Griffin, A. and Page, A.L. (1993). An interim report on measuring product development success and failure. *Journal of Product Innovation Management*, **10**, 291–308.
Griliches, Z. (1990). Patent statistics as economic indicators: a survey. *Journal of Economic Literature*, **28**, 1661–1707.
Hall, D.L. and Nauda, A. (1990). An interactive approach for selecting IR&D projects. *IEEE Transactions on Engineering Management*, **37**, 126–133.
Hauser, J.R. and Zettelmeyer, F. (1997). Metrics to evaluate R,D&E. *Research-Technology Management*, **40**, 32–38.
Henriksen, A.D. and Traynor, A.J. (1999). A practical R&D project-selection scoring tool. *IEEE Transactions on Engineering Management*, **46**, 158–170.
Hipp, C. and Grupp, H. (2005). Innovation in the service sector: the demand for service specific-innovation measurement concepts and typologies. *Research Policy*, **34**, 517–535.
Holbek, J. (1988). The innovation design dilemma: some notes on its relevance and solutions. In Grønhaug, K. and Kaufmann, G. (eds), *Innovation: A Cross-Disciplinary Perspective*. Norwegian University Press, pp. 253–277.
Hope Hailey, V. (2001). Breaking the mould? Innovation as a strategy for corporate renewal. *International Journal of Human Resource Management*, **12**, 1126–1140.
Hull, R., Coombs, R. and Peltu, M. (2000). Knowledge management practices for innovation: an audit tool for improvement. *International Journal of Technology Management*, **20**, 633–656.
Hultink, E.J., Hart, S., Robben, H.S.J. and Griffin, A. (2000). Launch decisions and new product success: an empirical comparison of consumer and industrial products. *Journal of Product Innovation Management*, **17**, 5–23.
Jassawalla, A.R. and Sashittal, H.C. (1999). Building collaborative cross-functional new product teams. *Academy of Management Executive*. **13**, 50–63.
Jenkins, S., Forbes, S., Durrani, T.S. and Banerjee, S.K. (1997). Managing the product development process 1. An assessment. *International Journal of Technology Management*, **13**, 359–378.
Kaplan, R.S. and Norton, D.P. (1992). The balanced scorecard – measures that drive performance. *Harvard Business Review*, January–February, 71–79.
Keller, R.T. (1986). Predictors of performance of project groups in R&D organizations. *Academy of Management Journal*, **29**, 715–726.
Kelm, K.M., Narayanan, V.K. and Pinches, G.E. (1995). Shareholder value creation during research-and-development innovation and commercialization stages. *Academy of Management Journal*, **38**, 770–786.
Kerssens-van Drongelen, I.C. and Bilderbeek, J. (1999). R&D performance measurement: more than choosing a set of metrics. *R&D Management*, **29**, 35–46.
Kerssens-van Drongelen, I.C. and de Weerd-Nederhof, P.C. (1999). The use of performance measurement tools for balancing short- and long-term NPD performance. *International Journal of Innovation Management*, **3**, 397–426.
Kessler, E.H. and Chakrabarti, A.K. (1996). Innovation speed: a conceptual model of context, antecedents and outcomes. *Academy of Management Review*, **21**, 1143–1191.
Kim, B. and Oh, H. (2002). An effective R&D performance measurement system: survey of Korean R&D researchers. *Omega – International Journal of Management Science*, **30**, 19–31.
Kim, J. and Wilemon, D. (2002). Strategic issues in managing innovation's fuzzy front-end. *European Journal of Innovation Management*, **5**, 27–39.

Kimberly, J.R. (1981). Managerial innovation. In Nystrom, P.C. and Starbuck, W.H. (eds), *Handbook of Organizational Design*, Vol. 1. New York: Oxford University Press, pp. 84–104.

King, N. (1992). Modelling the innovation process: an empirical comparison of approaches. *Journal of Occupational and Organizational Psychology*, **65**, 89–100.

Kirton, M.J. (1976). Adaptors and innovators: a description and measure. *Journal of Applied Psychology*, **61**, 622–629.

Kivimäki, M., Kuk, G., Elovainio, M., Thomson, L., Kalliomäki-Levanto, T. and Heikkilä, A. (1997). The team climate inventory (TCI) – four or five factors? Testing the structure of TCI in samples of low and high complexity jobs. *Journal of Occupational and Organizational Psychology*, **70**, 375–389.

Kivimäki, M., Lansisalmi, H., Elovainio, M., Heikkila, A., Lindstrom, K., Harisalo, R., Sipila, K. and Puolimatka, L. (2000). Communication as a determinant of organizational innovation. *R&D Management*, **30**, 33–42.

Kleinknecht, A. (1987). Measuring R&D in small firms: how much are we missing? *Journal of Industrial Economics*, **36**, 253–256.

Koen, P., Ajamian, G., Burkart, R., Clamen, A., Davidson, J., D'Amore, R., Elkins, C., Herald, K., Incorvia, M., Johnson, A., Karol, R., Seibert, R., Slavejkov, A. and Wagner, K. (2001). Providing clarity and a common language to the 'fuzzy front end'. *Research-Technology Management*, **44**, 46–55.

Koput, K. (1997). A chaotic model of innovative search: some answers, many questions. *Organization Science*, **8**, 528–542.

Lawrence, P.R. and Lorsch, J.W. (1967). *Organization and Environment*. Harvard, MA: Harvard University Press.

Lee, M., Son, B. and Lee, H. (1996). Measuring R&D effectiveness in Korean companies. *Research-Technology Management*, **39**, 28–31.

Leonard, D. and Sensiper, S. (1998). The role of tacit knowledge in group innovation. *California Management Review*, **40**, 112–132.

Leseure, M., Birdi, K., Bauer, J., Denyer, D. and Neely, A. (2004). *Adoption of Promising Practice: A Systematic Review of the Literature*. London: Advanced Institute of Management Research.

Li, H.Y. and Atuahene-Gima, K. (2001). Product innovation strategy and the performance of new technology ventures in China. *Academy of Management Journal*, **44**, 1123–1134.

Liao, J., Welsch, H. and Stoica, M. (2003). Organizational absorptive capacity and responsiveness: an empirical investigation of growth-oriented SMEs. *Entrepreneurship Theory and Practice*, **28**, 63–86.

Linstone, H.A. and Turoff, M. (eds) (2002). *The Delphi Method: Techniques and Applications*, http://www.is.njit.edu/pubs/delphibook

Loch, C., Stein, L. and Terwiesch, C. (1996). Measuring development performance in the electronics industry. *Journal of Product Innovation Management*, **13**, 3–20.

Mathisen, G.E. and Einarsen, S. (2004). A review of instruments assessing creative and innovative environments within organizations. *Creativity Research Journal*, **16**, 119–140.

Maylor, H. (2001). Assessing the relationship between practice changes and process: improvement in new product development. *Omega – International Journal of Management Science*, **29**, 85–96.

McAdam, R.M.S. (1999). The process of knowledge management within organizations: a critical assessment of both theory and practice. *Knowledge and Process Management*, **6**, 101–113.

McManus, R.J., Wilson, S., Delaney, B.C., Fitzmaurice, D.A., Hyde, C.J., Tobias, R.S., Jowett, S. and Hobbs, F.D.R. (1998). Review of the usefulness of contacting other experts when conducting a literature search for systematic reviews. *British Medical Journal*, **317**, 1562–1563.

Miles, R.E. and Snow, C.C. (1978). *Organization Strategy, Structure and Process*. New York: McGraw-Hill.

Miller, D. and Friesen, P.H. (1982). Innovation in conservative and entrepreneurial firms: two models of strategic momentum. *Strategic Management Journal*, **3**, 1–24.

Mintzberg, H. (1978). Patterns in strategy formation. *Management Science*, **24**, 934–948.

Mitroff, I. (1987). *Business Not As Usual: Rethinking our Individual, Corporate and Industrial Strategies for Global Competition*. London: Jossey-Bass.

Moenaert, R.K., De Meyer, A., Souder, W.E. and Deschoolmeester, D. (1995). R&D/Marketing communication during the fuzzy front-end. *IEEE Transactions on Engineering Management*, **42**, 243–257.

Neely, A. and Hii, J. (1998). *Innovation and Business Performance: A Literature Review*, Report produced for Government Office for the Eastern Region. Cambridge: The Judge Institute of Management Studies, University of Cambridge.

Nelson, R. and Winter, G. (1982). *An Evolutionary Theory of Economic Change*. Cambridge, MA: Belknap Press.

Nohria, N. and Gulati, R. (1996). Is slack good or bad for innovation? *Academy of Management Journal*, **39**, 1245–1264.

Nonaka, I. (1991). The knowledge-creating company. *Harvard Business Review*, November–December, 96–104.

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

O'Brien, J.P. (2003). The capital structure implications of pursuing a strategy of innovation. *Strategic Management Journal*, **24**, 415–431.

O'Reilly, C.A. and Tushman, M.L. (1997). Using culture for strategic advantage: promoting innovation through social control. In Tushman, M.L. and Anderson, P. (eds), *Managing Strategic Innovation and Change: A Collection of Readings*. New York: Oxford University Press, pp. 200–216.

Oliver, N., Dewberry, E. and Dostaler, I. (1999). New product development performance and practice: an international benchmarking study in the consumer electronics industry. In *Proceedings, 6th International Product Development Management Conference*, Cambridge, UK. Brussels: European Institute for Advanced Studies in Management.

Pakes, A. and Griliches, Z. (1980). Patents and R&D at the firm level: a first report. *Economic Letters*, **5**, 377–381.

Parthasarthy, R. and Hammond, J. (2002). Product innovation input and outcome: moderating effects of the innovation process. *Journal of Engineering and Technology Management*, **19**, 75–91.

Patterson, F. (2003). Innovation potential indicator. Available at: www.opp.co.uk

Phelps, B. (2004). *Smart Business Metrics: Measure What Really Counts and Manage What Makes the Difference*. London: FT-Prentice Hall.

Pinto, J.K. and Prescott, J.E. (1988). Changes in critical success factors over the stages in the project life cycle. *Journal of Management*, **14**, 5–18.

Pitt, M. and Clarke, K. (1999). Competing on competence: a knowledge perspective on the management of strategic innovation. *Technology Analysis and Strategic Management*, **11**, 301–316.

Pittaway, L., Robertson, M., Munir, K., Denyer, D. and Neely, A. (2004). *Networking and Innovation in the UK: a Systematic Review of the Literature*. London: Advanced Institute of Management Research.

Porter, M.E. and Ketels, C.H.M. (2003). *UK Competitiveness: Moving to the Next Stage*. DTI Economics Paper No 3, URN 03/899.

Pugh, D.S., Hickson, D.J., Hinings, C.R. and Turner, C. (1969). The context of organization structures. *Administrative Science Quarterly*, **14**, 91–114.

Ramanujam, V. and Mensch, G.O. (1985). Improving the strategy–innovation link. *Journal of Product Innovation Management*, **2**, 213–223.

Richard, O., McMillan, A., Chadwick, K. and Dwyer, S. (2003). Employing an innovation strategy in racially diverse workforces – effects on firm performance. *Group & Organization Management*, **28**, 107–126.

Rickards, T. (1991). Innovation and creativity, trees and pathways. *R&D Management*, **21**, 97–108.

Rochford, L. (1991). Generating and screening new product ideas. *Industrial Marketing Management*, **20**, 287–296.

Rothwell, R. (1992). Successful industrial innovation: critical factors for the 1990s. *R&D Management*, **22**, 221–239.

Rothwell, R., Freeman, C., Horseley, A., Jervis, V.T.P., Robertson, A.B. and Townsend, J. (1974). SAPPHO updated – Project SAPPHO phase II. *Research Policy*, **3**, 258–291.

Saleh, S.D. and Wang, C.K. (1993). The management of innovation – strategy, structure, and organizational climate. *IEEE Transactions on Engineering Management*, **40**, 14–21.

Schmidt, R.L. and Freeland, J.R. (1992). Recent progress in modelling R&D project-selection processes. *IEEE Transactions on Engineering Management*, **39**, 189–201.

Schroeder, R.G., Van de Ven, A.H., Scudder, G.D. and Polley, D. (1989). The development of innovation ideas. In Van de Ven, A.H., Angle, H.L. and Poole, M. (eds), *Research on the Management of Innovation: The Minnesota Studies*. New York: Harper & Row, pp. 107–133.

Scott, S. and Bruce, R. (1994). Determinants of innovative behaviour: a path model of individual innovation. *Academy of Management Journal*, **37**, 580–607.

Shane, S., Venkataraman, S. and MacMillan, I. (1995). Cultural differences in innovation championing strategies. *Journal of Management*, **21**, 931–952.

Shepard, H.A. (1967). Innovation-resisting and innovation producing organizations *Journal of Business*, **40**, 470–477.

Shin, J. and McClomb, G.E. (1998). Top executive leadership and organizational innovation: an

empirical investigation of nonprofit human service organizations (HSOS). *Administration in Social Work*, **22**, 1–21.
Single, A.W. and Spurgeon, W.M. (1996). Creating and commercializing innovation inside a skunk works. *Research-Technology Management*, **39**, 38–41.
Song, X.M. and Parry, M.E. (1996). What separates Japanese new product winners from losers. *Journal of Product Innovation Management*, **13**, 422–439.
Souitaris, V. (2002). Firm-specific competencies determining technological innovation: a survey in Greece. *R&D Management*, **32**, 61–77.
Stock, G.N., Greis, N.P. and Fischer, W.A. (2001). Absorptive capacity and new product development. *Journal of High Technology Management Research*, **12**, 77–91.
Sundbo, J. (1997). Management of innovation in services. *Service Industries Journal*, **17**, 432–455.
Sveiby, K.E. (1997). *The New Organizational Wealth: Managing and Measuring Knowledge-Based Assets*. San Francisco, CA: Berrett-Koehler.
Szakonyi, R. (1994). Measuring R&D effectiveness I. *Research-Technology Management*, **37**, 27–32.
Thompson, L. (2003). Improving the creativity of organizational work groups. *Academy of Management Executive*, **17**, 96–109.
Tidd, J., Bessant, J. and Pavitt, K. (1997). *Managing Innovation: Integrating Technological, Market and Organizational Change*. Chichester, UK: John Wiley.
Tipping, J. and Zeffren, E. (1995). Assessing the value of your technology. *Research–Technology Management*, **38**, 22–40.
Trajtenberg, M. (1990). A penny for your quotes – patent citations and the value of innovations. *Rand Journal of Economics*, **21**, 172–187.
Tranfield, D., Denyer, D. and Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of a systematic review. *British Journal of Management*, **14**, 207–222.
Tsai, W. (2001). Knowledge transfer in intraorganizational networks: effects of network position and absorptive capacity on business unit innovation and performance. *Academy of Management Journal*, **44**, 996–1004.
Van Den Bulte, C. (2000). New product diffusion acceleration: measurement and analysis. *Marketing Science*, **19**, 366–380.
Verhaeghe, A. and Kfir, R. (2002). Managing innovation in a knowledge intensive technology organisation (KITO). *R&D Management*, **32**, 409–417.
Verworn, B. (2002). The fuzzy front end of product development: an exploratory study. In *Proceedings, 9th International Product Development Management Conference*, Sophia Antipolis, France, pp. 863–878. Brussels: European Institute for Advanced Studies in Management.
Veryzer, R.W. (1998). Discontinuous innovation and the new product development process. *Journal of Product Innovation Management*, **15**, 304–321.
Volberda, H.W. (1996). Towards the flexible form: how to remain vital in hypercompetitive environments. *Organizational Science*, **7**, 359–374.
Von Hippel, E. (1986). Lead users: a source of novel product concepts. *Management Science*, **32**, 791–805.
Von Zedtwitz, M. (2002). Organizational learning through post-project reviews in R&D. *R&D Management*, **32**, 255–268.
Voss, C., Chase, R. and Roth, A. (1999). International service study. *Decision Line*, May, 4–7.
Vyakarnam, S. and Adams, R.J. (2001). Institutional barriers to enterprise support: an empirical study. *Environment and Planning C: Government and Policy*, **19**, 335–353.
Werner, B.M. and Souder, W.E. (1997). Measuring R&D performance – state of the art. *Research-Technology Management*, **40**, 34–42.
West, M.A. (1990). The social psychology of innovation in groups. In West, M.A. and Farr, J.L. (eds), *Innovation and Creativity at Work: Psychological and Organizational Strategies*. Chichester, UK: John Wiley, pp. 309–333.
West, M.A. and Anderson, N.R. (1996). Innovation in top management teams *Journal of Applied Psychology*, **81**, 680–693.
White, A. (2002). Enabling factors in the front end of the innovation process. In *Proceedings, 9th International Product Development Management Conference* Sophia Antipolis, France. Brussels: European Institute for Advanced Studies in Management, pp. 879–887.
Wolfe, R.A. (1994). Organizational innovation: review, critique and suggested research directions. *Journal of Management Studies*, **31**, 405–431.
Yoon, E. and Lilien, G.L. (1985). A new product launch-time decision model. *Journal of Product Innovation Management*, **3**, 134–144.
Zahra, S.A. and George, G. (2002). Absorptive capacity: a review, reconceptualization, and

extension. *Academy of Management Review*, **27**, 185.
Zaltman, G., Duncan, R. and Holbek, J. (1973). *Innovations and Organizations*. New York: John Wiley.
Zien, K.A. and Buckler, S.A. (1997). From experience: dreams to market: crafting a culture of innovation. *Journal of Product Innovation Management*, **14**, 274–287.

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