ELSEVIER

Development of a Technical Innovation Audit

Vittorio Chiesa, Paul Coughlan, and Chris A. Voss

Measuring performance is helpful, but it's only part of the story. To learn from our past successes and failures, we need to understand how they came about. To continually improve, we must examine not only our innovation performance, but the processes with which we develop and exploit these innovations.

Vittorio Chiesa, Paul Coughlan, and Chris Voss present a framework for auditing technical innovation management. Their auditing methodology goes beyond performance measurement by highlighting problems and needs, and providing information that can be used in developing action plans for improving performance.

The foundation of their audit methodology is a process model of technical innovation. The model addresses the managerial processes and the organizational mechanisms through which innovation is performed. Underlying this method is the notion that success in innovation is related to good practice in the relevant management processes. The model identifies four core processes: concept generation, product development, process innovation, and technology acquisition. Supporting these core processes are three enabling processes: the deployment of human and financial resources, the effective use of appropriate systems and tools, and senior management leadership and direction. The outcome from these core and enabling processes is performance in terms of innovation and the resulting competitiveness in the marketplace.

This model provides the basis for a detailed audit of current innovation practice and performance. The audit has two dimensions: the process audit assesses whether the processes necessary for innovation are in place and the degree to which best practice is used; and the performance audit focuses on the outcomes of each core and enabling process and of the overall process of technological innovation and its effect on competitiveness. The performance audit helps identify needs and problems, but it doesn't explain why gaps exist between current and required performance and it doesn't provide an action plan for closing these gaps. The process audit meets these needs.

The audit methodology uses a two-level approach: a rapid assessment based on innovation scorecards and an in-depth audit. These scorecards provide an overview of the company's strengths and weaknesses with regard to technical innovation management, highlighting those areas that require in-depth examination. The in-depth audit identifies not only the processes, but the areas within each requiring attention.

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Introduction

Measurement of a firm's innovation performance has focused traditionally on macro-level indicators of input and output. Yet, increasingly in other areas, in particular quality management, it is being stated that indicators of input and output, whether macro- or micro-, indicate rather than explain performance. If we are to understand innovation performance more profoundly, we must look at innovation capability and the processes involved in developing and exploiting innovations. We feel that the widely applied and influential quality awards, such as the European Quality Award [27] and its U.S. equivalent, the Malcolm Baldrige National Quality Award [57], account for much of their support through their use as audits of the processes of quality rather than as the basis of awards. Auditing goes beyond measuring: it builds on this to identify gaps between current and desired performance, to identify where there are problems and needs, and to provide information that can be used in developing action plans to improve performance.

This article describes the development of an actionable instrument for auditing technical innovation management. The objectives of the development of an audit for technical innovation lay in the U.K. Department of Trade and Industry's (DTI) mission to improve the competitiveness of U.K. industry. It saw technical innovation as one of the drivers of national competitiveness and sought means of getting companies to develop and improve their innovation management processes and performance. One means of doing this was by developing an audit that could be used by companies for self- or third-party assessment, which could then act as trigger for improvement in practice by the company. The DTI contracted a team based at London Business School to develop and test such an audit. The goals were to develop an audit of technical innovation, drawing on published research and other sources of best practice; to test this in a representative sample of organizations; and after this to develop and disseminate the audit throughout the United Kingdom.

An audit of technical innovation capability has to address not only the process of formulation of innovation strategies, it should also address the firm's capabilities to implement such strategies and to adapt innovation practices in response to changing contexts. In this article, we propose a model for auditing a firm's innovation capability, based on a process model of technical innovation. This model has four core processes; the identification of new product concepts—concept generation; taking the innovation from concept to launch—product development; the development of innovation in production—process innovation; and the development and management of technology per se—technology acquisition. The model links the core to enabling processes and outcomes that together constitute the innovation process in the firm. It facilitates two ways of assessing an organization: a process audit and a performance audit. The process audit focuses on the individual processes necessary for innovation and the extent to which best practice is applied. The performance audit focuses on the effectiveness of the individual processes and of the overall process of innovation, in terms of their impact on competitiveness.

In this article we draw on existing research in innovation management to develop the content of the audit of technical innovation; we then describe the use of the audit in terms of process and performance auditing, the results of field testing and refinement, and present two case studies of its use. Finally we discuss the lessons learned and issues for the future of auditing technical innovation.

BIOGRAPHICAL SKETCHES

Vittorio Chiesa is Senior Researcher at the National Research Council of Italy and a lecturer in Business Organization and Economics at Politecnico di Milano. He obtained a Master's Degree in electronic engineering at Politecnico di Milano and has been Visiting Researcher at London Business School in the Centre for Operations Management. His main research interests concern R&D and technology management, internationalization of R&D, innovation management, and benchmarking. He is the author of several articles published in international journals.

Paul Coughlan is Lucas Professor in Manufacturing Systems and Management at the School of Business Studies, Trinity College, Dublin. He holds a Ph.D. from the University of Western Ontario and an M.B.A. and first degree in engineering from the National University of Ireland. His current research interests include the introduction and evaluation of multifunctional approaches to managing manufacturing and product development.

Chris Voss is BT Professor of Total Quality Management and Director of the Centre for Operations Management at London Business School. He previously worked at the University of Warwick and the University of Western Ontario, having gained his doctorate at London Business School. His current research focuses on operational practices and performance in manufacturing, service, and technology management. His work has appeared in the *Journal of Product Innovation Management, Research Policy,* and the *International Journal of Operations and Production Management.* He is currently chairman of the European Operations Management Association.

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Auditing—Background

Audits of management processes have been developed in many areas. We have already highlighted the use of quality award models for auditing in both Europe and the United States. For example, in describing the use of the European Quality Award framework, the European Foundation for Quality Management describes a self-assessment audit as:

> a comprehensive, systematic and regular review of an organization's activities and results referenced against a model of business excellence. [The] process allows the organization to discern clearly its strengths and areas in which improvements can be made and culminates in planned improvement actions which are monitored for progress. The process offers the organization the opportunity to learn [27].

A number of writers have addressed the challenge of evaluating a firm's technical innovation capability and performance. For example, Burgelman et al. developed an innovative capability framework to audit technological and functional capabilities, formulation and implementation of innovation strategies, together with supportive organizational mechanisms [12]. This framework includes five main dimensions:

- resource availability and allocation (as indicated by level of R&D funding, breadth and depth of skills, distinctive competencies, allocation of R&D resources);
- understanding competitors' innovative strategies and industry evolution;
- understanding the technological environment;
- structural and cultural context (as indicated by managing R&D projects, transferring them from R&D to manufacturing, integrating functional groups);
- strategic management capacity to deal with entrepreneurial behavior.

For Adler et al. [4], technical functions need a way to benchmark not only their products but also their strategic management process. They provide a framework for assessing the overall functional strategies of technical units. They set out three main elements of strategic management: direction setting, policies, and adjustment mechanisms. Within the policy element, they analyze the role of processes (such as personnel management, technical project management, quality assurance management), resources (intellectual property, funding, facilities, and equipment), and linkages (structure, interfunctional linkages, external linkages, regulatory compliance). They give a number of examples of successful innovative companies and associated with them the practices adopted.

This theme, relating success in innovation to good practice in the relevant management processes, has been supported by many writers. For example, this relationship has been found in many different specific aspects of the innovation process (the product development process [16]; R&D management and the technology acquisition process [70]; implementation in production innovations [80]).

Audits seem to have a number of characteristics. They embrace a model that sets out the scope of what is to be audited, they develop a set of detailed questions around this model that enable the auditor to determine whether good practice is in place, and they will have a process for its use. We decided to follow this pattern and proposed that to audit a firm's innovation capability we should develop a model that views innovation as a business process. This model was to address the managerial processes and organizational mechanisms through which innovation is performed.

Constructing the Audit Model

Before constructing the model, it was necessary to define the scope of innovation to be considered. This we took as industrial technological innovation, as defined by Freeman [31]. He sees this as a process that includes the technical, design, manufacturing, management, and commercial activities involved in the marketing of a new or improved product or the first use of a new or improved manufacturing process or equipment. Our next step in developing a model for an innovation audit was to identify the key processes of innovation. This task required a framework within which we could distinguish between different types of processes. We chose one based on conversion of inputs to outputs. In this framework, there are three categories: core processes, through which the firm converts its substantive product or process concepts into deliveries to external customers; enabling processes, through which the firm supports the core processes with the conversion of resources and strategic visions into guidance and a foundation for innovative activity; and the outcome is performance in terms of both innovation and the resulting competitiveness and performance in the marketplace. These processes cross functional, hierarchical, and organizational boundaries. To identify the core and enabling processes of innovation, Roberts' [65] definition of technological innovation provided a useful basis. He stated that the overall management of technological innovation includes the organization and direction of human and capital resources towards effectively: (1) creating new knowledge, (2) generating ideas aimed at new and enhanced products, manufacturing processes and services, (3) developing those ideas into working prototypes and (4) transferring them into manufacturing distribution and use. Based on this, our model comprises the following core and enabling processes:

Core Processes

- identification of new product concepts—concept generation
- taking the innovation from concept, through development and transfer to manufacturing and use—product development
- the development of innovations in manufacturing processes—process innovation
- the development and management of technology per se—technology acquisition

Audits such as the European Quality Award also stress the importance of those activities that support the core—the enabling processes.

Enabling Processes

- the deployment of human and financial resources—resources
- the effective use of appropriate systems and tools—systems and tools
- providing the top management leadership and direction—leadership

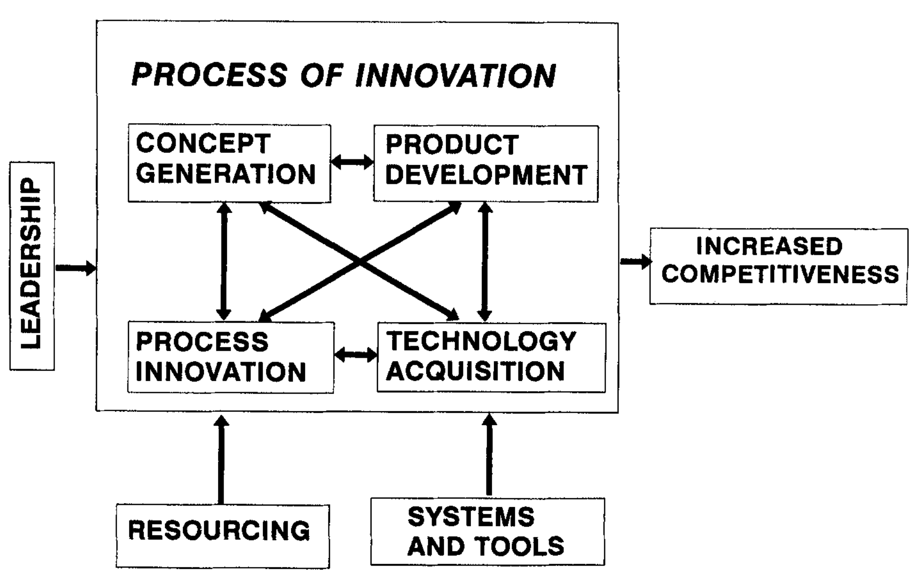
Finally, the process of technical innovation should result in improved innovation performance, which in turn leads to increased competitiveness. The above are combined in our overall model, which is outlined in Figure 1.

From Model to Detailed Audit

Having developed a model, we next needed to translate it into a detailed audit. A comprehensive approach to auditing a firm's technical innovation capability should encompass a means for:

- assessing the current innovation practice and performance;
- identifying the gaps between current and targeted practice and performance and the reasons for gaps;
- defining the action plans needed to close these gaps.

Figure 1. The process-based model of innovation.



As such, an audit can have two dimensions: a process audit and a performance audit.

> *Process audit*—a process audit focuses on such questions as whether the individual processes necessary for innovation are in place and the degree to which best practice is used and implemented effectively.
> *Performance audit*—a performance audit focuses on the outcomes of each individual core and enabling process and of the overall process of technological innovation and the impact of this on competitiveness. A performance audit produces quantitative results that facilitate comparison both between and within organizations and monitors trends. Its weakness, however, is that it is insufficient in itself to be a basis for learning and improvement. Although it indicates where needs and problems exist and the extent of the gap between current and required performance, a performance audit does not suggest why there are gaps or an action plan to cover gaps. For this we require the process audit.

Process Audit

In general, auditing implies assessment (either self or external) of the practices used through comparison with known best practice. The framework developed in the first part of this article provided the basis for doing this. We propose a two level approach: a rapid assessment approach based on innovation scorecards and an in-depth approach based on that applied in quality awards.

A process audit of a firm's innovation capability requires that practices adopted to manage the innovation process are reviewed to assess:

- the degree to which there are appropriate business processes in place;
- the deployment of good practice—the breadth of use in the company;
- the degree to which each practice meets known best in class or world class standards.

Having defined a model, the next step was to identify, from literature review, the subprocesses and factors that made up each of the processes. In some of these areas there was a strong research literature; in others there was little and we had to rely more on the assertions of experts and practitioners. For the core processes, this review and the development of the detailed underpinning of the audit are described in Appendix 1. In doing this we disaggregated each process into a number of elements or subprocesses. The full set of processes and subprocesses or elements, together with the key literature and implications for audit, is shown in Table 1. These formed the basis of both the innovation scorecards and the in-depth audit.

Innovation Scorecards

Innovation scorecards provide a rapid overall assessment of the practices adopted with respect to the known best practice and whether or not the required managerial processes are in place. The basis of the scorecard approach is a description, for each process of innovation, of the characteristics of good practice and poor practice. This description can be translated into scales against which companies can review themselves.

We carried out an extensive literature review to identify, for each process, the characteristics associated with success and failure in innovation. The number of different processes involved in technological innovation precludes discussing in this article the development of an audit scorecard for each core and enabling process. However, we can demonstrate this development through examining part of the audit—the generating new product concepts element of the concept generation process. In attempting to describe the characteristics of best practice, we examined writings in the area, which are summarized in Table 1. For example, Maidique and Zirger [52] and Rochford and Rudelius [68] stress the importance of systematically monitoring new product needs, Cooper [19] and Tushman and Moore [73] noted the importance of identifying customer needs and matching them with technological capabilities. Further, von Hippel proposed that direct links with customers and exploiting lead users as a source of innovative concepts [79]. Tushman and Moore noted the use of broadly based teams drawn from a variety of functions in developing new product concepts [73]. Finally, Clark and Fujimoto described the importance of early involvement of differing functions in the process [16]. We took these statements as indicators of the characteristics of good practice, and we constructed a hierarchy of good process characteristics for this element.

In order for companies to use these statements to assess their own processes, we ranked the characteristics on a 4-point scale: 1 being unsatisfactory, 4 being good. Table 2 shows such a hierarchy for the concept generation activity.

Table 1. Processes and Subprocesses of Innovation

Process Element	Source	Implications for Audit
Concept generation process:		
Generating new product concept	Maidique and Zirger [52]; Rochford and Rudelius [68]; Moenart and Souder [54]; Moenart et al. [54] Von Hippel [55]	• systematically monitoring market needs • putting up mechanisms for functional groups to meet the customer • use of feedback from functions that meet the customer • building long-term relationships with customers and especially lead users • cross-functional screening of new product concept ideas
	Cooper [18]; Tushman and Moore [73]; Johne and Snelson [74]	• matching technological capabilities to market needs
Product innovation planning	Utterback [77]; Crawford [22]	• linking the product innovation plan to the corporate plan • market led planning process • prioritizing product development projects
	Twiss [75]; Wheelwright and Clark [83]	• establishing procedures for selecting new or enhanced products
	Adler [3]	• integrating processes for generating new product concepts, planning product innovation, and realizing new products
Innovativeness and creativity	Twiss [75]; Felberg and DeMarco [28]	• eliciting and supporting new product ideas and initiatives from employees • rewarding entrepreneurial behavior • supporting unplanned product initiatives • circulating new product ideas
	Kaplan [45]; Twiss [75]	• structuring organization for favoring creativity and inventiveness
	Maidique [51]; Allen [5] Felberg and DeMarco [28]	• choosing the appropriate people for critical innovative roles
Exploiting innovation	Maidique [51]; Burgleman [11]; Roberts and Berry [67]	• evaluating alternatives for developing new business opportunities
	Roberts [66]	• selecting venture alternatives for entering a new business
	Burgleman et al. [12]	• assessing the relatedness of enterpreneurial initiatives to core competencies • using governmental funding mechanisms
Product development process:		
Product development process	Cooper [19, 20]	• managing product development projects from the concept to launch, establishing the scope of the process, phases, gates, reviews, sign-off procedures
Teamwork	Cooper [19]; Clark and Fujimoto [16]; Thamhain [72]	• integrating all relevant functions in the product development process
	Clark and Fujimoto [16]; Pinto and Pinto [61]	• early involvement of the key internal functions and external organizations
	Clark and Fujimoto [16]	• facilitating communication among the different groups involved in the development process • degree of parallelism, integration of steps and task interdependence built into the process • establishing role and priority of project progress reviews
Transfer to manufacturing and distribution	Wheelwright and Clark [83]	• linking manufacturing and engineering • handling engineering changes
	Hayes and Clark [38]; Coughlan [21]	• rapid feedback from manufacturing to design and engineering
Teamwork and organization	Hise et al. [42]	• Use of cross-functional teams • Defining the states of project managers in the organization
	Ciccantelli and Magidson [15]	• Use of organizational integration mechanisms at the initial stages
Industrial design	Dumas and Minzberg [26]	• Incorporation of industrial design into product development • Use of inside or outside design consultancy teams
	Bailetti and Litva [7]	• Creating mechanisms for customer requirement information to be integrated into product design

Table 1. Continued

Process Element	Source	Implications for Audit
Production process innovation process:		
Formulating a manufacturing strategy	Hill [41]	• evaluating the capabilities of existing production processes • establishing a formal procedure for generating a manufacturing strategy
	Hayes and Wheelwright [39]	• matching process capabilities to the requirements of the marketplace • linking process innovation to product innovation • allocating resources for developing new process technologies • monitoring sources of process innovations
Implementation of new processes	Voss [81]; Leonard-Barton [47]; Gerwin [32]	• matching technology complexity to the capability to adopt
	Voss [81]; Adler [2]; Tyre [76]	• managing the links with suppliers in the development and implementation
	Voss [81]; Adler [2]; Tyre [76]; Drazin and Kazanjian [25]	• accompanying production process innovations with the appropriate changes to the organization • modifying performance measures to reflect the capabilities of new processes
Continuous improvement	Hayes and Clarke [38]; Bessant [8]	• identifying opportunities for improvement in processes
	Deming [23]	• integrating process improvement with quality control
	Camp [14]	• benchmarking production process performance
	Wood and Elgie [85]	• involving manufacturing process developers in improvement after installation
Technology acquisition process:		
Formulating technology strategy	Little [50], Mitchell [53]; Hax and Majluf [37]	• systematically monitoring trends in existing and future technologies
	Little [37]; Burgleman et al. [12]; Roussel et al. [70]; Foster [1986]; Papas [59]; Prahalad and Hamel [62]	• assessing competitors' technological capabilities • identifying emerging technologies • understanding core technologies and competencies of the firm
	Hax and Majluf [37]; Prahalad and Hamel [62]	• building the required core competencies based on the technological capabilities
	Mitchell [53]; Roussel et al. [70]	• relating technology to business objectives and strategies
Selection, generation, and sourcing of technology	Little [50]; Twiss [75]	• choosing sources of technologies (in-house), R&D, licensing, partnering, external alliances) • use of both quantitative and qualitative methods to evaluate R&D projects
	Roussel et al. [70]	• corporate procedure for selecting R&D projects • choosing a portfolio balancing risk and reward, project timescales • Identifying key issues in R&D organization supporting the firm's technology policy • favoring communication, creating structural interfaces of R&D with other functions, optimizing resources corporate wide
Management of intellectual property	Twiss [75]; Roberts and Berry [67]	• protecting intellectual property rights (patenting, trade secrets) • exploiting intellectual property (licensing out)
Leadership process:		
Human resources	Adler et al. [3]	• defining the firm mission in technology and innovation
	Burgleman et al. [12]; Quinn [63]	• building innovation strategies into corporate strategies and plans
	Prahalad and Hamel [62]	• identifying the core distinctive competencies • including representatives of innovation and technical functions on the board

Table 1. Continued

Process Element	Source	Implications for Audit
Process for innovation	Quinn [63]	• evaluating processes for generating and implementing innovations
	Camp [14]	• benchmarking processes for innovation against best practices
	Van de Ven [78]; Burger [13]	• making innovation processes visible to top management
Climate for innovation	Tushman and Nadler [74]	• encouraging new idea development, risk taking, and entrepreneurship
	Nadler and Tushman [56]; Tushman and Nadler [74]; Van de Ven [78]	• making innovation policies shared and understood in the organization • defining performance measurement system encouraging innovation
Resource provision process:		
Goals for innovation	Adler et al. [3]; Allen [5]; Tushman and Nadler [74]; Adler et al. [4]	• identifying the key roles needed for managing the innovation process • recruiting, developing, evaluating, and rewarding human resources • establishing career development paths for technical people (dual ladder, international development, cross-functional developments)
Funding	Twiss [75]; Wheelwright and Clark [83]	• stability of funding of R&D activities and technology acquisition • flexibility of funding of product and process development
	Prahalad and Hamel [62]	• sharing risks and reducing costs of innovation through alliance networks
Systems and tools provision process:		
Systems	Orlando [58]	• information and product system used to support the processes for product development • information systems enhancing communication in the innovation process
Tools	Adler [3]; Rosenthal et al. [69]	• use of tools for capturing customer needs • use of tools for design of new products
	Rickards [64]	• use of tools for promoting creativity
Quality assurance	Clausing [17]; Hauser [35]	• managing quality in the design process • use of methods to analyze and improve the quality of innovation processes • integrating process improvement and product innovation with quality management

We repeated this for each one of the detailed elements of the audit framework. From this, we constructed individual hierarchies for each element. In the final audit document, these were edited to produce a set of scorecards. The full set of scorecards is shown in Appendix 2.

In the terms commonly used by companies in benchmarking, the difference between the actual and ideal score is the gap between current and good practice. This gap is represented diagrammatically in Figure 2. As with the Baldrige Award [57], an organization can be rated on both use and deployment—the breadth of use of a process in the company. The resulting profile can reflect that a company may have islands of good practice and process that, unless fully deployed across the company, may not be fully effective.

The scorecard approach can provide companies with an overview of their strengths and weaknesses with regards to technical innovation management. It can enable them to highlight the areas that they should examine in more depth.

In-Depth Audit

To enable organizations to assess in more detail their management of innovation, we developed an in-depth

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Table 2. Example of Hierarchy for Innovation Scorecard Concept Development

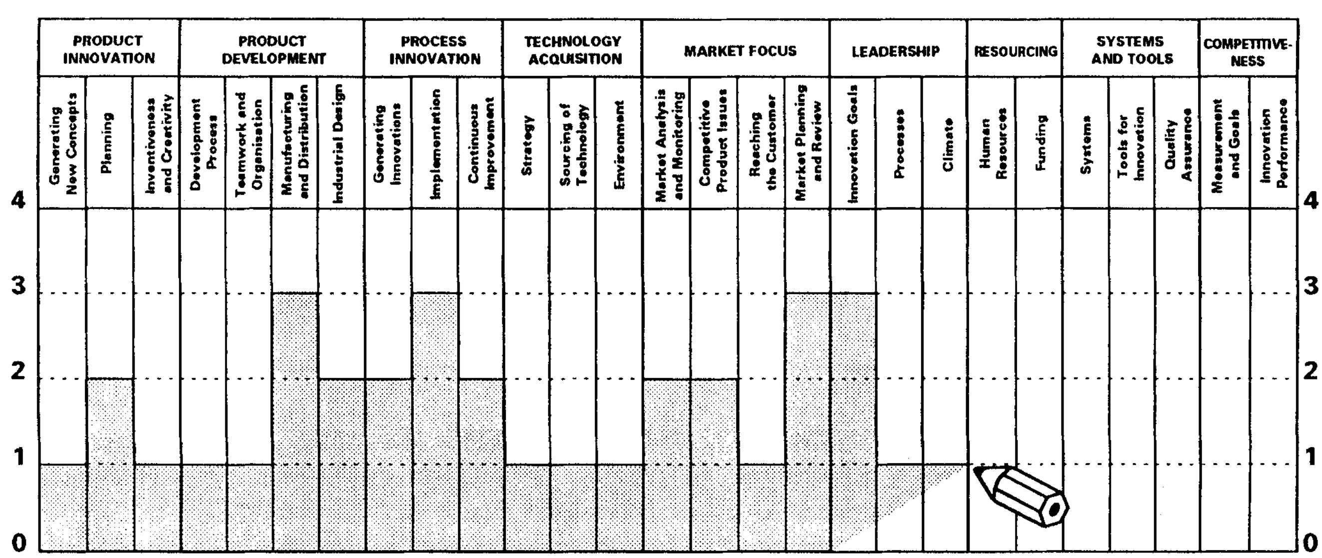
	1	2	3	4
Generating new product concepts	• Ad hoc development of new product concepts.	• Product concepts developed within single functions. Ideas internally based. • Limited customer contact.	• New product ideas sought in the marketplace and research into customer needs. • Involvement of marketing and technical functions in developing and screening new product concepts.	• Direct links with customers and lead users to identify expressed and latent needs. • Broad range of functions involved in concept development and screening of opportunities. • Early analysis of new concepts.
Product innovation planning	• No product planning.	• Planning for next generation of products.	• Planning for up to two generations of products.	• Longterm planning for three + generations of products, 5–15 years horizon. • Market-driven innovation planning.

audit to identify not just the processes, but also the areas within each where attention should be focused. To facilitate an in-depth audit, we drew on the literature review outlined in Table 1. For each process, we then specified at an extra level of detail, the areas where attention should be focused in auditing each innovation process. To illustrate this, in Appendix 3 we give an example of the areas specified in the product development process. The resulting in-depth process audit can provide information on strengths and deficiencies in current practices, indicate where good processes might be found, and provide a rich set of data for learning and managerial action for improvement.

Performance Audit

As in the process audit, a firm's innovation performance can be measured in two ways:

Figure 2. Diagram of gaps between current and best practice [82].



the performance of each core and enabling process that is relevant for the firm;

the global result of the innovation process, that is how it impacts on the competitive capability of the firm.

Measuring the Performance of the Innovation Process

Concept development. Measurement of performance in this area focuses on efficiency of the innovation process [16], that is the number of innovations developed. Related measures include: the number of innovations (that can be split into product enhancements and new products); the number of new product ideas generated, evaluated, and developed; number of new product-based ventures or business areas started; the average product life cycle length; and the product planning horizon (years, number of product generations). Measurement of concept development also addresses the effectiveness of the process in terms of customer satisfaction. Related measures include: number of designs meeting customer needs and the degree of product variety and product range. Other measures of product innovation effectiveness, such as quality of an innovation and functional performance, were included under product development.

Product development. Product development performance can be measured on three dimensions: speed, product performance, and engineering/design performance [16,81]. The concept of time-based competition [71] links speed to competitive advantage. Measures of speed include time to market (from concept to launch) and time taken for the various stages (concept, design, initial production, launch). As innovations sometimes occur on the basis of customer stimuli, speed is reflected also in the response time to a customer request. Griffin [33] suggested three time variables for measuring cycle times in new product development: development time, concept to cycle time, and total (cycle) time.

Product performance can be measured on three main dimensions: cost, including unit cost, production cost and development cost broken down by stage; technical performance, including how well the product functions); and product quality.

Engineering/design performance can be measured by the manufacturability, testability, and industrial design of a product. Measures of manufacturability and testability include the number of the required redesigns and the manufacturing cost, and these measures are objective. In contrast, industrial design performance includes ergonomic and aesthetic aspects and is both highly subjective and difficult to measure.

Production process innovation. Production process innovation performance can be measured in terms of its effectiveness, development speed, and cost [80]. Measures of effectiveness include the numbers of new production processes and significant process enhancements per year. Process innovations often result from continuous improvement activities [8] reflected in such measures as: the number of suggestions per employee, the percentage of them that have been implemented, and the average annual improvement in the process parameters (quality, cost, lead time, work in progress, reliability, down time, capability).

Technology acquisition. Performance of the technology acquisition process can be measured in terms of efficiency and effectiveness [29,30,75]. A measure of efficiency is the R&D productivity, that is the ratio of technical performance to the R&D effort. A second efficiency measure is the R&D/technology acquisition cost per new product. Effectiveness can be measured by the ratio of profits to technical progress or technical performance improvement. Other measures of effectiveness include: the percentage of R&D projects that led to successful new or enhanced products, licenses or patents; and the number of licenses in/out and patents in a certain time span.

Leadership. The performance of leadership related to innovation should reflect top management involvement in ensuring that the innovation process is effective. However, by its nature leadership impacts on the whole process of innovation, and thus finding measures of its effectiveness that are not too broad is difficult. Surrogate measures can be used such as board membership of technical/product development people; the degree of awareness, at each level of employee, of the company innovation policies; and the number of pages in the annual report devoted to innovation/technology.

Resourcing. Performance of the resourcing process reflects the appropriateness of the resources devoted to the innovation efforts. Measures include the percentage of activities that have been delayed or canceled due to lack of funding or human resources and the number of people at the various levels of the organization playing key roles in innovation such as sponsors, champions, and gatekeepers.

Systems and tools. Systems and tools used are likely to be specific to the company's nature and environment. For example, engineering companies might use computer-aided design (CAD) in product design, whereas process industries might use simulation tools in process design. Performance measures thus should be related to the appropriateness of systems and tools and systems used in the organization, and the depth and breadth of use of tools. Measures include the percentage of products developed using CAD and the percentage of engineers trained in simulation techniques.

Our approach to measuring performance of the innovation process is summarized in Table 3, listing a set of metrics and indicators of performance in each core and enabling process.

In using these measures, as well as measuring performance at a single point in time, we may wish to measure how performance evolved, through comparisons between past and present performance and identification of trends. We may also wish to compare performance against the goals set for innovation by companies and against the competition, in order to find whether there are gaps between the current and the required performance. These comparisons can be used as the basis for setting performance targets for the future.

Measuring the Impact of Innovation on Competitive Performance

Ultimately for innovation performance to be beneficial to the firm, it has to lead to increased competitiveness. ''New product introductions provide the potential for innovating firms to gain a preferred market position in

Table 3. Performance Measures

Concept generation
- Number of new product ideas, product enhancement ideas evaluated in the last year
- Number of new product–based business area/ventures started in the past 5 years
- Customer satisfaction (design meeting customer needs; product range and variety)
- Product planning horizon (years, product generations)
- Average product life cycle length

Product development
- Time to market:
  - average concept-to-launch time
  - time for each phase (concept, design, initial production, launch)
  - average overrun
  - average time of product enhancement
  - average time of redesign
- Product performance:
  - cost (unit cost, production cost, development cost)
  - technical performance (e.g., case of use, operating cost, serviceability)
  - quality
- Design performance:
  - manufacturing cost
  - manufacturability
  - testability
  - number of product redesigns

Process innovation
- Effectiveness:
  - number of new processes and significant enhancements per year
- Speed
  - installation lead times (start to trouble-free working)
- Development cost
- Continuous improvement:
  - number of improvement suggestions per employee
  - percentage implemented
  - average annual improvement in process parameters (quality cost, lead time, work in progress, reliability, down time, capability)

Technology acquisition
- R&D/technology acquisition cost per new product
- R&D projects that lead to new or enhanced products, process innovations, licenses, patients (% number of projects, % R&D expenditure)
- number of licenses in/out over the last 3 years
- number of patients over the last 3 years
- cost/benefit performance of completed R&D projects

Leadership
- number/percentage of members from technical functions/product development in the main and subsidiary/divisional boards
- percentage of employees aware of, sharing the innovation policies and values
- number of pages in the annual report devoted to innovation and technology

Resourcing
- personnel in product development and technical functions who have worked in more than one function
- percentage of projects delayed, canceled due to lack of funding
- percentage of projects delayed, canceled due to lack of human resources

Systems and tools
- percentage of designers/engineers with access to CAD screens
- percentage of products on CAD database
- percentage of projects on which specific tools are applied (FMEA, QFD, Rapid prototyping, Taguchi methods)
- percentage of designers/engineers trained to design for manufacture
- percentage of team leaders trained in creativity techniques
- certified processes

relation to rivals and realize more durable returns than would otherwise be possible'' [46]. Measures of how an individual innovation (new or enhanced product or process) contributes to enhancing the firm's competitiveness can be based on whether the innovation has had market impact or been financially successful. The market impact of individual innovations can be used as indicators of the competitive impact of the overall innovation process.

The impact of an innovation on competitiveness can be measured by sales and profits generated from that innovation and by the market share gained. These measures can be compared against both competitors and expected results. The impact on the profitability and sales of the product portfolio can be measured by comparing sales and profits of the portfolio before and after the innovation has been completed. Finally, performance measures should reflect the degree to which an innovation enhances a firm's capability to produce innovations. Proxy measures could include sales, market shares, and profits of a series of innovations linked to one another (among which the innovation considered).

However, there are some limitations to measurement at the level of the individual innovation. For example, it does not take into account factors such as the influence of one innovation on financial results of other products belonging to the same category [10] or whether and how the innovation changes a firm's resource base or influences the capability for further innovations.

As such, measures of impact on competitiveness should address three main areas:

- the performance of the innovation in financial terms;
- the impact of the innovation on the competitive performance of the product portfolio to which the innovation belongs;
- the contribution to the firm's process of learning.

The first two areas are concerned with the analysis of the impact of an innovation on competitiveness at a given point. The second area takes into account that an innovation can be successful considered by itself but may have a negative impact on the financial performance of other products in the portfolio.

The third area views each as an element within a series of innovations of which results should be measured globally and not just individually. (Even an unsuccessful innovation may have benefits that can be exploited afterward in other innovation projects in the same product range). These measures concern the impact of an individual innovation on a firm's competitiveness. In addition, measures of the impact of the innovation process on competitiveness over time are needed. Such measures can include percentages of sales and profits from new or enhanced products introduced in the time span considered and total market share. Table 4 summarizes a sample set of metrics that can be used to measure the impact of innovation on competitiveness.

Testing and Using the Audit Tool

The testing and issuing of an audit can go through a number of phases. The first is field testing, resulting in modifications and improvement; the second is implementation in the field; the third is testing in the longer term when firms have used it, have taken actions as a result, and these actions have been evaluated as to their long-term effectiveness. For this innovation audit, the first two phases have taken place; the long-term effectiveness will only be evaluated after some years of use.

Table 4. Performance Measures Competitiveness

Type of Impact on Competitiveness	Metrics
Impact on firm's competitiveness of an individual innovation (to be compared against competitor's and/or expected results)	Sales: domestic market regional market global market Market share: domestic market regional market global market Profits
Impact on firm's product portfolio of an individual innovation	Sales of the portofolio before and after innovation Profits of the portfolio before and after innovation
Impact on firm's competitiveness of a series of innovations	Sales, market share, and profits of a series of innovations to which the innovation belongs
Impact of the innovation process on competitiveness over time	% Sales/Profits from products introduced in the last 3/5 years % Sales/Profits from products with significant enhancements in the last 3/5 years

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Frequently, academic research provides the foundation for tools for practitioners to use in diagnosing and improving business practice. Such tools are often derived from research that has been through a thorough academic testing process where attention has been paid to issues of validity [17]. However, we propose that to be of value to practitioners they must also pass tests of both usefulness and usability, sometimes known in industry as beta testing.

Beta Testing

Dolan and Matthews [24], in a thorough review of beta test design and management, state that it has a curious status in new product development. They define it as "one of a variety of procedures by which potential users 'try out' a product." beta testing refers to testing with a small number of potential adopters, not randomly chosen, where complexity, cost, and time pressures mean that large sample, statistically significant testing cannot be used. It is widely used and its utility has been established, yet it is often informal.

Dolan and Matthews see beta testing as including the following steps: pre-Beta activity leading to a frozen design and purpose, site recruitment, and data collection. The core purpose of beta testing is the testing of the system, product, or service. All 21 programs studied by Dolan and Matthews did this.

The process of testing starts with the recruitment of users. Typically, the sample starts at about five test sites and may be expanded to more. The next step is data collection from the site and the feedback of this data to the testing firm. This will typically involve a full functionality test in a variety of application environments and debugging and appropriate redesign of the product or service. The output will be a validated core product/service and support material. Other outputs will depend on the objectives but will include testimonials, ideas for the next generation of products, and success stories/reference sites for use in marketing.

They suggest a number of conditions under which beta testing might be appropriate. The audit tool closely met four of these:[1]

- *Users are heterogeneous.* An important objective for the DTI in using such a framework was that it had to be generic. That is to say it should be usable by a wide range of companies in the United Kingdom, and it should cover the full set of processes involved in managing technical innovation.
- *Potential applications are not fully understood.* There was no tradition in the United Kingdom of such audit tools, and companies were not experienced in self-assessment.
- *Alpha testing is unable to guarantee a bug-free product.* There are limited opportunities for alpha testing the tools before testing in the field. Tests with academic colleagues and students cannot properly replicate industry use.
- *Limits the potential sample size due to complexity.* Whereas a questionnaire can be tested easily by mailing to an initial set of users, testing an audit tool requires recruiting collaborating companies and working with them on a case basis. This limits the ability to work with a large sample size.

All four factors pointed toward beta testing as an appropriate process in this case. In describing the beta testing of the audit tool, we will follow the structure suggested by Dolan and Matthews [24]: objectives, site recruitment, test design, test implementation (data collection), and outcome.

Objectives

In translating academic work into a tool for managers, we identified three requirements that we had to test in the field: functionality, usability, and usefulness.

- *Functionality.* A primary objective of field testing was to test both the basic functionality of the tool and the functionality of the support process. The second objective was to test the degree to which the tool was generic: that it was appropriate for companies from different sectors, different sizes, and with different technologies.
- *Usability.* The tool was designed for stand-alone use by practitioners. This placed a high premium on testing for usability. Usability includes a number of areas. One is the degree to which users are able to use the tool properly without support from

[1] The other conditions put forward by Dolan and Matthews were that the decision-making unit for purchase is complex and the opinion leader phenomenon is operative. Neither of these applied to the audit tool.

academics or consultants. Another is the clarity of language. Academics are not renowned for their ability to write in plain English. Overuse of academic terminology might result in difficulty in using the tool.

- *Usefulness.* Any tool is only worth using if it provides value to the user. In the short-term, usefulness could be seen in terms of companies' perceptions of whether they found it of use and whether it led to effective action plans to improve innovation management in their organizations. In the longer tem, this can be evaluated through measuring the effectiveness of the programs that resulted from the assessment.

Sample Recruitment

As the audit tool was to be made available to all U.K. manufacturing companies, it was important that testing was done on a sample that reflected the heterogeneity of industry. Pavitt argues that factors such as the development trajectory and the source of ideas are contingent on the type of business [60]. He stated that businesses can be classified into four areas: science based, scale intensive, information intensive, and specialized suppliers. Selection of companies from each area would provide a breadth of testing and in particular help validate the generic nature of the audit. In addition, the DTI was concerned that the tool should not be applicable solely to large and sophisticated companies. It was therefore felt important to involve firms of different sizes. Sample firms were recruited through the U.K. Confederation of British Industry. An initial group of 10 firms was invited to take part in testing the audit tool. Four firms declined or were unable to participate leaving a sample of six. This is similar in size to that of the typical reported beta test group [24]. The characteristics of the firms are shown in Table 5. Firms A–F were used for beta testing. They represent a full range of size and production processes and cover all four of the categories suggested by Pavitt [60]. After the launch of the tool in the United Kingdom, its use was audited in two further firms, G & H.

Test Design and Implementation

Testing was designed to take place in three phases. The first two involved individual meetings with the companies and analysis by the companies. The final phase involved a benchmarking meeting of participating companies.

Phase one was designed to test user understanding of the tool and its terminology. As expected, there were many areas where companies did not understand the language or the concepts. In general, they found the initial version of the framework too complex. Unless it could be understood, then it was not likely to be used properly. Language problems included both use of academic phraseology and use of U.S. terminology that had not yet crossed the Atlantic. An example of the latter was the phrase ''product realization process''; none of our sample knew what this meant. These comments were reviewed, and a considerably revised framework and tool were produced. In addition, we reviewed the functionality of the framework and the tool. Companies commented on areas that they thought were missing. This highlighted the area of metrics, and additional attention was paid to determining jointly what metrics might be usable and incorporating them into the framework.

Table 5. Firms Testing the Audit Tool

Firm	Industry	Processes	Size[a]	Type[b]
A	Petrochemicals	High volume process	Very large	Scale based
B	Electrical fittings	High volume line	Medium	Specialized supplier
C	Systems integration	Low volume batch	Medium	Information based
D	Fibers and chemicals	High and med volume process	Large	Science based
E	Adhesives	Medium volume batch	Medium	Specialized supplier
F	Specialty paper	Medium volume process	Small	Scale intensive
G	Ink jet printers	Low and medium volume batch	Small	Specialized supplier
H	Chemicals (multibusiness company)[c]	High and medium volume process and batch	Large	Scale based and science based

[a] Small, <200 employees; medium, 200–499 employees; large, 500–5000 employees; very large, >5000 employees.
[b] Based on Pavitt [60].
[c] Company H implemented the audit tool in all of its businesses, which included a wide range from high to low volume, from scale-intensive bulk chemicals to science-based specialty chemicals.

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In phase two, the companies were asked to use the audit tool unaided by the development team. Two versions of the tool, one simple and the other more thorough, were tested in different companies. This test indicated that (as might have been expected) the simpler version was much easier to use.

As it was envisaged that the tool would be used not just for internal self-assessment but as a framework to guide benchmarking, in the final stage of the testing, we tried to emulate the latter. This was done in the format of a benchmarking club. Although benchmarking is normally done against best in class, in countries smaller than the United States, this may limit its use as there may not be a world class company to benchmark against. In addition, something useful can be learnt through benchmarking against most companies, even if they are not world class. As a result, benchmarking clubs are widely used in the United Kingdom. They are groups of companies seeking to benchmark an individual of set of processes and are formed through a variety of mechanisms, including industry associations, sponsorship by the U.K. DTI, and facilitation by universities or consultants. In our club, the group of companies, having conducted self-assessment, met to share knowledge of their own performance and processes in a series of meetings. In addition, we used these meetings to gain feedback on the audit tool and its use for benchmarking. This proved successful, with each company having used the benchmarking framework to analyze their own processes and being able to contribute to the exchange and to learn from the others.

During this stage, we debriefed the companies to determine how well the tool met its functional goals and also met our goals of usability. In addition, we sought feedback on the processes used, difficulties encountered, and the organization for self-assessment and benchmarking. The feedback from each of these is described next.

Test Outcome

Functionality—Generic Application of the Audit Tool

Of particular concern was whether the tool was generic, i.e., the degree to which a single set of tools and frameworks could be used by a wide range of companies. The feedback from companies indicated all felt that they could use the tools equally well. That is, in the areas that they wished to evaluate themselves, they felt that the tool provided a proper evaluation of their processes. Feedback came in two specific areas. First, companies focused on particular rather than all areas in their use of the tool. Second, all found difficulty in collecting data for the metrics.

The focus of innovation will differ between firms and can change over time. For example, Abernathy and Utterback [1] stated that the relative focus of innovation will depend on the firm's position in the product life cycle. During earlier stages, the focus is on product innovation; as the cycle develops, process innovation plays an increasingly important role. As noted earlier, Pavitt [60] has proposed four distinct groupings of companies each having different technological trajectories and focuses for innovation. We reviewed the pattern of use made by companies, categorized into Pavitt's four types of firm (see Table 6). We found that the focus differed depending the nature of the company. In science-intensive companies, the focus was as expected to be on technology acquisition; in scale-intensive companies, on process innovation; in information-intensive companies, on product innovation and development; and in specialized suppliers, on product innovation and development. There was surprisingly little difference based on company size: small companies were as concerned with technology management and innovation and were as capable of using the audit tool as large companies. Company F had better systems in place for process innovation than many larger companies, and company G, which we review later, was as sophisticated in its technology acquisition as companies 100 times its size, with a complex network of technology linkages.

These observations were consistent with the indi-

Table 6. Use of the Tool by Firm Type

Company	Type	Focus
A	Scale intensive	Technology acquisition, process innovation
F	Scale intensive	Process innovation, technology, acquisition, product innovation
C	Information intensive	Product development, technology acquisition
B	Specialized supplier	Product innovation and development
E	Specialized supplier	All
G	Specialized supplier	Technology acquisition, product innovation, and development
D	Science based	Technology acquisition, product development

vidual discussions with the firms which indicated that the tool was equally usable by a wide range of users but that their use would focus on those areas appropriate for the technology and management concerns. Our conclusion was that the audit tool was generic and robust, but as firms would have different foci, the supporting documentation should indicate that companies may wish to focus on particular areas of concern or relevance to themselves.

Metrics created much debate. The underlying philosophy of the tool was that it should be used to audit the processes of innovation and suggest metrics that companies should use in reviewing and comparing the performance of individual processes. At the outset of the testing, most companies had no metrics associated with any of the processes. Some measures suggested in the literature, such as patents, were not seen by the companies as valid measures of performance. As a result, all companies in the testing found difficulty in developing and collecting data for the metrics during the test program. It was generally agreed that the easiest areas in which to collect data were measures of product innovation such as percent of sales from products that have been introduced in the last 3 years. This difficulty was not always seen as negative. Company A stated that one of the biggest benefits to them of using the audit tool was that it provided a framework for them to think about and to define the metrics that were needed in the future. One of their actions following the beta testing period was development of routine data collection for a number of key metrics.

Usability

We were particularly interested in the usability of the tool and questions such as what resources were needed, how long it took, and how best companies should organize for use of the audit. We found a wide variety of answers to these questions, together with a number of underlying patterns of use that were found to be particularly successful.

Organization. Half of the audits were conducted by an individual, in one case the managing director. The other companies conducted the audit with a team. The feedback on team use was very positive. A team drawn from different functions was able to give a far more objective view of the process as it brought together strengths of different perspectives and viewed processes not just from within a function but also from outside. Senior management in larger firms was too far from processes to be the best auditors. Leaders of audit teams were drawn from a wide range of functions, including R&D, marketing, and product development. When a cross-functional team was used for the audit, the functional origin of the team leader was not seen to be important.

Time to perform the audit. The audit tool contained two parts, a scorecard for the initial assessment and a detailed audit for in-depth assessment. The initial audit using the scorecard approach could be done over 2 to 8 weeks, depending on the size and complexity of the company. The typical time involved ranged from 4 to 20 days. The time for detailed audit varied greatly, as companies could choose to do a detailed audit on a narrow or a wide range of areas. In general, the time required was two or three times that for the initial audit.

Our conclusion based on the feedback from the beta testing was that auditing where possible should be performed by a team, which should bring a broad set of perspectives. The audit leaders' function is less important than their ability to manage a team and their credibility with both the team and senior management.

Usefulness

Our final objective was to test the usefulness of the tool. At a company level, an indicator of usefulness is whether it led to effective action plans to improve innovation management in the organization. It could also be viewed in terms of subjective assessment of its use to companies. For the DTI, usefulness ultimately will be tested in the longer term, through performance of U.K. industry, in the short-term by the degree of adoption of the tool by companies.

As the effectiveness of the tool will only affect performance over the long-term, testing usefulness is by its nature difficult and qualitative in the short-term. We have therefore reported on the initial views of the participating companies. At the end of the final workshop, questions concerning success were asked of each of the participating organizations. The responses were very positive. All companies stated that they found the tools and frameworks challenging and useful. The chief executive of one stated this effect to a public to a meeting of 500 companies at the Confederation British Industry. The managing director of another company stated that he had used many tools and questionnaires but that this one had really made him think. On a more concrete level, most of the companies took specific action as a result of using the audit. Some examples are given:

Company A—The development of metrics to measure innovation performance
Company C—Revisions to be simultaneous engineering programs
Company E—Creating a debate at the senior management level about the role of innovation in the firm
Company G—A prioritized set of actions to improve the product development process and the control by senior management
Company H—Actions to improve the teamwork and cross-functional management in the organization

A frequent, though minor output of beta test programs is testimonials, and the willingness of the participants in the beta testing to give testimonials can be seen as an indicator of usefulness. The sponsor of the tool development, the DTI, decided to contact some of the companies for testimonials for use in marketing the tool to industry in the United Kingdom. They used a third party to contact companies. All beta test companies contacted gave testimonials.

Despite the qualitative nature of the data, both we and the DTI concluded that feedback from the companies indicated that at the initial stage, the usefulness was satisfactory. The ultimate test of usefulness will come only in the longer term, once the impact of the actions chosen by the companies can be evaluated.

From Test to Use

Dissemination—Workbook and Training

Once the beta testing had been completed, the feedback was reviewed for improvements that might be needed. On the content side, it was agreed that in its initial form, it had not addressed the marketing area directly. A set of market-related questions were constructed by the DTI and added to the audit under the heading market focus. This and other necessary changes were made to the content of the audit tools. The feedback from the companies on their use of the tool was used to develop a set of guidelines for its use both for self-assessment and for benchmarking. A six-step approach was developed. This final version of tools and guidelines for use was translated by the DTI into a workbook that was launched with a national program for its dissemination and use [82]. To support its dissemination, a full set of training materials was developed by the DTI. Its dissemination philosophy was not to go to companies direct, but to use service providers such as consultants, training organizations, and educational establishments. Training was provided for these groups, who in turn provided wider dissemination and training for managers and companies. As of early 1995, managers from more than 500 companies had been trained in the use of the audit tool. Further support material was under development including laser discs.

Case Studies

We felt further feedback could be gained through reviewing the final workbook version of the audit tool in use. We developed case studies of two users of the tools in contrasting companies and use: one a small company, using the tool with outside facilitation; the other, a large multinational, independently adapting the tool for companywide use. Case studies of the two users are shown in Exhibits 1 and 2.

A number of tentative conclusions can be drawn from these two cases. First, the audit process works in diverse environments, the two companies are different in many dimensions. The companies have used it without undue difficulty to audit their innovation and technology management processes, and this audit has led to actions for improvement. It does not indicate yet whether these actions will successfully improve innovation performance. The two cases illuminate the organization for the audit. In both cases, team approaches were used and certainly in case H were seen to be essential. Both cases also used facilitators—one external, one internal. The facilitator's role, particularly in case H, focused not on providing technical expertise but with helping make the team processes work. Both were championed and pushed by very senior managers, who had the support of other senior colleagues.

Case H was also illustrative of the way in which the audit could be tailored. The company adapted the audit tool's use to fit the needs of differing companies in the group. There has been some feedback from the cases that indicates some details may have been missed in the beta test. Both companies fed back the results to their managers using a 10- or 100-point scale, not the 4-point scale used in the scorecard. Both used stronger language in their description of scoring. Company G called a full score world class; company H called it

Exhibit 1. Case Study G

Background

The company is a small high-technology company based on ink jet technology. From its start-up in the 1980s, it has expanded to become a leading world player in its field with a stream of innovative products. It operates in virtually every market in the world.

The board of the company is extremely concerned with developing and maintaining world class processes and performance in all of its processes. One area vital to its long-term competitive position is innovation.

The Audit

The audit was initiated by one of the directors who had heard about the audit tools developed by the research team. He asked the team to facilitate an initial audit of the innovation and manufacturing processes at the company. The audit consisted of the following stages:

Set Up

Two facilitators from the research team met with senior functional managers and directors of the company to determine the scope of the audit, and to instruct the company in the use of the audit tools. The technical director was made responsible for conducting the innovation audit. The quality manager was made responsible for all coordination within the organization.

Audit

The technical director formed a small team drawn from various parts of the company to audit the company's processes, using the scorecard part of the audit tool. Over 2 weeks, these data were collected by the team. This was followed by a review meeting between the team and the technical director to discuss the initial findings and to explore the issues behind these. Shortly afterward, the outside facilitators spent a second day at the site interviewing employees involved with the innovation process. (In addition, an audit tool concerned with world-class manufacturing was administered). The facilitators collated the interview data and the data from the innovation and manufacturing audit tools.

Review Meeting

One week later, a review meeting was held at the company, led by a facilitator. The meeting consisted of a broad cross-section of those from the functions involved, including a number of board members. The outcome from the audit was presented by the facilitators. This was as numerical data in bar chart form together with a commentary based on the feedback of the teams and the interviews conducted by the facilitators. The summary of the audit is shown in Figure 3.

The audit and subsequent discussion led to identification of gaps between current and desired processes and performance. Just as valuable was validation of many existing programs and activities. Examples of the issues discussed included:

- *Identification of key opportunities for improvement*
  - The processes for designing for manufacture and transfer from design to manufacture were poor and led to low reliability and delivery problems.
  - There was insufficient attention paid to the voice of the customer; in particular, there was a lack of formal feedback processes.
- *Gaps recognized and programs in place*
  - In a number of areas the audit revealed gaps that had already been recognized and where the current programs of improvement and trajectories of change were correct and should lead to high levels of practice and performance. These included industrial design and the product development processes.
- *Identifying mismatches*
  - The company had a wide range of improvement programs in place. Some of these did not reflect the real needs as identified by the audit. Given their limited resource, this led to consideration of whether the portfolio of improvement actions should be changed.
- *Validating current areas*
  - An often missed output from an audit is the confirmation that much existing activity is excellent and should be recognized as such. In this company, a number of processes such as the technology acquisition were generally of a very high standard.
- *Dilemmas*
  - Audits can provide data showing conflicting facets of an issue. Despite being an innovation led company with exceptional leadership, there were also elements of the company's culture and style that reduced risk taking and innovation at the middle management level.

These issues and others were debated at the review meeting. At the end, a set of priority areas for improvement was identified. Responsibilities were assigned for implementation.

Six weeks after the review meeting, a separate meeting was held with the chairman of the company. The objectives were to explain to him the process, to brief him on the outcome and the key actions required, in particular those actions which involved him personally, and finally to get his commitment to making the improvement actions in the company. Implementation is now taking place.

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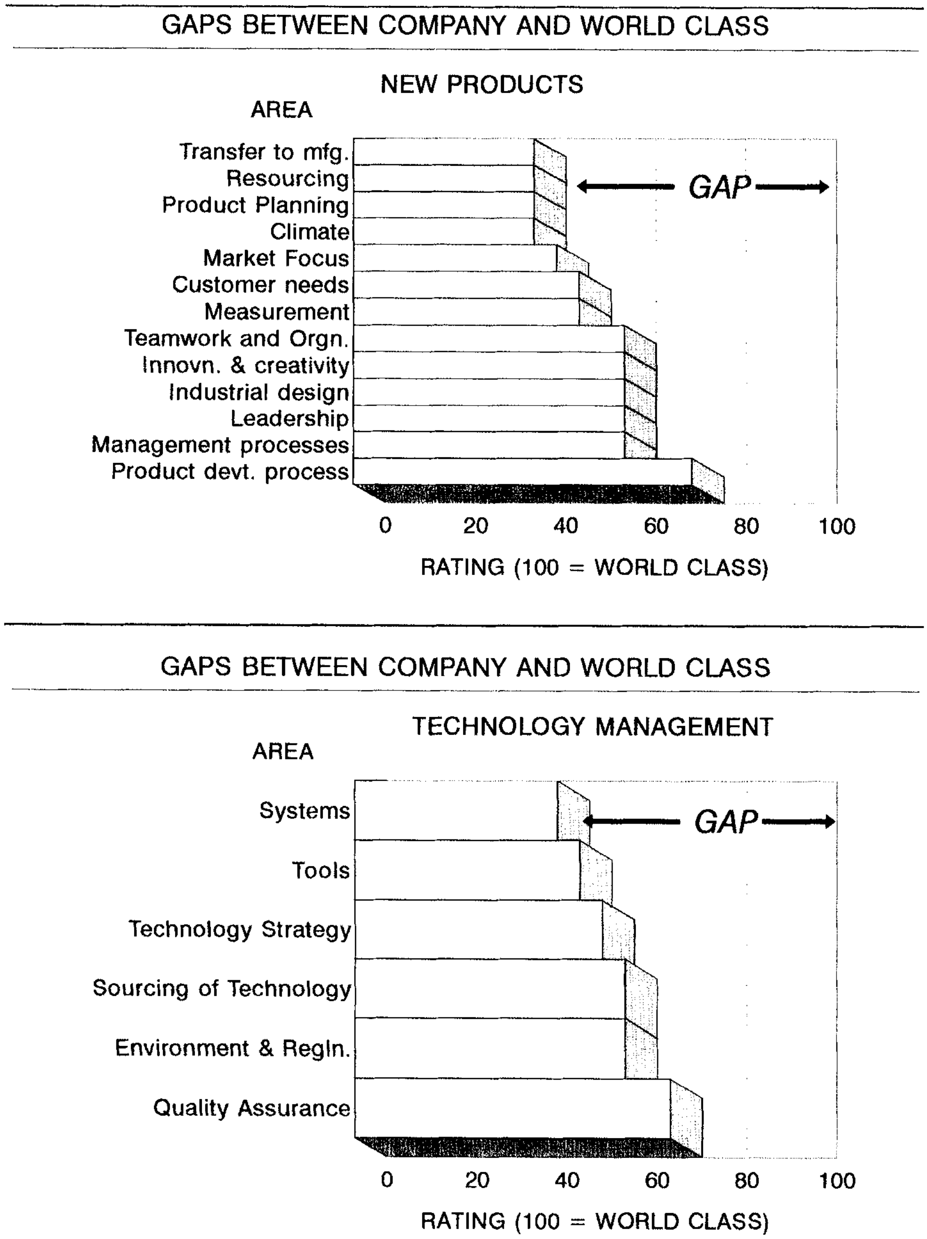


Figure 3. Summary of audit of Company G.

ideal and best practice. Any revisions of the tool should take these into account. Finally, both companies restricted themselves to using the scorecard part of the tool, finding it sufficient for their needs. If widespread, it may indicate that the detailed audit tool is not necessary for every company or that the detailed tool is too complex for the average company to use in most situations. This is consistent with the experience of the Baldrige award. Companies using Baldrige as a self-audit tool have frequently developed simpler tools, based on the framework. This question needs to be examined through longer term study.

Discussion

The preceding sections have described the development of an audit that has two parts; a performance

Exhibit 2. Case Study H

Background

This company is the regional entity of a large multinational chemical corporation. It consists of eight separate operating divisions. These divisions are diverse both in size, processes, and type of business. In 1993, the company wished to develop an internal self-assessment capability to be used as part of its technology management standards. They decided to use and adapt the audit tool to do this. Before doing this, they studied the tool and decided to review it in terms of its applicability to the needs of the company. A small team was brought together by the chief scientist and spent 1 day in a brainstorming session, reviewing the areas of the audit to see if they were appropriate for the company and whether anything should be added. They identified a number of areas that they wanted to add, such as management of know-how, and removed or retitled some parts of the existing audit.

In addition, they examined the suggested metrics and selected a subset of these that they felt most appropriate to themselves. The resulting changes are summarized in Table 7. Although new areas such as as management of know-how were added, much of the rest represents retitling and reordering to match the company's focus. These reflect the science-based nature of the company, with a particular focus on the management of the technology base. Most existing audit questions were kept the same, but the scale was modified to a 1–10 scale.

The Audit

Built in to Company Processes

The company has an explicit technology policy of taking full advantage of technology-based opportunities to generate growth and enhance long-term competitiveness and to develop its technology capability by building on existing skills and establishing long-term relationships with leading technology organizations in areas of strategic interest. This policy is accompanied by a set of technology management standards. The audit was designed to be incorporated into the company's technology management standards as a technology self-diagnostic. This diagnostic matched closely eight sections of the company's existing standards and provided a means of auditing these on an annual basis.

Organization for the Audit

The audit is mandatory for all divisions. The audit is carried out in each operating division by a panel. This panel normally consists of technical people, business managers, and where possible, sales people. The objective of the broad composition is twofold: first to provide honest dialogue, second to provide a broad perspective. "If the dominant technology management view is not challenged, learning will have failed." The panel gets the audit tool in advance, then meets in an intensive 3- to 4-hour session to discuss and to rate their practices and performance. All but two of the divisions used a facilitator to help them with their audit. The view of the company was that the process went much better with a facilitator.

For divisions that operated in more than one market, there were significant differences between markets, and it was more relevant to audit the processes associated with each market rather than try to average them. Differences between divisions were not seen as a problem; where a category of the audit was not relevant, it was ignored. An example is product development in a division whose sole focus was chemical processes and did not develop new products per se.

Gap Analysis

The data were analyzed by using a gap analysis format. Divisions were asked to identify target as well as actual—the differences being the gap. An example of a gap analysis from a particular division is shown in Figure 4. The overall average of the gaps for the eight divisions is shown in Figure 5. Whereas the gaps in individual divisions varied greatly, an underlying gap across the whole of the company was in the area of teamwork.

Action

The identification of gaps leads to the next step, which is the debate of the issue in the division. This needed tact, using a "maybe we are not quite as good as we think we are" approach rather than direct "we are bad." Once agreement on the gap and problem has been reached, the company culture supports rapid deployment of resource and action. The process has been through its first annual cycle successfully and is expected to be repeated again, as it is embedded in the technology management standards.

audit to provide simple but revealing performance measures for each core and enabling process and a process audit to evaluate the processes of technical innovation. The two can be considered complementary. The performance audit, although it might identify gaps between a firm's actual and desired practice, does not identify the causes of gaps and thus does not help define action plans for improvement. However, this is addressed by the process audit. In addition, performance measures are inherently difficult to define and to find comparators, whereas the process audit can more clearly indicate potential problems. Combining both the performance and process audits can lead to a thorough understanding of a firm's innovation performance. Further, a virtuous cycle can take place when performance measures and process audits are used together. Performance measures offer synthetic and effective indicators of results of innovation and help focus the attention on critical areas. A process audit enables a deeper understanding of what occurs in the

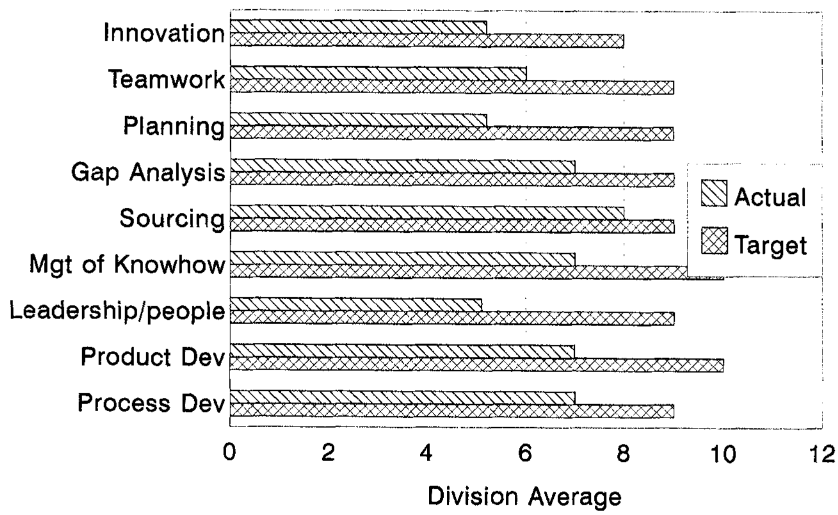


Figure 4. Example of audit results for a division in Case H.

innovation process and the good and bad characteristics of practices adopted. Therefore, they help define where actions should be taken and what to do. At this point, performance measures can help to assess the extent of improvement due to the actions taken and so on.

The testing of the tool has indicated that it can be used successfully by a range of organizations. However, we see four potential limitations:

Scope. The audit was developed with a clear technological innovation orientation. This may limit its applicability to product innovations that do not rely on technology as an input. It is based around product innovation, and though conceptually applicable to service innovation, the language does not fit the service environment very well. The scope of the audit is outlined in Figure 1. There may be other areas outside the scope of this audit.

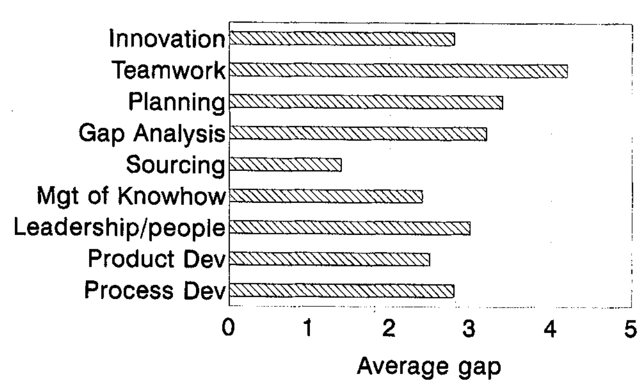
Best practice evolves. Management does not stand still, and new approaches are developed and new research sheds light on new factors contributing to success and failure. As with case study H, users of the audit may wish to add or modify factors.

An audit asks questions—it does not provide all the answers. Users should not expect an audit to provide them with a complete set of answers to potential problems. Audits ask questions and identify gaps and problems. As described in case G, this can lead to identification of gaps between current and desired processes and performance, identifying key opportunities for improvement. Just as valuable can be validation of many existing programs and activities. The individual solutions and actions required may very well be con-

Table 7. Changes Made by Company H

Original Audit Areas	Revised Audit Areas
Concept generation	Innovation and creativity
Product development	Product innovation and development
	Teamwork and organization
Resourcing innovation systems and tools	
Process innovation	Chemical process innovation
Technology acquisition	Technology gap analysis
	Sourcing of technology
	Management of know-how
	Technology planning process
Leadership	Technical leadership and people development
Increased competitiveness	

Figure 5. Average Gaps by Category in Case H Divisions (n = 8 divisions).



tingent on the nature of the organization. One audit user described the process as "intelligent signposting."

Expertise required. The two levels of audit, scorecard and in-depth, have been developed and tested. The experience from the field indicated wide use of the scorecards but more limited use of the in-depth audit. This raises questions as to whether the in-depth audit may be too complex for stand-alone use and requires greater training and expertise in the auditor than the typical company can provide.

Conclusions

The use of a process-based approach has led to an organic tool for auditing a firm's innovation capability. The use of this tool has the potential to help companies in a number of ways:

- to identify the processes relevant to innovation, bringing together the core processes (product concept generation, product development, production process innovation, and technology acquisition) and the enabling processes (leadership, human, and financial resource management, the adoption of systems and tools for innovation);
- to develop performance measures for each process of innovation and to assess the overall impact of innovation on competitiveness;
- to allow companies to audit their innovation capability through measuring the overall innovation performance and the performance of each innovation process, auditing innovation processes and benchmarking the practices adopted against the world class practice.
- through combining the performance and process audit approaches, to allow a broad audit with both qualitative and quantitative measures.

The tool has been through initial field testing. It is designed to be generic, covering a range of business and administrative systems within technological innovation, and applicable across a wide range of businesses. It can be used for auditing the capability of a single area and/or process of innovation on the basis of the past performance and of comparisons against competitors' and/or known best practices (the importance of each area can be different in different industries and in different companies). It can also be used at various levels (product line, business unit, corporate) and helps look at innovation as a cross-functional and cross-hierarchy process. Although the scope of the work has been industrial technological innovation, the proposed approach would be broadly valid in services, but some modification might be needed particularly in the terminology and the focus. Much of service and business process innovation is information technology–based, and its scope often extends beyond just the process or service to changing the nature of the business or even industry.

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Appendix 1. Content of the Core and Enabling Processes

Core Processes

In this section we examine each of the four core processes:

- concept generation,
- product development,
- production process innovation,
- technology acquisition,

and review the subprocesses and the key literature assertions concerning practice and performance.

Concept Generation

Concept generation concerns the process for identifying customer needs and matching these with technological capabilities to generate potential new product concepts and enhancements of existing products. It includes four main activities:

- generating new product ideas—identifying customer needs and matching these with technological capabilities to generate potential new product concepts and enhancements of existing products;
- planning product innovation—generating the product innovation strategy, including scope and rate of innovativeness and timing of market entry;
- initiating and supporting creativity;
- exploiting innovation through new businesses and supporting new product initiatives in existing businesses.

Looking first at generating new product ideas, successful innovations often arise in response to a recognized need, and the customer plays an integral role in the development of innovative ideas. Critical processes include how market needs and opportunities are monitored and uncovered—especially, how functional groups that meet the customer (such as marketing, field service, and support) are involved in building such knowledge and how innovative customers (lead users) are identified and involved in developing and testing new product concepts and enhancements [7,54,55,79]. Hise et al. [42] show that marketing should have a high level of involvement in new product development particularly at the design and evaluation stage. Identification of customer problems is an essential starting point for successful concept development. An important cause of failure has been identified as the absence of a perceived need [19]. Ciccantelli and Magidson [15] suggest that "design . . . could be greatly enhanced by focusing more attention on understanding customer behavior and needs, especially in the initial stages of product development.'' The marketing information system is the means by which many organizations identify changes that lead to the development of the new product concept.

Researchers have highlighted the need for multi-functional teams in product idea generation and screening to ensure that there is the diversity of information required [44,73]. However, marketing inputs alone cannot identify major developments in the technical environment. Technical inputs also play a role and need to be balanced with marketing inputs. For example, product concept generation needs to be shaped in such a way that both demand-pull and technology push are taken into account. A second activity concerns product innovation planning, that is defining a product innovation charter including target business arenas, the objectives of product innovation, and specific programs of activities. Adopting a formalized approach to product innovation planning helps managers coordinate and integrate the activities involved. Moreover, it helps prioritize product development projects in the face of multiple product opportunities, different rates of innovativeness and timing of market entry, and limited resources [22,58,63]. Product concept generation requires innovativeness and creativity. Mechanisms such as eliciting new product ideas from employees, supporting unplanned product initiatives, circulating new product ideas, and rewarding entrepreneurial behavior have been recognized as part of the most innovative organizations. Innovativeness and creativity can be achieved through both the adoption of more open organizational structures and the creation of individual roles critical to innovation such as idea generators, product champions, gatekeepers, and product development program managers [5,28,45,51, 75].

Exploiting innovation requires new business development techniques and procedures, and strategic and organizational activities such as venture capital investments, internal ventures, sponsored spin-offs. The use of each alternative may depend upon the familiarity of the firm with the new product market and technology [12,66].

Product Development

Product development is the process whereby new product concepts are taken through the stages of development, testing, and manufacturing to successful launch and support of the product. Four main activities may be observed:

- project management of product development, including tasks and procedures for taking a new product from concept to launch;
- teamworking and project organization;
- transfer from design to manufacturing and distribution;
- industrial design.

Researchers have studied project management and the organization needed to bring a new product concept to the marketplace [13]. For example, Cooper [20] and Wood and Coughlan [84] described the stage-gate system for driving new product projects from idea through to launch. Others have shown how successful product development requires a certain degree of integration and parallelism of steps, the concurrent engineering approach [16,19]. In the area of cross-functional teamworking and related activities, Thamhain [72], for example, studied the characteristics of innovative team performance and identified a range of tasks, people, and organization-related factors associated with successful innovation. Effective teamworking requires a high degree of cross-functional cooperation and the early involvement of key internal and external functions [16,40]; projects are more successful when project leaders are responsible from the start to the finish and their status, influence, and responsibility are clearly defined within the organization. Teamworking also requires that the input of functions to project teams and the weight and phasing of functional inputs to the definition of the product concept and of the functional specifications are clearly established [61,63]. Mechanisms used to facilitate and enhance two-way communication between the different groups involved in the product development process include meetings, liaison roles, sharing of common technology development systems, and use of electronic communication networks [72].

Transferring from design to manufacturing and distribution is a key activity of the product development process. This activity includes linking manufacturing and engineering (through prototype testing, rapid feedback from manufacturing to design and engineering, handling of engineering changes, production ramp up) and linking manufacturing and distribution. Again, the early involvement of the different functions (designers, engineers, manufacturing people, marketing people) and the use of integration mechanisms allow a reduction in the number of late product changes and the change costs [21].

An often neglected aspect of product development in the United Kingdom and the United States is industrial design. In many European companies, such as Braun, and Japanese companies, such as Toshiba, industrial design is central to their product innovation strategies and is built in as an integral part of the development process [26].

Production Process Innovation

Innovations of production processes are crucial as both a direct source of competitive advantage and indirectly in association with product innovations. The main activities include:

- generating production process innovations—the process for generating a manufacturing strategy matching manufacturing capabilities and market needs and for developing new production technologies;
- implementing new production processes;
- continuous improvement of production processes.

Formulating a manufacturing strategy and ensuring continuing innovation in production processes requires mechanisms to understand the capability of existing processes, to ensure that the manufacturing processes support the business needs and objectives, to monitor and tap into external sources of process technologies, to link product and process innovations [39,41]. Production process implementation is a critical area and field of study [32,39,47,76,80]. Effective implementation relies on the use of multifunctional teams, involving technology suppliers, the capability to match the production organization to the production process innovation [25,80,85]. In this way, the firm can match technology complexity to the capability to adopt and reduce the associated risk. A third area that has attracted the attention of researchers is that of continuous improvement in process innovations [38]. These improvements frequently result from a series of incremental innovations. A number of practices facilitate continuous improvement in manufacturing processes: creating work teams to identify opportunities for improvement; using process control data, customer feedback, and competitive benchmarks; and involving production process developers in improvement after initial installation [14,23].

Technology Acquisition

Technology acquisition involves monitoring, selection, and acquisition of technologies; the development of new or improved technologies through R&D or external acquisition; and the exploitation of technical knowledge. The main activities include:

- formulating the company's technology strategy, setting technological goals and plans;
- R&D management and organization—including the processes for R&D project management, the use of external sources and relationships for technology acquisition, licensing, and building technology alliances;
- management of the intellectual property—the policies for protecting and exploiting the property rights.

Formulating a technology strategy sets long-term technological plans and strategies [36,43,53]. This activity includes external technology intelligence, scrutiny of internal technological capabilities, technology selection, technology sourcing (make or buy in R&D [6]). The critical areas are the identification of core and complementary technologies, the evaluation of a firm's capabilities in core technologies, and the definition of the processes leading to a firm's core competencies that make it distinctive from competitors [62]. Roussel et al. have suggested that in successful firms, a partnership is established between business managers and R&D people. This partnership ensures that decisions are taken considering all the factors relevant to technology development programs, such as risk, reward, timescale, strategic relevance, and option creation for further technology developments [70].

The R&D management system should identify the key issues in organization and make the trade-offs explicit. Typical organizational trade-offs include the extent to which the control of technology development should be centralized, the extent to which acquired technological capabilities should be integrated into a firm's R&D, the changes in the R&D organization that can reduce product development lead time, and the extent to which there should be market research capabilities in R&D. Structural choices should be taken as answers to these key issues. In terms of R&D management, successful organizations stress aspects such as communication, linked structural interfaces, transparency and shared uncertainty, creation of a sense of importance and urgency in individual researchers, willingness to kill projects, and corporate-wide opti-

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mization of resources [70]. Finally, technology acquisition requires explicit definition of a policy for protecting and exploiting intellectual properties and knowledge through policies for patenting, trade secrets, and licensing out [36,37,43].

Enabling Processes

In this section, we examine the supporting or enabling processes of innovation:

- leadership—leadership from top management in strategy, process, and setting and maintaining a climate for innovation;
- resource provision—provision of appropriate organizational and financial resources;
- systems and tools—provision and use of appropriate systems and tools to support the core processes of innovation.

Leadership

The relevance of top management leadership in innovation has been pointed out by many authors. For example, the role of leadership is illustrated by Burger [13] in developing a research agenda for the Product Development and Management Association. Here, leadership was number one in the ranking of perceived importance of major issues. Leadership looks at the top management involvement in setting goals and priorities for innovation [4], championing the corporate effort to achieve best practice for each of the core processes of innovation, and setting stretch goals to the organization [62]. Central to leadership is creating a climate that encourages and supports innovation and entrepreneurship. This would include encouraging new idea development and risk taking, having a performance measurement system that encourages this, and disseminating the company's policies on innovation within the organization [56,74,78].

Resource Provision

Resourcing innovation includes the mechanisms and organizational processes for:

- recruiting, developing, evaluating, and rewarding human resources required for innovation;
- funding innovative projects, product development, R&D, and technology acquisition.

Human resources represent a key asset for successful management of innovation. In particular, the availability of appropriate people in the critical innovation roles [73] can lead to a sustainable competitive advantage [34,62]. These roles relate to different issues in innovation: the entrepreneur, who exercises the control of the venture and assumes the risks of the business; the product champion, who adopts an idea for an innovation and make possible the innovation's successful implementation; sponsors, who are the executives channeling resources to innovative projects; and technological and market gatekeeperes [5,51]. The relative weight and importance of these roles vary according to the firm's organizational development, including size and degree of diversification. Funding innovation appropriately requires funding stability (of the total amount) and flexibility (so that short-term opportunities can be exploited) [70,75,83].

Systems and Tools

This area addresses the relevance of methodologies, systems, and tools for supporting the innovation process. There is a very wide range available. Which of these are appropriate to an individual organization will vary greatly with the context, but in all areas there will be a particular set that can support the core processes. We see this area as comprising:

- the systems used to support the processes of product development and the communication between the functions involved;
- the contribution of tools to achieve faster and more effective product development;
- the management of quality in the design process and the methods used to analyze and improve the quality of the innovation process itself.

There is a wide-ranging literature on systems and tools [69]. Systems include computer-aided logistics systems (CALS) [58], computer-aided design (CAD) [2,49], and simulation. Tools include rapid prototyping, K–J analysis, and quality function deployment (QFD), design for manufacture, and creativity [3,9,35,64]. These systems and tools are continuously evolving, and some are specific to particular contexts. In addition to specific quality tools, quality management stresses the continuous improvement of processes, which is equally as important in the process of innovation as anything else.

Appendix 2. Full Set of Scorecards

1	2	3	4
Product Innovation			
Generating New Product Concepts			
New product development unplanned.	Product concepts developed in one department with limited customer contact.	New ideas sought in the marketplace with research into customer needs and with marketing and technical functions involved.	Direct links with customers and leading users to identify expressed and latent needs. A broad range of functions involved in concept development and screening and with early analysis.
Product Innovation Planning			
None!	Next generation of products planned.	Up to two generations of products planned.	Long-term planning for three or more generations of products.
Inventiveness and Creativity			
Control systems and organization discourage creativity.	New ideas encouraged, but risk avoided.	Risk taking encouraged and champions for new ideas sought and supported.	Employees' innovative and entrepreneurial behavior encouraged and rewarded. Mechanisms available to fund unplanned activities.
Product Development			
The Product Development Process			
No product development procedures.	Simple procedures applied to all projects but no parallel activities.	Project development on major products planned in phases with reviews.	Established processes and objectives with flexibility to allow small projects to move through quickly. Parallel and integrated activities.
Team work and Organization			
No teamwork and little communication between functions.	Some use of functionally based teams but with weak project management and no involvement of other functions prior to start-up.	Widespread use of multidiscipline teams. Clear project authority, internal cross-functional review prior to development but limited involvement from purchasing and suppliers.	Wide use of multidiscipline teams with early involvement by all. Strong team leadership and with team and leader empowered to make decisions.
Transfer to manufacturing and distribution			
No transfer process. Designs "thrown over the wall" to the next department.	Manufacturing–engineering communication prior to transfer.	Strong links between manufacturing and design.	Manufacturing has effective capability to test prototypes and ramp-up new products. Effective handling of engineering changes.
Industrial Design			
No consideration of industrial design.	Design introduced at a late stage in the process.	Use of internal designers or external design consultancies.	Industrial designers involved as core part of project team from concept stage.

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Appendix 2. Continued

1	2	3	4
Process Innovation			
Generating Process Innovations			
Serious differences between process requirements and technology available.	No manufacturing strategy: process technology bought off the shelf.	Manufacturing strategy ensures that process capabilities support market needs. Investment in improving existing and developing technologies.	Strong links between product and process development. Information on new process technology actively sought and new processes tested to gain experience.
Implementation of New Processes			
No attention to implementation.	Implementation seen as installation.	Cross-functional implementation teams.	Implementation teams stay together into full production to ensure learning and improvement. Active involvement of suppliers.
Continuous Improvement			
If it isn't broken, leave it alone.	Focus on maintenance of processes, not improvement.	Need for continuous improvement of processes recognized—primarily the responsibility of process engineering function.	Work teams encouraged to identify opportunities for improvement. Use of wide range of internal and external data to support improvement.
Technology Acquisition			
Technology Strategy			
No technology strategy and no mechanisms for understanding technology.	Inward-looking technology strategy identifies needs on a project-by-project basis.	Understanding of technical needs in each function with monitoring of trends and product-driven joint ventures and technical alliances.	The company understands its core competencies in technology and innovation and has policies for allocating resources to build and strengthen them. Monitoring of the technologies use by competitors.
Selection Generation and Sourcing of Technology			
"Not invented here syndrome"—No R&D sourcing plan.	Participation in industry technical associations but little external technology sourcing.	Ongoing contacts with universities, government agencies, industry consortia, etc. and close relationships with leading suppliers and customers.	Explicit policies for sourcing technologies, including in-house R&D, licensing in and out, partnerships and external linkages.
Environment and Regulation			
No policies or controls—get away with what you can.	Formal policies and procedures to deal with environmental and regulatory issues but passive general management.	Active management to promote compliance and improvement.	Proactive, anticipating trends with line responsibility for compliance. Products and processes designed to minimize environmental impact and health and safety hazards.

Appendix 2. Continued

1	2	3	4
Leadership			
Innovation Goals			
No management involvement in innovation.	No innovation goals and technical functions not represented at board level.	Innovation and technology capability seen as a means of gaining competitive edge and incorporated in the mission statement.	Explicit and challenging goals set for innovation with a long-term corporate understanding of how it can shape business strategy.
Processes for Generating and Implementing Innovation			
Management not concerned.	Management encourages good practice in innovation management.	Innovation management, product realization, and technology acquisition presented to and discussed at board level.	Management is proactive in ensuring best practice in innovation and product realization.
Climate for Innovation			
Management encourages short-term profitability and risk minimization by managers and employees at the expense of innovation.	General encouragement for innovation, but no measurement or reward.	Performance measures for innovation reviewed regularly by board with a customer-led climate encouraged.	Management ensures that risk taking is encouraged rather than penalized and new ideas rewarded. It ensures that the technology mission of the company is shared and understood throughout the company.
Resourcing			
Human Resources			
No human resource planning for innovation; key skills missing.	The human resources needed for innovation generally known and available, but usually slow to be applied.	The skills required for innovation are identified and are fully resourced through recruitment and training.	Career structures support innovation through development in all functions.
Funding			
Last year's spend adjusted up for inflation and down for cash availability.	Industry average levels. R&D and innovation budgets subject to sharp fluctuations from year to year.	Policies on how R&D should be funded. Some mechanisms to ensure that capacity is available in suppliers, manufacturing, and support functions.	Related to potential business contribution over short- and long-term with minimal fluctuations despite cash flow variation.
Systems and Tools			
Systems			
Limited use of information systems of CAD.	Information system usage within functions.	Widespread information system usage, primarily for one-way information flow including CAD, CAD/CAM, and process simulation on a functional basis to improve design effectiveness. Systems links with suppliers and customers.	Systems geared to improving design effectiveness and to shortening product development lead times.

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Appendix 2. Continued

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Tools for Innovation			
No significant usage of management and design tools.	Ad hoc tool usage, with no clear objectives.	Some use of design tools to improve product and process design effectiveness and/or creativity.	Widespread use of appropriate tools to capture customer needs and to ensure the effectiveness of product and process design. Established protocols such as design for manufacture, design for test, design for customer use.
Quality Assurance			
Limited quality management.	Quality control in manufacturing, but little involvement by engineering. ISO 9000 possibly in place, but focus on procedure only.	Quality practices and procedures in place for quality assurance of products and processes.	TQM program in place including a focus on achieving improved innovation performance.
Increased Competitiveness			
Measurement and Goals			
No measures of innovation performance or customer satisfaction.	Measures of financial and sales performance of new products and measures of product quality.	Operational targets are set for some aspects of innovation at departmental level.	Customer satisfaction feedback surveys initiated with feedback into the innovation process.
Innovation performance			
Anecdotal evidence only.	Positive trends in most areas.	Good-to-excellent results in major areas with evidence that results are caused by active management of innovation.	Excellent results in major areas with sustained results. Results clearly caused by active management of innovation.

Appendix 3. Example of Areas to Consider for In-Depth Audit of Processes

Product Development	Areas to Address
Product development process: *Describe the processes and procedures for taking a new product from concept to launch.*	a) The product development process; the scope of the process; the phases, gates, the phase reviews, and sign-off procedures. The balance between documentation and bureaucracy, the extent to which the process is replicable and compliance is mandatory, the degree of uniformity across the firm. b) The degree to which simultaneous engineering approaches are used; the degree of parallelism and integration of steps, degree of task interdependence/overlapping working and integration between the phases, which can take place and is built into the process. c) The flexibility of the procedures to allow for small projects to move through fast. d) The relationship between objectives of the development process objectives (e.g., development cost, product quality, development time, process predictability, product cost) and the key development activities (e.g., specification, integration, evaluation).

Appendix 3. Continued

Product Development	Areas to Address
Teamwork and organization: *Describe how the development process integrates all relevant functions; ensures that product concepts are properly defined prior to the start of development; communication between the different groups involved in the development process is facilitated.*	a) The location, dedication, and cross-functionality of project teams. The degree to which teams and their leaders are responsible for the product from start to finish and are empowered to make decisions. b) The status, influence and responsibilities of project managers in the organization (e.g., spending authority, leadership, budgetary control, conflict resolution, team selection, input to performance reviews, dedicated full time or part time). c) The procedures to ensure early involvement by all key internal functions (including engineering, design, manufacturing, customer interface functions, marketing, and purchasing), and external organizations such as key suppliers. d) The input of functions to project teams, the weight and phasing of functional inputs to definition of the product concept and creation of the functional specification. The inclusion of project performance goals in functional managers' performance reviews. e) How major risk areas are identified up front, the mechanisms for early identification of problems and how resources are put into managing these areas. f) The mechanisms for ensuring rapid two-way communication between individuals' teams, organizations (inside and outside the company). (1) Integrating mechanisms such as meetings, physical location, secondment, liaison roles, matrix organization. (2) Information systems such as shared databases, CAD/CAM.
Transfer to manufacturing and distribution: *Describe the process for ensuring the successful transfer from design into manufacturing and subsequent distribution to the customer.*	a) The strength of the links between manufacturing and engineering. The capability of manufacturing to test prototypes, to identify key risks and problems, and to give rapid feedback to engineering and to ramp up new products into fullscale production. b) The involvement of line production workers to ensure that new products can be manufactured easily. c) The procedures for the effective handling of engineering changes. d) The degree to which product teams take products into manufacturing and through to the marketplace and feed information back into the innovation process. e) The feedback from manufacturing on quality, manufacturability, etc. to design.
Industrial design: *Describe how industrial design is built into the innovation process.*	a) The use of internal expertise and external design groups to ensure high quality industrial design. b) The involvement of designers throughout the innovation process.