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# The Management of TECHNOLOGICAL INNOVATION

Completely  
Revised and  
Updated

Mark Dodgson, David Gann, and Ammon Salter

STRATEGY AND PRACTICE

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# ENDORSEMENTS

This is an outstanding book which gives the management of innovation its rightful role in understanding of modern capitalism and its restless nature. Everyone who is interested in the theory and practice of technological innovation should place this book on their reading list.

*Prof Stan Metcalfe, University of Manchester*

The Management of Technological Innovation brings the role of design into the heart of the innovation process, enabling students from a wide range of disciplines to understand how to integrate and manage product and service innovation.

*Prof Andrew Hargadon, University of California (Davis)*

Dodgson, Gann, and Salter have written the first indispensable innovation textbook for the 21st century. It combines advanced tools and techniques on managing open, distributed innovation processes along with the latest on intellectual property and public policy.

*Prof Hank Chesbrough, Haas School of Business, UC Berkeley*

This is a valuable addition to the bookshelf for those—students and practitioners alike—interested in how to manage innovation. With its emphasis on dealing with this key issue in strategic fashion and plenty of up-to-date case material it offers an excellent resource for courses in the subject.

*Prof John Bessant, Imperial College London*

This is a very comprehensive and useful textbook that provides the essential tools for managing innovation in a dynamic and changing business context.

*Prof Franco Malerba, Bocconi University*

The Management of Technological Innovation is a very comprehensive and well-written survey of the state of the art in this exciting field. The book provides students with a refreshingly clear strategic perspective and includes practical cases from around the world. Dodgson, Gann, & Salter's work will doubtless play an important role in the training of the next generation of strategists and managers.

*Prof Christopher Tucci, EPFL, Switzerland*

The Management of Technological Innovation is an excellent course book drawing together all the elements needed to succeed in the innovation process from creative intent to commercial realisation.

*Prof Dorothy Leonard, Harvard Business School*

## vi ENDORSEMENTS

This textbook embodies the managerial tasks of building innovation and technology strategies, organizing and leveraging people's skills and expertise within and across firms. It helps students appreciate these essential managerial practices to enable value creation through innovation.

*Prof Deborah Dougherty, Rutgers University*

There is great need for a comprehensive textbook on the management of technological innovation. This book provides an excellent introduction to the innovation process and the strategies needed to manage it.

*Prof Michael Cusumano, MIT Sloan School of Management*

Students in a wide range of design disciplines will turn to this book to understand the essential role of design in relation to product and service innovation.

*Prof Jeremy Myerson, Royal College of Art*

This welcome new textbook is distinguished by the range and freshness of the case examples, which span the traditional manufacturing/services divide, and by its rigorous treatment of the challenges of innovation management in global markets.

*Prof Alan Hughes, University of Cambridge*

The Management of Technological Innovation combines relevant case studies with valuable insights to offer a coherent argument for the strategic management of innovation. A valuable book packed with tools and techniques to help put ideas into practice.

*Prof Andy Neely, Deputy Director of Advanced Institute for Management Research, Cranfield School of Management*

This textbook provides a robust framework for understanding the interconnections between national and regional design and innovation systems and the internationalisation of production and markets.

*Prof Kevin Morgan, Cardiff University*

It is refreshing to see such an international approach taken in this book, to bring home the fact that nations continue to matter in formulating innovation strategy.

*Prof Mari Sako, Saïd Business School, Oxford University*

In the fast-changing, hyper-competitive, global world we live in, innovation is critical not only to the health of every business but to its very survival. Yet, managers generally learn how to effectively deal with innovation 'on the job', sometimes successfully—often much less so. 'The Management of Technological Innovation—strategy and practice' is an excellent account of the main tools and techniques involved in managing 21st Century innovation processes. It is essential reading for anyone getting a business degree as well as those on executive courses.

*Irving Wladawsky-Berger, VP, Technical Strategy and Innovation, IBM*

An excellent synthesis of the multiple dimensions involved in managing technological innovation. It provides practical techniques and essential case studies for those on corporate management development courses.

*Lem Lasher, Chief Innovation Officer, Computer Sciences Corporation*

This textbook provides the foundations for managing innovation in a wide range of businesses and organisations, ending with an inspiring set of future challenges about environmental sustainability, corporate responsibility and the role of government—which all managers should be thinking about.

*Baroness Denise Kingsmill*

Managing technological innovation is part craft, part science. This textbook captures the essential features in a highly readable format.

*Mike Phillips, Head of Applied Technologies, McLaren*

The idea of management of technological innovation presents a most valuable contribution to companies. Visionary strategies and progressive practices illustrated in this book provide useful techniques and tools for innovators, researchers and students.

*Yusuke Yamazaki, General Manager, Institute of Technology, Shimizu Corporation*

Not only is this an excellent text for students, it also provides deep practical understanding for managers in business.

*Malcolm Skingle, Director, Academic Liaison, Worldwide Business Development, GSK*

Firms will find this accessible book an invaluable source for their professional development programmes.

*Dr John Miles, Director and Chairman, Global Consulting Services, Arup*

Delivering successful and sustainable innovation is a goal for all world-class businesses. While innovation can be complex and challenging, it brings a multitude of rewards that few other business endeavours could. This textbook articulates the essential contribution of design thinking in achieving this goal.

*Mat Hunter, Director, IDEO*

Most business leaders acknowledge the critical role that technology and innovation play in the success of their organisation's activities. But taking full advantage of the opportunities offered by technology, in a continuous and systematic way, has proven to be an elusive skill. By bringing together theory and practice from a variety of industries, this book enables managers and researchers to get a real head start in harnessing the power of innovation.

*Humza Malik, Group Strategy and Corporate Development Director, National Grid plc*



This book provides an essential reference point for students and those on executive development courses, showing how managing innovation unlocks future prosperity—as well as creating fun and vibrancy in the workplace.

*Ray O'Rourke, Chairman, Laing O'Rourke plc*

Innovation is a well-used phrase, meaning many things to different people. But managing technological innovation is essential for the success of most growing businesses. This book aims to clarify definitions and provides engineers, scientists and business students with essential information and approaches that will enable them to enhance their own innovative thinking, in a broad range of markets and activities.

*Dr Alison Hodge, University Partnerships Director, QinetiQ*

The creation and management of intellectual property is a key part of the innovation process. This book shows clearly how creative approaches to intellectual property will deliver value through innovation for both the customer and the company.

*Ian Harvey, Chairman, Intellectual Property Institute*

Managing the development of new products and services is the future life-blood for every organisation. This textbook equips students with all the core elements required to understand how to deliver value and create new markets.

*Bronwyn Curtis, Head of European Broadcasting, Bloomberg*

The management of technological innovation is a fundamental issue for executives in companies large and small. This book will provide a useful reader for all those on executive development courses.

*Ian Coleman, Global Head, Valuation and Strategy, PricewaterhouseCoopers*

Technological innovation creates value for firms in all industries. This book articulates how the process of delivering that value can be realised.

*Dr Robert Easton, Managing Director, Carlyle Group*

Technological innovation is fun, generally expensive and risky. The management of it is an art and this book gives a good insight into it.

*Keith Clarke, Chief Executive, Atkins plc*

*For Chris Freeman*

# PREFACE

The management of technological innovation (MTI) is one of the most important and challenging aspects of contemporary business. As technological innovation is a fundamental driver of competitiveness for firms in a wide variety of business sectors, it is essential that the strategies and practices of MTI are well understood.

This book describes and analyses these strategies and practices. It examines the ways they create and deliver value for firms through innovation networks and communities, research and development (R & D), innovation in products, services, operations and processes, and the commercialization process. It examines the high levels of complexity and risk associated with MTI. While MTI is one of the most important aspects of management, it is also one of the most difficult.

Although the primary focus of the discussion is the firm, many of the issues addressed in this book apply to other organizations—public or private—that are concerned with innovation. Efficiency, productivity, and sustainability are the concern of managers in all organizations.

Throughout the book, the particular aspects of MTI are discussed in the context of the general environment in which businesses are operating—an environment that is extraordinarily dynamic. The organization and structure of industry and business are being transformed; firms and their technology are increasingly becoming integrated into various networks and systems; management philosophies and practices are altering with increased focus on issues such as learning, knowledge, and trust; the innovation process itself is changing with the use of new electronic media; and globalization is having a greater impact on management practices. All these changes impact upon MTI.

What differentiates this volume from other books on MTI is, first, its breadth of coverage. It examines a broader range of aspects of MTI than the majority of books in the field, moving from the management of basic science to operations, from consideration of innovation strategy to design. It considers some issues from a theoretical perspective—especially within a Schumpeterian framework—and others from the practical point of view of ‘what is the best way of managing this?’ It is firmly based in the view that good practice depends on good theory.

Second, it is international in focus. The vast majority of books on this subject take a US perspective (and a US large-firm perspective). However, innovation development and diffusion are essentially international activities, and innovative firms usually have an international focus either because they sell products and services overseas, and/or because they work with foreign suppliers and partners. This book draws on best practice

from across the world. Permanent, sustained, corporate advantage depends upon learning about the best management practices available internationally—found in firms in the UK, the USA, Taiwan, Italy, Korea, Japan, Israel, Australia, or elsewhere—and understanding that there are always better ways of doing things and improvements to be made. No one country has a monopoly on good ideas, and it would be a mistake to believe that any particular international model of management has all the answers for MTI. This is important, as many of the most pressing challenges for the future of MTI relate to its international management.

Third, as well as examining the activities of large firms, in this book we discuss MTI in small and medium-sized firms. These firms are important sources and users of technological innovation, and the challenges and opportunities they face are often different from those that confront larger firms.

Fourth, many of the issues discussed are applicable to both manufacturing and service companies. The boundary between the two is becoming increasingly blurred, and MTI best practices found in one sector can often be successfully transferred to others.

Fifth, in an area where there seems to be an obsession with using only the most up-to-date material, the book integrates analyses and research findings from the 1950s to the present. A great deal of insightful and useful research into MTI tends to be ignored because it is deemed to be out of date and not applicable to present circumstances. We hold the view that much of this older research is still relevant.

Sixth, the book is not driven by the desire to provide simple answers to the problems of MTI or to promote a particular management technique. There are no recipes for successful MTI; it is a difficult and idiosyncratic process. Some of the techniques that have been followed in the past with evangelical zeal, such as business process re-engineering and total quality management, have been marketed as providing all the answers. Some tools and techniques have a role to play in MTI, but they are not the whole solution. The real picture, as we shall see, is much more complex.

Seventh, the book takes a strategic approach to MTI. It shows how many of the tools and techniques used in the management of R&D, new product and service development, operations and technological collaboration cannot be fully effective unless they are guided by a strategy. Such a strategy has to be informed by an understanding of the broad changes taking place in industry and business, and the book locates MTI in the context of the resulting challenges. As technological innovation is an evolving and often uncertain process, the book describes why many common approaches to business strategy cannot be used effectively by innovative firms.

The book is structured in three major sections. Part 1 (Chapters 1–3) defines MTI and examines the broad *context* and *forms* in which technological innovation occurs. Chapter 1 examines what MTI encompasses by using a number of composite case studies to illustrate the challenges facing innovative firms. Chapter 2 analyzes some of the

major contextual and environmental changes occurring in contemporary business and management that influence MTI. Chapter 3 studies technological innovation in depth, considering different types, levels, sources, and outcomes.

Part 2 (Chapters 4–9) looks at ways MTI helps *create*, *shape*, and *deliver* innovation for firms. A number of approaches, tools, and techniques for managing these areas are described, including those that help firms decide what to do in innovation and those that help implement their decisions. These chapters commonly accentuate the importance of innovation strategy for effectively building company competitiveness. Chapter 4 highlights the difficulties of analysing and developing innovation strategies, but emphasizes their importance and describes how they can be formulated and implemented. Chapter 5 examines the role of innovation communities and networks in supporting innovation, and management of technological collaborations among limited numbers of firms. Chapter 6 considers R & D, and how it is most effectively managed. Chapter 7 addresses innovation in products and services, and Chapter 8 innovation in operations and processes. Chapter 9 is concerned with the ways firms deliver value from innovation in the market for product and services and the market for ideas.

Part 3 comprises a single chapter (10), which concludes with an examination of the *future challenges* of MTI. It argues that these challenges need to be addressed by firms, governments, research organizations, public interest groups, and informed citizens.

Case studies are used throughout the book to illustrate key issues and themes. These are presented in the text and in a series of boxes, which can be read as stand-alone items.

This book is a completely revised and rewritten version of an earlier book by Mark Dodgson. Since publication of the original book in 2000, Mark Dodgson, David Gann, and Ammon Salter have been actively researching together (see, e.g., *Think, Play, Do: Innovation, Technology, and Organization*, Oxford University Press, 2005), and have co-developed a wide range of teaching material in MTI for a variety of degree programmes: Master of Business Administration, Master of Management, Master of Technology and Innovation Management, final year undergraduate Business and Engineering degrees, and executive programmes. Extensive new teaching and research material is included in this edition. It has been developed and tested on groups of excellent students and companies across the world. Our students' world views, experiences, and future career aspirations, their enthusiasm, insights, and internationalism have inspired this book. We hope it reflects their ideals and will be a guide for their successors.

The authors wish to acknowledge those academics and business people who have generously given of their time and knowledge and contributed substantially to the substance of this book. We are particularly grateful to Virginia Acha, Erkko Autio, James Barlow, John Bessant, Catelijne Coopmans, Paola Criscuolo, Linus Dahlander, Ben Dankbaar, Andy Davies, Gabriela Dutrénit, Lars Frederiksen, Elizabeth Garnsey, Annabelle Gawer, Andrew Griffiths, Alan Hughes, Tim Kstelle, Keld Laursen, Nick Leon, Ian Mackenzie, Orietta Marsili, Pascale Michaud, Ritsuko Ozaki, Nelson Phillips, Jaideep Prabhu, Toke

Reichstein, Jonathan Sapsed, Tony Sheehan, John Steen, Florian Taeube, Bruce Tether, Jennifer Whyte, Tim Venables, and Marina Zhang. We thank Mikko Paananen and Vandana Ujjual for their research assistance.

The planning of the book began in Collorgues in Languedoc-Roussillon, France, and we are very grateful to Jeff and Julie Rodrigues for their generous hospitality and the numerous surrounding *caves* for their agreeable sustenance. Parts of the book were written in Sidmouth, Devon, and we are grateful to Jo Frith and Jimmie and Gita Rae for being such gracious and considerate hosts.

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Many thanks to Virginia Harris and to Cynthia Little for her exhaustive editorial work.

This book is dedicated to Chris Freeman who for over 50 years has led the way in the study of innovation and whose personal kindness and intellectual generosity have been a constant source of inspiration.

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# ABBREVIATIONS

ASIC	application-specific integrated circuits
ATM	automated telling machine
BAA	British Airports Authority
BP	British Petroleum
BPR	business process re-engineering
BTG	British Technology Group
C&D	connect and develop
CAD	computer-aided design
CAE	computer-aided-engineering
CAM	computer-aided manufacturing
CD	compact disc
CEDD	Centres of Excellence of Drug Discovery
CFD	computational fluid dynamics
CIM	computer-integrated manufacturing
CIO	Chief Innovation Officers
CIS	community innovation survey
CMM	capability maturity module
CNC	computer numerated control
CoPS	complex products and systems
CPU	central processing unit
CRM	customer-relationship management
CSR	corporate social responsibility
CTO	chief technology officers
DCF	discounted cash flow
DNA	deoxyribonucleic acid
DRAM	dynamic random access memory
DSM	design structure matrix/dependency structure matrix
DVD	digital video disc
EPLD	electrically programmable logic devices
EPO	European Patent Office

ERP	enterprise resource planning
ETSI	European Telecommunications Standards Institute
F&G	Fuller and Gordon
F1	Formula 1
FDI	foreign direct investment
FGCS	fifth-generation computer systems
FMA	first-mover advantage
Fojal	Jalisco Fund for the Promotion of the Enterprise
GATT	General Agreement on Tariffs and Trade
GCG	Global Consumer Group
GM	General Motors
GNP	gross national product
GSM	global system for mobile communications
GTS	Global Transaction Services
GUI	graphical user interface
HP	Hewlett-Packard
HRM	human resource management
ICT	information and communication technologies
IPCC	intergovernmental panel on climate change
IPO	initial public offering
IPR	intellectual property rights
IRAP	Industrial Research Assistance Program
IS	information systems
ISI	Institute for Scientific Information
ISO	International Organization for Standardization
IT	information technology
ITRI	Industrial Technology Research Institute
IVF	in vitro fertilization
IvT	innovation technology
Jaltrade	Jalisco Foreign Trade Institute
JFWTC	John F. Welch Technology Centre
JIT	just-in-time
MCA	multi-criteria assessment
MFN	most-favoured nation
MRI	magnetic resonance imaging

MRP	materials requirement planning
MRPII	manufacturing resource planning
MTI	management of technological innovation
NACI	National Advisory Committee of Innovation
NESTA	National Endowment for Science, Technology, and the Arts
NIU	Netafim Irrigation University
NFC	Near Field Communication
NIH	not invented here
NIS	national innovation system
NME	New Millennium Experience
NPV	net present value
NTBF	new technology-based firms
O & T	Operations and Technology
OEC	Orbital Engine Company
OECD	Organisation of Economic Cooperation and Development
OEL	Ohsaki Electronics Laboratory
OS	open source
OSS	open source software
PARC	Palo Alto Research Centre
PC	personal computer
PDA	personal digital assistants
PDM	product data management
PDO	protected designation of origin
PGI	protected geographical indication
PIMS	profit impact of marketing strategy
PLC	product life cycle
PLU	price look-up
PSI	product and service innovation
QA	quality assurance
QC	quality control
QFD	quality function deployment
R & D	research and development
RETS	Rapid Exit Taxiway Systems
RFID	radio frequency identification
ROI	Return on investment

SBIR	small business innovation research
SGT	Sidmuth Gene Technology
SI	systems integration
SME	small and medium-sized enterprise
SNA	social network analysis
SPRU	science policy research unit
SSI	sectoral system of innovation
Telcos	telecommunications operators
TQC	total quality control
TQM	total quality management
TRIPS	trade-related aspects of intellectual property rights agreement
USPTO	US Patents and Trademarks Office
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
WWS	Worldwide Security Services

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# **1 What is the Management of Technological Innovation and Why is it Important?**

## **Introduction**

Of all the challenges faced by managers today, the management of technological innovation (MTI) is one of the most demanding. Get it right and firms create value and profit, develop sustainable competitiveness, and become vibrant, fun places to work, attracting and retaining the most productive and creative staff. Get it wrong and firms can face serious, and perhaps terminal, problems through losing money, workers, and reputation. In the vast majority of business sectors, if firms do not innovate, their competitors will, and they will be put out of business in any case.

The overarching objectives of managers lie in improving efficiencies and enhancing sustainable competitiveness in their organizations. As we show in this book, technological innovation plays a major role in helping managers meet these objectives. Successful MTI occurs when all the wide range of innovative elements and activities of organizations are managed well and effectively combined within an innovation strategy. This allows firms to fulfil their overall purpose—be it profit generation, growth, better quality and range of delivery, greater market share, or increased employee remuneration, job security, or satisfaction. This book examines the ways in which MTI contributes to meeting the challenges and realizing the objectives of firms and organizations.

MTI encompasses all those elements of firms where developing and using technological innovation improves capacity to meet objectives. It includes the management of innovation strategy, innovation communities and networks, research and development (R & D), design and new product and service development, operations, and value delivery. While there are many incentives to innovate, there are considerable obstacles to success. MTI often involves managing in circumstances where there is a high degree of ambiguity, uncertainty, and risk. As technological innovation is for many firms the primary means of competing in the knowledge-intensive economies of the twenty-first century, MTI is a vital activity.

### Box 1.1 Definitions of technology and innovation

Technology is a replicable artefact with practical application, and the knowledge that enables it to be developed and used. Technology is manifested in new products, processes, and systems, including the knowledge and capabilities needed to deliver functionality that is reproducible.

Innovation is much more than invention—the creation of a new idea and its reduction to practice—and it includes all the activities required in the *commercialization* of new technologies (Freeman and Soete 1997). Essentially, innovation is the successful commercial exploitation of new ideas. It includes the scientific, technological, organizational, financial, and business activities leading to the commercial introduction of a new (or improved) product or service.

Firms compete successfully when they offer new, better, and/or cheaper products and services, which their customers can use to advantage, and which their competitors cannot provide. Competitive advantage therefore derives from the ability to make and do things more cheaply and better, or to make and do new things. It has a relative dimension: advantage is found in the activities of firms compared to their competitors. It also has an absolute dimension: there must be a market for what the firm does. Technological innovation plays a central role in providing comparative and absolute advantages.

Although we might be very clear in our minds about what constitutes technological innovation—that is, a new computer, automated telling machine (ATM), or pharmaceutical—definitions of technology and innovation are actually very broad ranging (see Box 1.1). This highlights how technological innovation can occur in many, often unexpected, sectors, demonstrated in our case studies on innovation in condoms, food, cruise ships, and car insurance. Innovation also involves many more parts of a firm than the ‘technology’ areas. Decisions on strategy, organization, finance, marketing, and location of business are made alongside those related to research, design, and operations (see Box 1.2). The challenge for business is to make effective decisions in each of these different areas, often at the same time. These features point to the complexity of technological innovation, and hence to the challenge of managing it.

From these definitions we can see that technological innovation involves more than the successful application of new ideas to products and services; it often requires changes in the organization and strategies that support it. As we shall see from the following case studies and Chapter 2, technological innovation involves addressing a wide range of issues and activities that compound the challenges in managing it, add to its risk and uncertainty, and make it difficult to develop generic recipes for its success. It is the very difficulty of managing technological innovation that makes it such a source of competitive advantage. If every firm could do it successfully, it would not provide a source of relative competitive advantage. As Frederick Gardner Cottrell of the University of California and a founder of the US Research Corporation said in 1912: ‘[A] number

of meritorious patents given to the public absolutely freely by their inventors have never come upon the market chiefly because “what is everyone’s business is nobody’s business”’ (Cottrell 1912 quoted in Mowery et al. 2004: 59).

To add to the complexity, there are different types and dimensions of innovation. Innovation is at once an *outcome*, a new product, process, or service, and a *process* of managerial and organizational combinations and decisions. An innovation, by definition, is successful (although it may be limited or short lived; in Chapter 7 we discuss the ambiguity surrounding definitions of success and failure). Any innovation *process*, in contrast, can fail to support the successful exploitation of new ideas.

Innovation is found in products, processes, or services, but the boundaries between them can be blurred and one company’s product may be another’s process. Innovation can involve minor *incremental* adaptations and improvements in a product or small component of a system, or *radical* changes to the whole product or system. It may be new to the firm, industry, or nation, or new to the world. It can emerge from existing technologies or completely new ones. Most often it materializes from new combinations of existing technologies. Another factor affecting MTI lies in the innovation process itself, which, as we shall see in Chapter 3, is changing. All the various types and levels of innovation and innovation processes pose different challenges for managers.

MTI requires a broad appreciation of the business and industry context in which it occurs. Chapter 2 discusses the contextual and influential issues for MTI of technological change, the knowledge economy, business and innovation systems and networks, the changing nature of management, and globalization.

Subsequent chapters address a wide range of MTI issues.

In a business environment where innovation provides distinctive and sustainable competitive advantages, *innovation strategy* is the basis for the firm’s overall strategy. Innovation strategy involves analysis of firms’ business, market, and technological environments and consideration of what resources they have to draw upon. It involves making choices about innovation in uncertain and ambiguous circumstances, with diverse strategies for different levels of uncertainty. It entails building the innovative capabilities firms need, to meld skills and resources to analyze, select, and deliver innovation to enhance organizational performance. It requires consideration of how new initiatives in innovation fit with firms’ existing portfolio and how innovation strategy complements overall corporate strategy. It is concerned with integrating all the areas of MTI into a coherent whole. Innovation strategy is discussed in Chapter 4.

Small and medium-sized enterprises (SME) face particular issues in their innovation strategies, especially in relation to the problems of managing growth, and these are discussed in Chapter 4.

Technological innovation rarely occurs through the activities of single firms. It is more commonly a result of inputs from a variety of organizations, working together as customers and suppliers, in various forms of *communities and networks*, and in



#### 4 WHAT IS THE MANAGEMENT OF TECHNOLOGICAL INNOVATION?

formal *technological collaborations*. MTI therefore includes technological collaboration, alliances, and networks. This aspect of MTI is examined in Chapter 5.

Centrally important is the management of *research and development* (R & D), which provides an organized source of idea generation and improves the ability of firms to absorb useful information from outside. MTI includes issues ranging from techniques of technology forecasting and assessment to organizational questions, such as the extent of the centralization or decentralization of R & D, the degree to which R & D is internationalized, and the ways internal capabilities link with external sources of R & D—in universities, research institutes, and other companies. It includes balancing shorter-term, applied R & D and longer-term, more speculative basic research. It involves managing creative and productive researchers and research teams. Managing R & D is discussed in Chapter 6.

MTI entails the management of *product and service innovation*. This includes *efficiency* factors, encouraged, for example, through the use of various project management systems; and *effectiveness* factors, such as whether chosen new products and services complement and build upon firms' existing product bases, expertise, reputations, and overall innovation strategies. The management of *design* is an important component of new product and service development. Design entails selection of elegant and efficient choices to provide a solution. It encompasses choices made in relation to aesthetic appeal and delight, impact, function, and reliability. These elements of MTI are examined in Chapter 7.

The management of *operations and process innovation* includes the way operations and production complement existing activities, and provide options for new innovation activities. Its management is concerned with broad business and organizational issues. Some of the innovations in the management of existing operations, for example, in quality will be discussed. And innovation in new processes, such as new relationships with suppliers, will be described. Specific focus will be placed on the move from mass to 'lean' and 'agile' production and consumption and the combination of operation capacities with those of design and development, and the integration of supply chains. MTI and operations are discussed in Chapter 8.

The eventual aim of MTI is the *delivery of value*, and the process of commercialization—that is, obtaining returns from innovation investments—is a central element of MTI. Appropriating value from firms' investments in technological innovation involves consideration of intellectual property rights (IPR), licensing, the creation of technical standards, speed, and secrecy, and the ownership of 'complementary assets'. The so-called appropriability regime identifies the extent to which firms can ensure that they receive adequate returns from their investment. Commercialization may not be immediate, firms can valuably expand options for the future through the innovation process, and this has to be considered when evaluating its commercial returns. These issues are discussed in Chapter 9.

**Box 1.2 Innovation in manufacturing and services**

The boundary between services and manufacturing industry is increasingly blurred (Quinn 1992; Miles 2000; Dougherty 2004; Davies and Hobday 2005). Is a company that designs car engines a manufacturing firm or a service firm? Can IBM be considered a manufacturing firm when the focus of its strategy is to supply customer 'solutions' rather than products? Are software houses (sometimes known as software factories) using highly computerized writing tools, making products? Many important activities carried out by manufacturing firms—marketing, distribution, engineering, design, maintenance, accounting—would be described as services if they were supplied externally. Many services such as bank telling are now delivered electro-mechanically, and the value of manufactured products often lies in intangible attributes such as speedy delivery, convenience of use, brand identity, and reliability, which, if not embodied in products, would be thought of as services (Lester 1998). Many service companies describe their offerings as products. Furthermore, many physical products are packaged together with intangible services (Davies 2004). An example is Ericsson's and Nokia's packaging of services around their products. As service companies create R & D capabilities—to increase product differentiation, reduce costs of developing and delivering services, and protect proprietary technology—they are dealing with many issues analogous to those in manufacturing firms. Therefore, the majority of the issues discussed in respect to MTI apply equally to services and manufactured goods. Cases and examples will be provided of both manufacturing and service companies.

The ways in which technological innovations are developed and used continue to change and MTI responds by being a dynamic and evolving field of practice. New challenges are emerging around strategies for technology-based competition, the role of the government, the contribution of basic research, the evolving innovation process, and environmental concerns. These issues are discussed in Chapter 10 of the book.

The management of information technology (IT) and information systems (IS) is incorporated within these areas and is not included as a distinct area of MTI. Many strategic and organizational issues, such as the development of new IT products and software and the use of IT and IS in R & D and operations, are included in the definition of MTI and are therefore discussed here.

## Why is MTI so important?

The question of why MTI is so important is examined from a corporate, national/industrial, theoretical, and individual perspective.

### A CORPORATE PERSPECTIVE

MTI is important for firms' growth, profitability, and survival. History is littered with examples of companies that went out of business because they could not keep up with the demands of innovation. Each of the various areas of MTI is important, but some are critical for particular firms. The ability of pharmaceutical and electronics firms to

## 6 WHAT IS THE MANAGEMENT OF TECHNOLOGICAL INNOVATION?

compete, for example, depends upon their capacity to manage R & D. It is R & D that provides the opportunities to create distinctive new products and markets. Drug companies, such as GSK, Pfizer, and Merck, rely on research to create highly profitable drugs for treating ulcers or producing AIDS inhibitors. Companies such as Sony in consumer electronics, Samsung in DRAM semiconductors, BMW in cars, HSBC with its online financial services (First Direct), and Google with its search engines, depend on new products and services to provide the means by which they compete, and these innovations to a large extent define their companies. Operations prowess endows companies, such as Toyota, with the ability to produce better cars more cheaply than the competitors, and enables electronics companies, such as Acer in Taiwan, to produce efficiently for major electronics industry customers in the USA, Europe, and Japan. The success of supermarkets, such as Wal-Mart and Tesco, depends to a significant extent on their highly innovative operations.

When NEC decided it wanted to develop expertise in semiconductors, which it saw as a key strategic technology central to its competitiveness in a number of industries, it used over a hundred technological alliances to do so. Powerful technology companies, such as Boeing, are heavily reliant on their communities and networks. Boeing now works collaboratively in the production of aircraft, with partners responsible for the design and manufacture of major components, such as engines, fuselage, and rudders. Boeing can no longer design and manufacture aircraft by itself.

Companies often fail to obtain value from their technological innovations. Ampex failed to see the real market for its developments in video recorders. RCA, famously, did not make the business transition from vacuum tubes to transistors. The effectiveness and quality of the commercialization process determine the outcome of technological innovation. Sony's Betamax video system was technically better than Matsushita's competing VHS system, but lost out in the competition for the consumer market. The IBM personal computer was in many ways inferior to other competing products, but became hugely successful. The ability of Matsushita and IBM to commercialize their innovations more effectively than their opponents provided their competitive advantage.

Of all the aspects of MTI, innovation strategy is the most demanding. Very few companies have consistently been capable of developing and implementing innovation strategies. Adopting leading positions in technology can confer significant competitive advantage. SAP, the German applications software company, benefited significantly from foreseeing the importance of using Unix then Microsoft NT systems with its customers. Similarly, when market assessments are accurate and prescient—such as when Matsushita saw the market in home video recorders—innovation leaders can benefit significantly. At the same time, leaders can fail to capitalize on new ideas, allowing product innovation followers, such as Dell, to succeed. As Chapter 4 shows, firms in the same industry pursue a variety of different strategies in line with their resources,

capabilities, and ambitions. When these strategies are well chosen, significant benefits accrue. For example, Benetton and Zara, the Italian and Spanish clothing companies, have been particularly effective at integrating innovation in products, operations, marketing, and sales, allowing them to achieve their competitive aims of quickly delivering ever-changing fashion goods to market. They can deliver 'fast fashion', ensuring that what Madonna wore at her Saturday-night concert is in the shops the following Wednesday.

## A NATIONAL PERSPECTIVE

The ability to manage innovation matters at national, regional, and local levels because it has implications for overall levels of employment, the types of work people do, and the ways in which countries, regions, and cities prosper or decline. Globalization of production and markets, together with increased use of digital communications and services, have led to significant restructuring of whole economies and the ways in which innovation processes are managed on a local and international scale. Nevertheless, there remains a strong spatial dimension to the management of innovation processes (Morgan 2004). Nations still matter for innovation.

Empirical research findings showing the importance of technological innovation include:

- High-technology industries grew more than two-and-a-half times faster than manufacturing industry as a whole between 1980 and 2003 (NSB 2006).
- Trade in high-technology goods (requiring high levels of R & D) doubled in real terms in the OECD countries between 1994 and 2003 (OECD 2005).
- High-technology industries in the USA increased from 11 per cent of domestic production in 1980 to 13.5 per cent in 1990, and to 34 per cent in 2003 (NSB 2006).
- Innovative countries and regions have higher productivity and income than the less innovative ones (Fagerberg 2005).
- The returns to R & D investment, both 'social' (to society as a whole), and 'private' (to the firm making the investment), are consistently assessed to be high. In a study of seventeen innovations, Mansfield et al. (1977), found the social returns from R & D investment to be 56 per cent, and private returns to be 25 per cent.
- Technological innovation has played a significant role in the economic transformation of the East Asian economies (Kim and Nelson 2000).
- Entire industries, such as the Swiss watch industry, and geographical regions, such as Silicon Valley in California, can be invigorated or depressed by technological change (Saxenian 1994; Utterback 1994).

## 8 WHAT IS THE MANAGEMENT OF TECHNOLOGICAL INNOVATION?

- At the corporate level, new products less than five years old are estimated to account for 30 per cent of the profits of US firms, and in high-performing firms to account for nearly half of sales and profits (Cooper and Edgett 2007).
- Innovative firms are more likely to be granted credit and easy access to finance than non-innovators (Czarnitzki and Kraft 2004).
- In the UK, innovators in both the service and manufacturing industries have higher productivity and productivity growth than non-innovators (Criscuolo, Martin, and Haskel 2003).
- Technology licensing and royalty payments increased in constant prices from \$7 billion in 1976 to over \$120 billion in 2004 (World Bank 2006).

## A THEORETICAL PERSPECTIVE

Empirical findings on the significance of technological innovation are reinforced by new theoretical approaches, which reveal the importance of innovation, particularly evolutionary economics and new or endogenous growth theory (see Box 1.3).

### Box 1.3 Evolutionary economics

The importance of technology for economic development has been well understood by political economists from Adam Smith to Karl Marx to Alfred Marshall, but it was Joseph Schumpeter who first placed innovation centrally in his economic analysis. For Schumpeter, innovation—defined as new products, methods of production, sources of supply, markets and ways of organizing—explained how economies grow: '[N]othing can be more plain or even more trite common sense than the proposition that innovation... is at the center of practically all the phenomena, difficulties, and problems of economic life in capitalist society' (1939: 87). Capitalism was understood by Schumpeter to be continually dynamic and evolving, and this dynamism was caused by more than firms simply responding to price signals in the market. Notions of equilibrium in economic models are considered to be transient rather than automatic. Evolutionary economics sees capitalism as a system that creates continuous variety—new ideas, firms, and technologies created by entrepreneurs and the innovative activities of large research groups (Nelson and Winter 1982, 2002; Dosi 1988; Metcalfe 1994, 1998; Nelson 1995). Selection processes choose from that variety through the decisions for firms, consumers, and governments. Some of these market selections are successfully propagated and are fully developed into new firms, businesses, and technologies that provide the basis for future investments in creating variety. Much of the variety and selections that occur are disruptive or fail to be propagated, so the evolutionary development of the economy is typified by significant uncertainty, disruption, and failure. From an evolutionary economics perspective, success in innovation explains the differential performance of nations, regions, and businesses.

Contemporary evolutionary economic theory (Andersen 1994; Dopfer and Potts 2007; Frenken 2000) continues to argue that economic growth and development is first and foremost a consequence of innovation, and it brings additional insight from complexity theory. Economic growth is an enormously complex process, involving multiple parties in open systems with resultant unpredictable outcomes. Innovation brings profits, but it also brings structural change (Schumpeter's 'creative destruction'), uncertainty, and 'wasted' investments.

The implications of evolutionary economics for MTI lie in the way it helps explain the central importance of innovation, yet shows that innovation is complex and uncertain and typified by failure. It highlights the central paradox of innovation: that it is essential yet continually problematical.

**Box 1.4 Major features of new growth theory**

- Technology is ‘endogenous’—a central part of the economic system, a key factor of production along with capital and labour.
- Although any given technological breakthrough may appear random, technology overall increases in proportion to the resources devoted to it.
- Technology produces ‘positive returns’. Traditional theory predicts diminishing returns to investment, yet sustained, robust growth can be achieved by technological investment.
- Investment can make technology more valuable and technology can make investment more valuable—a virtuous circle that can permanently raise an economy’s growth rate.
- Monopoly power is useful in providing incentives to technological research (Schumpeterian rent).
- The emerging world economy is based on ideas rather than objects and this requires different institutional arrangements and pricing systems taking into account, for example, that prices depend on development time, cost, and risk not unit production costs.
- The possibilities for discovery and continual improvements are endless.

Traditional neoclassical economics considers technology to be an ‘exogenous’ factor in explaining economic growth: essentially it is taken as given. Simply put, this form of analysis believes that productivity and growth are a function of combinations of the three productive factors: land, labour, and capital, with a large unexplained residual in the calculations. In this body of theory, technological innovation may be part of the explanation for this residual, but there is little concern to establish its importance. The sources of technology and the distinctive and idiosyncratic ways innovation is used in individual firms to create growth are ignored. Furthermore, technological investments, such as all capital investments, are assumed to produce declining returns over time (Verspagen 1993).

In contrast, new growth theory argues that technology is an important ‘endogenous’ factor explaining growth, and comprehension of the way technology flows between firms and industries is essential (Romer 1990), (see Box 1.4). Additionally, unlike conventional investments in plant and equipment, which generally have declining returns over time, technological investments are argued to produce positive returns through creating new knowledge, options, and opportunities (Arthur 1990).

## AN INDIVIDUAL PERSPECTIVE

The contribution to society of past and current innovators, such as Edison, Marconi, Steve Jobs at Apple, and Bill Gates at Microsoft, are well known and celebrated. But as we shall see throughout this book, innovations do not just occur through the heroic efforts of individuals; they most commonly result from the combined activities of groups of people and organizations building upon each other’s knowledge and experience. The

work they undertake may entail more of Edison's '99 per cent perspiration', than his '1 per cent inspiration', and indeed occasionally may be, as Nathan Rosenberg (1976) puts it 'grubby and pedestrian'. Yet innovation is the result of the application of innate human inventiveness and ingenuity. As we shall see in Chapter 6, creativity is something that everyone is capable of, and the application of the innovativeness of all of us is a source of excitement, challenge, satisfaction, and happiness.

## The challenges of MTI

The more the focus of innovation activity moves away from simple incremental improvements towards more demanding changes, and the greater the number of players engaged in its creation, the more MTI involves trying to manage something that is *complex* and *risky*. In addition to the intrinsic complication of many products and services, a key aspect of complexity lies in the systemic nature of contemporary business. Complexity in this sense is defined as having emergent properties: it is characteristic of systems that have multiple contributors and unpredictable outcomes. Furthermore, technology-based innovations, be they aeroplanes, cars, buildings, home banking, or mobile phones, are comprised of various component systems. Computers, for example, comprise central processing units, operating systems, applications software, disk drives, memory chips, power supplies, and communications devices, including keyboards and screens. The integration of these often highly complicated systems is a key MTI task.

Some of these complex systems have been described as a particular form of industrial production, requiring different management approaches (Hobday 1998). Thus, for complex products and systems (CoPS; including high-value products, capital goods, control systems, networks, and engineering constructs, such as aircraft engines, avionics systems, offshore oil equipment, and intelligent buildings), there are particular requirements for design, project management, systems engineering, and systems integration (Brusoni, Prencipe and Pavitt 2001).

Levels of risk are determined by a number of factors, including the extent to which innovation outcomes are unpredictable, costly, and appropriable. The innovative activities of firms, for example, are confronted by general *business* uncertainty of future decisions on investment; *technical* uncertainty about future technological developments and the parameters of technological performance and cost; *market* uncertainty about the commercial viability of particular new products or processes (Freeman and Soete 1997). With the high degree of risk and uncertainty of investments in technological innovation (see Chapter 3), and the very high levels of investment in it (some firms spend billions of dollars annually on R & D, and some industrial sectors, such as electronics and pharmaceuticals, spend over 10 per cent of annual sales income on R & D), there



are enormous pressures internationally on firms to reduce the costs of technological innovation or to get better returns from it.

There are challenges associated with all the methods used to ensure desired returns to innovation investment, such as whether intellectual property protection is awardable and can be maintained, or secrets can be kept. They explain why innovators so often fail to appropriate returns to their efforts, an issue examined in Chapters 3, 4, and 9. An additional consideration is the question of speed: how quickly can innovation be protected and returns achieved? New markets can develop very rapidly on the basis of new technology. In the decade since its development, it is estimated that global electronic commerce has become a trillion dollar business. Operating in such fast-changing environments poses challenges for many firms, but also opportunities for others.

Whether applied to developing or improving new products, processes, and services, MTI requires the *organizational ability to learn fast* and move quickly when winning notions emerge. As we shall see in succeeding chapters, firms develop organizational rigidities and can become averse to innovation and to external sources of ideas. All these challenges of MTI—complexity, risk, and learning—will be examined in this book.

## Case studies in MTI

Some of the aspects, issues, and common problems of MTI are briefly illustrated in the following short case studies, which are composite descriptions of actual companies highlighting the opportunities and issues they face.<sup>1</sup>

### THE US BIOTECHNOLOGY FIRM

The biotechnology firm emerged in the late 1970s in the USA. These firms began as vehicles for transferring new scientific discoveries in genetic engineering and immunology into industry, from government research laboratories and universities. Some firms were

<sup>1</sup> The description of the case studies derives from a number of research projects conducted by Mark Dodgson. The pump firm case derives from a research project in the British pump industry conducted by Professors Ron Dore and Hugh Whittaker. The Japanese electronics firm case is based on a study of the Japanese multimedia industry conducted with Professor Mari Sako, and research into a major Japanese electronics company in Singapore. The biotechnology example was based on a study of Celltech and the biotechnology industry. The Taiwanese case is based on numerous research visits to Taiwan, encompassing both large and small firms, and ITRI. Dodgson acted as advisor to the Taiwanese National Science Council's research programme in the machine-tool industry. The Indian software company case was based on a number of research visits to India and particularly to Bangalore, and on a case study of the international technology strategy of Ericsson. The Mexican study encapsulates some of the issues raised in the special edition of *Innovation: Management, Policy and Practice* (2005) on innovation in Latin America edited by Gabriela Dutrénit and Mark Dodgson.



initially expected to follow the pattern of the IT industry and duplicate the remarkable growth of firms such as Apple, Intel, and Microsoft. Few biotechnology firms, however, have grown to reach any size; many have been acquired by large pharmaceutical firms, and those that remained independent have focused mainly on product development, rather than becoming integrated producers and distributors.

Sidmuth Gene Technology (SGT) is an example of a US biotechnology firm seeking the best way of delivering value from its intellectual property. The company is based in Cambridge, Massachusetts, and employs forty-five people, including twenty Ph.D. scientists, in the development of gene technology repressing the growth of liver cancer.

SGT was started by two scientists, Elaine Weissman and Peter Georghiou, and a venture capitalist, Jenny Kuper, on the basis of a scientific discovery with two potential market applications. Laboratory tests had proven very successful, and Weissman and Georghiou believe their discovery would contribute to overcoming liver cancer, a disease that has produced a multimillion-dollar market in the USA.

The challenges facing SGT are considerable. They include managing the regulatory process needed to first, protect, and second, to develop its discovery. The company patented its discovery (which was the basis of Jenny Kuper's original investment), but there were a number of technical aspects allied to the major discovery that were not fully patented. This was due a certain naiveté on the part of the directors of the new company, and a concern to control the costs of patent registrations. Subsequently, SGT discovered that the real commercial value-added of its discovery lay not in the substance itself (a complex protein), but in the process of scaling-up and manufacturing the product. This process is delicate, involving growing the product in quantities of a few grams, using the medium of a specific animal gene. Considerable intellectual capital had been invested in developing this production process, but it had not been patented, and competitor firms had mastered the technology because Weissman and Georghiou had continued their academic tradition of publishing and discussing their research findings. Although the company knew it was in the knowledge-selling business, it failed to recognize which aspect of its knowledge was most valuable.

A second problem facing SGT is the amount of time and money it takes to gain approval for the development of a new drug. In the US regulatory system, it can take between 4 and 14 years, and cost in excess of \$750 million to secure approval for a new drug, due to the strictly controlled testing and approval process involved. SGT had initially focused on developing one of the two potential applications. It found, however, that although the new product worked, it did not perform demonstrably better than existing products in the marketplace. So they turned their attention to the second application, and this involved considerable delay and increased cost.

SGT could not possibly afford to proceed through the regulatory process of drug approval by itself, nor could it attempt to develop the huge marketing and distribution

effort required to bring its products to market. It had initially thought that its potential product was so efficacious that it would be sold on prescription in pharmacies, but subsequently had decided that greater supervision of use was necessary. It explored the possibility of targeting specialist care in hospitals. Weissman and Georghiou thought that whereas in the first case SGT would have had to sell the product rights to a large company that could afford the cost of marketing and distribution, in the second it would be able to retain some rights to the product. The cost of commercializing the product in this way, however, also proved prohibitively costly. To improve its cash flow, it had begun offering research services to other companies, using the expertise of its staff and its scientific equipment to analyze and sequence various genetic materials. After much debate and with some reluctance, it entered into a strategic alliance with a major US pharmaceutical company, receiving substantial investment capital in return for all rights to the developed product.

The management challenges facing the biotechnology firm's three directors are therefore considerable. The two scientists, rather than doing research, find their time consumed with liaising with regulatory bodies, and dealing with patent infringements and the drug approval process of the US Food and Drug Administration, performing routine procedures to assist cash flow, and managing the sometimes difficult and demanding relationship with the large partner pharmaceutical firm. Weissman and Georghiou want to maintain the excitement and desire for discovery in the company, and encourage the creativity required for continuing new product development and the building of the firm's knowledge base. Jenny Kuper had achieved considerable success in the computer industry, but had little experience of the pharmaceutical business. Her expectations of fast returns have not been fulfilled, and she is undecided about her exit strategy. She could continue to bankroll the company in syndication until other products are developed, or nearly developed, and then sell the company in an Initial Public Offering (IPO), potentially making very substantial returns. Or she could continue to encourage SGT to sell its intellectual property at a much lower return to a larger pharmaceutical firm, exposing herself to less risk.

The company faces important strategic decisions about its future. It could become a research services company, but where is the fun for creative scientists in that? It needs to decide whether to continue to fund its own expensive research to develop a pipeline of new products, or whether to be very ambitious and attempt to develop and market its own products, perhaps in collaboration with other firms. It has to consider whether to sell out to a pharmaceutical company, and if so at what stage it should attempt to do so.

## THE MEXICAN AUTOMOTIVE COMPONENT SUPPLIER

Mexico's *maquiladoras* are primarily manufacturing assembly firms. They enjoy the tariff advantages of duty-free importation of materials, provided goods are then exported back

into the USA (which in turn offers favourable tariffs compared to other countries). The *maquiladoras*, which have been an extremely important part of Mexican industry since the 1960s, have been facing severe cost competition from East Asian countries, and especially Thai firms.

Camino is a *maquiladora* supplying electronic circuitry to the US automotive industry. It is an example of a company wishing to move up the supply chain by providing more value-added products through innovation. It employs 120 people in the Jalisco region, and has been in operation since 1985. Traditionally the roughly 3,000 *maquiladoras* in Mexico compete on the basis of low costs and low skills, but many are upgrading their skill base.

Camino is owned by a married couple. Gabriela Camino has 20-years experience in marketing for CEMEX, one of Mexico's largest companies and a global supplier of building components, products, materials, and solutions. Rodrigo Camino is an electrical engineer with an M.Sc. in management, who has worked for a number of US multinationals in Mexico City. The couple decided they had had enough working for other people and also wanted to return to their home town of Guadalajara. They foresaw a business opportunity to upgrade a factory in need of investment, which would allow Rodrigo to pursue his ambition of developing a new kind of lighting system based on a circuit board design he had been working on for several years. They bought the company, renaming it in 1999.

The first challenge for Camino was to improve the machinery and quality control systems in the company, but Gabriela and Rodrigo recognized this was not by itself sufficient to support their ambitions. The company has a strategy of rapid technological upgrading, including the development of design and R & D capabilities.

The key component of this strategy is collaboration with other local suppliers and several of Jalisco's seventeen universities. It has involved extensive discussion with senior faculty in university engineering departments on skills requirements, industrial project placements for students, and collaborative research projects. Camino is keen to recruit more graduate electronic engineers with good design and project management skills. It has also recruited more than thirty technicians to operate and maintain its computerized machine tools. Creating the scale of resources necessary to invest in worthwhile research projects is beyond the budget of individual firms, and the Caminos have been highly active in creating a local industry support network allowing research projects with common applications to be explored, articulated, and funded. The network works closely with the Jalisco Quality Institute to help improve quality certification, Jaltrade (Jalisco Foreign Trade Institute) to support its exports, and Fojal (Jalisco Fund for the Promotion of the Enterprise) to access credit lines, training, and technical assistance. The regional government has been an active supporter of the network and always ensures that visiting trade delegations visit one or more of its members.

One of the major challenges for Camino is gaining the confidence of US customers that as well as providing high-quality production capabilities, it is a source of innovative products. Gabriela's marketing experience is valuable here, and she is a regular attendee at automotive industry trade shows, but the company has also cleverly used Internet-based innovation portals to demonstrate its capabilities. Several car manufacturers, and their top-tier suppliers, use Internet-based innovation markets to buy and sell technology (see Chapter 9 for a description of one such). Rodrigo has astutely observed the postings of technology requirements for automotive lighting, and constructed a portfolio of solutions developed by him, to demonstrate the company's design competence. The provision of several successful solutions has brought some very welcome additional investment funds into Camino. As some of these solutions have involved using instrumentation and resources at local universities, the company has been very careful to ensure that these universities receive appropriate remuneration. The latest technological solution provided by Camino received a certificate of commendation from Ford, which now features prominently in the company's marketing literature.

The Camino's strategy is based upon the development of highly reliable production and operations capabilities delivering quality components. They believe that this will provide a reputational platform from which they can offer their more innovative products. Should Gabriela manage to persuade a major automotive supplier to buy Camino's innovative lighting system, it will need to know that delivery can be guaranteed, either from Camino or its network of local companies.

## THE TAIWANESE MACHINE-TOOL COMPANY

Taiwan has a thriving machine-tool industry, encouraged by supportive government policies. Machine tools are a key industrial technology. They make up the components of other machines, including, of course, the parts of which they themselves are made. They perform the various processes involved in cutting metals and other materials, such as milling, turning, drilling, and boring. These processes are highly computerized, ensuring high quality and standardization. They are also increasingly complicated in the extent to which they are integrated into other aspects of manufacturing. In planning, factories operate using shared databases controlling production sequences and linking design and production. In production, machine tools are linked with robots and automated transfer mechanisms in flexible manufacturing systems.

Li Ping Machine Tools is an example of a company searching for innovative products and designs. Established in 1964 in Kaosiung in the south of Taiwan, Li Ping employs 250 people producing computer-controlled machine tools. Its products are used in the manufacture of sophisticated gears and valves for the automotive, chemical plant, and aerospace industries.

Li Ping began by producing traditional, non-computerized machine tools to turn simple components for the domestic bicycle industry. The founder of the company sent his son, Tim Zhang, to study engineering in the USA. After staying on to complete his MBA and to work for a few years for a supplier to the US aerospace industry, Zhang returned to Taiwan and immediately set about upgrading the company's technology and product range. He invested heavily in new design technologies and databases and embarked on a strong export drive assisted by favourable loans from the government. Zhang introduced computer control of the machine tools, purchasing the components from a Japanese supplier. He improved the design and functionality of the products so that they could perform several machining functions, by working closely with the Industrial Technology Research Institute (ITRI), a government research agency. ITRI receives funds from the Taiwanese government to develop the machine-tool industry and had assiduously collected information about technological advances around the world. It had created a research group in Taiwan, which undertook collaborative research projects for machine-tool producers, and Li Ping participated in and helped direct the technical aims of a number of them.

The company recruited a number of first-class researchers and engineers working in the USA and Europe to help with these developments, including a very talented industrial designer, Sarah Chen. Li Ping's interest in design was influenced by Tina Chou, Tim's wife, who has a background in the clothing industry and had completed a course in computer-aided design (CAD) during her studies at the London School of Fashion. The company's recent investments have been in advanced product management systems and software, which enable it to store and retrieve design data, to prototype virtually, and integrate more closely with its suppliers.

Tim Zhang faces a number of challenges. First, the imported Japanese computer and software component of the product is becoming an increasingly important element of the product's cost. A fluctuating Yen, and an inability to control supply, has made the company keen to produce the computer controls domestically; however, it lacks expertise in this area.

Second, competition in the standard machine-tool market has intensified. The demand in export markets and in Taiwan lies in highly sophisticated machines capable of cutting new materials to extraordinarily high precision, in production contexts ranging from the aerospace industry to the increasingly sophisticated bicycle industry. The company needs to develop expertise at the forefront of the interfaces between mechanical and electronic engineering. It requires access to basic scientific knowledge about complex mathematical calculus and the properties of new materials. It also needs to consider possible entry into the emerging field of additive technologies, such as rapid prototyping, which build parts layer-by-layer, rather than machining them to shape. The company has performed superbly in catching up with world's best practices and is now at the technological forefront. Its future competitiveness depends on developing technological

leadership and managing the substantial risk this involves. In addition, ITRI, although helpful in the beginning, is less capable of assisting a firm at the technological frontier. The current system of government support would need to change radically in order to continue to assist Li Ping and similar firms.

Li Ping has many challenges to deal with. Should it acquire one of the many innovative local computer companies and focus it on machine-tool controls? Or should it collaborate with a local computer company in developing its own control system?

Zhang is convinced that a key element in the solution to the problems he faces lies in the creation of highly autonomous and creative new product development teams. This is a rather radical departure in a traditionally hierarchical organization, and would require considerable cultural change. In his view these teams would be able to quickly design and deliver new options for the firm, ahead of competitors. He believes he has the necessary engineering skills within the firm to be able to absorb and use new scientific and technological information. He knows that in Sarah Chen he has a designer who is capable of leading projects that will produce tools that will be very attractive to customers. His challenge is to foster efficient teamwork linking research, development, operations, and marketing to make sure that the speed of response to new opportunities exceeds that of his competitors.

## THE JAPANESE MULTINATIONAL COMPANY'S CORPORATE R & D LABORATORY

Japanese electronics was one of the industrial success stories of the second half of the twentieth century. Throughout Japan's development, from catching up with the industrialized economies after the Second World War to its present position of international technological leadership in many fields, its firms have engaged in substantial R & D. Most Japanese electronics firms support centralized R & D laboratories close to the corporate headquarters.

Ohsaki Electronics is an example of a major multinational company rethinking the role of its corporate R & D laboratory. The company is part of a conglomerate with business operations in fifty countries, whose divisions produce consumer electronics, industrial power systems, heavy plant and equipment, hotel and retailing services, and office equipment. Its present governance structure was created in the late 1940s. Ohsaki is one of the world's most successful consumer electronics companies. It spends nearly \$3 billion on R & D each year, mostly on the company's fifteen decentralized divisional laboratories. Around 10 per cent of the company's total R & D spending is allocated to the central laboratory—Ohsaki Electronics Laboratory (OEL)—which employs 400 people in Japan and 120 overseas, and has responsibility for longer-term research, defined as having expected outcomes beyond five years.

OEL has been successful in providing scientific support to the company's divisional research functions, and its researchers are highly productive, measured by the number of academic publications and patents produced. It has successfully contributed to the development of the firm's technological base.

Masao Yamamoto, OEL's Director, is facing a number of conflicting pressures. He has to extend the range of expertise in the firm to meet the technological requirements of the businesses he supports. At the same time, because of adverse macroeconomic circumstances, his budget is being reduced and he is under strong pressure to speed up the returns to research efforts. The core areas of science underpinning the company's activities are becoming broader and therefore less controllable, and he no longer has the breadth of knowledge in his staff, or the range of scientific equipment, required to undertake the research he considers necessary. He understands the reasons for the firm's desire for faster results from its R & D investments, but knows OEL's major contributions to the company in the past have been through longer-term, more basic R & D.

The expertise required by OEL ranges from abstract theoretical particle physics to the development of new generations of embedded software. Its overseas research laboratories are linked to universities with particularly advanced expertise in these areas. While this system is working quite well in searching for and bringing excellent information back to Japan, Yamamoto is concerned that OEL may be locked into some rather inflexible university relationships. He is also worried about whether the lab is missing out on the potential of research conducted in emerging collaborative e-science networks and he has difficulty managing the international R & D labs. Their culture is different from that found in Japan, and tends to be much less hierarchical with a greater focus on individual creativity. He is also apprehensive about maintaining sufficient levels of expertise within his organization to be receptive to the wide range of inputs he needs.

Yamamoto's major challenge lies in converging the laboratory's mission of undertaking basic research with the greater demands he is facing for quicker returns to the Ohsaki's investment. He knows there are many instances of disruptive technologies emerging with the potential to threaten existing business strengths, but appreciates that in the present economic conditions Ohsaki's focus is getting the best returns from current investments. He is also under some pressure from within his company and from his contacts in the Japanese government to increase the amount of work with local universities, whose scientific expertise in required areas is gradually increasing, but is still some way behind that found elsewhere.

Discussions are taking place at board level in Ohsaki about securing funding for longer-term R & D investments. As part of this process, Yamamoto has been encouraged to explore new methods for justifying and measuring the returns to R & D projects, and for making earlier decisions about which projects to support or terminate. There is continual pressure from the board to improve R & D productivity.



One opportunity Yamamoto sees for achieving this lies in collaborative and subcontracted R & D. OEL has been engaged in a number of Japanese government-sponsored collaborative R & D projects, with varying degrees of success. While his staff have been uncomfortable sharing scientific research with companies with which they vigorously compete, experiences of working collaboratively with smaller overseas firms, which are generally much quicker at commercializing basic research, have been very positive. Yamamoto is also aware of the potential of a number of highly specialized local small research and software firms, whose creativity he wishes to access. He is aware, however, of the dangers of imposing Ohsaki's large-firm management controls and reducing the distinctive advantages brought about by partners' flexible, unbureaucratic structures and incentive systems, despite the management problems that such structures would pose for him.

## THE INDIAN SOFTWARE COMPANY

Located in several major cities, such as Bangalore and Hyderabad, the Indian software industry has grown over the last 20 years to be an international leader in software production. Indian software engineers are renowned for their high technical skills and comparatively low labour costs. It is these attributes that attracted companies, such as Microsoft, IBM, and Intel, to make substantial investments in India.

Bangalabad Systems is an ambitious, young, Indian software company seeking the best way to realize its plans for growth. The company is 10 years old and employs eighty-five people, only ten of whom are over 35. It works as a 'software factory', writing millions of lines of code as a systems-software subcontractor, mainly for a number of US and European firms and for two locally based companies. Orders come in with highly specified requirements, and the company writes the code on a jobbing basis, mainly using computer-aided software engineering tools.

Bangalabad was started by two brothers, both graduates of the prestigious Indian Institute of Technology. Jajesh Chakravarti worked as a programmer for a large German electronics company in India while his brother, Kumar, worked for a number of years as a software engineer for a major US software company. They inherited some family money and decided to start a company together. The company then recruited a chief executive, Nitin Shah, a relative and an experienced manager from a Canadian telecommunications company.

The company is based in Bangalore. The decision to locate there was made primarily on the basis of the city's large labour market for programmers and software engineers. Many multinational IT companies are based there. Furthermore, and importantly, its lower levels of pollution and traffic congestion mean that the general working



environment is more agreeable than many Indian cities. Bangalore is famous for its nightlife and bars—an important draw for the young workforce.

One of the company's major selling points is its strict adherence to quality management. As a legacy of Jajesh's association with the German company, a large amount of time and resources have been dedicated to winning ISO 9000 approval from the International Organization for Standardization (ISO). The company is one of the few in Bangalore to hold all relevant ISO quality management approvals.

At first sight, the company is doing well. It is profitable and has good relationships with its customers. But the Chakravartis are worried about meeting their very high aspirations, and these concerns led them to appoint Nitin Shah. One of the major problems confronting the company is a tightening labour market. Salaries are increasing rapidly, and good software engineers are now in a position to pick and choose among employers. Whereas a few years ago salary level was the primary consideration for employees, recently the company has been losing employees to other companies offering more interesting and varied work and greater leisure time, which has also made it more difficult for it to recruit new staff. The profit margins of the company are becoming squeezed, and the company's largest client has opened a software company in China, where salary levels are significantly lower.

A second problem lies in the rapid growth of the company. Neither of the Chakravarti brothers has managerial experience or training. Although the business has been successful in the past based on its excellent project and quality management skills, the brothers admit that they have 'flown by the seat of their pants' in other areas, such as marketing and human resource management.

Nitin Shah is aware of these challenges and thinks that the company's future depends upon managing collaborative development projects. He believes that software subcontracting of the sort the company has been involved in the past is a 'race to the bottom'. Prices and margins will continue to be squeezed. He knows that competitiveness depends on attracting the best and brightest workforce, and wants the company to be attractive to the most talented and creative local employees, but is aware that he will never be able to recruit all the clever programmers that Banglabad needs.

His business strategy has two elements. First, he plans to start selling applications software services to companies in the telecommunications industry, a sector he knows well. The company has experience in working in open, client-server, architectures and he feels it can produce software that will fit seamlessly with customers' current environments. He needs to identify the best-possible collaborators to work with, a major issue given the great size difference between his firm and his customers. Second, he realizes that the company's project management skills give the firm the opportunity to coordinate other local subcontractors to create significant scale in software writing projects. Here the company's edge derives particularly from expertise in using capability maturity module (CMM), a package developed to measure how effective a software organization is in

managing software projects to budget, and its ISO quality approvals. In effect, he plans to position the firm as the prime contractor, coordinating a network of subcontractors.

Nitin's plans include reorganizing the workforce around key collaborative projects and promoting five of the highest-potential engineers to project management positions. He recognizes the need to develop a technologically aware marketing function. Previously, the company's marketing was reactive and domestic in nature. It now needs to become international and proactive in identifying and working with key clients. He needs to develop the management skills of the workforce such that it can manage both clients and its own new software products, and at the same time develop the 'network management' skills required to coordinate local software suppliers. The company also needs to continue and develop its effective use of such tools as CMM, as it expands its technological ambitions in collaborative projects.

## THE BRITISH PUMP FIRM

The pump industry is well established in Britain, with a number of firms over a century old. It includes companies producing relatively simple products for irrigation projects in Africa, to highly sophisticated pumps used for oil exploration at great depths. Few firms have successfully diversified or grown to any significant size, and the industry has seen numerous company closures over the past decade.

Fuller and Gordon (F&G), a British pump firm, provides a classic case of a traditional manufacturing company and the changes confronting its managers. The company, established in 1875, is based in Huddersfield in the north of England and currently employs 550 people. It offers a wide range of specialized products for pumping industrial fluids, including some of the most highly corrosive and toxic currently in use.

The Managing Director, Joe Fuller, an engineer who has been with F&G all his working life, is very aware of the innovation challenges confronting his company. He remembers how 20 years ago innovation in the firm was driven by local sales representatives reporting customer dissatisfaction with a particular facet of the product. Occasionally, new products might have emerged from the R & D or engineering function of the firm, incorporating some improvement, which would prove attractive to purchasers.

Currently, Joe is confronted by a radically different and more challenging global competitive environment where innovation is the key to survival and growth. Cheap, high-quality pumps are available from lower-wage economies. Efficient pumps using lightweight materials and less energy are offered from a wide range of advanced economies, all with distributors or licensees in the UK. Competitors are experimenting with rapid prototyping technologies, the introduction of electronic sensors and controls, and the bundling of services around performance control and maintenance, providing customers with a whole new range of innovative choices.

To remain competitive F&G has to be exceptionally smart and strategic in its innovation activities. It must be intimately aware of customer needs; indeed, it may sometimes have to anticipate them. The company must consider how it might benefit from outsourcing some of its activities to lower-cost countries. It has to stay abreast of recent scientific and technological advances in new materials and designs, and it requires links with research groups in universities and research institutes to take on problem areas in pump technology, such as cavitation, which it cannot solve by itself. F&G has to decide whether and how it might add services to its traditional production offerings. In short, the company has to reconsider its business model around the use of innovation.

Since the 1980s, the company has invested in several generations of expensive CAD system to assist its design processes. These have been integrated with its production system to facilitate the efficient manufacture of its designs to the high levels of quality expected in the industry. On occasion in the past, substantial development work has gone into a product that subsequently the company was not able to manufacture as the cost of retooling the factory was prohibitive. Technological integration between design and production has alleviated this problem. Joe Fuller is aware of the advantages for the company from such past and any future technological investments, but he knows the challenges facing the company will not be solved by technology alone.

Fuller is sensitive to the need for the company's internal organizational processes to be highly efficient so that creative ideas are quickly acted upon. He believes speed to market will help the company establish a leadership position. In the past there have been miscommunications between design and production staff, leading to delays. He has to ensure that the different functions in the firm—marketing, engineering, production, distribution, and service—are well integrated so that they can respond to market demands and technological opportunities. And he has to find the necessary investment funds required to undertake investments in a flat market. He is also aware that many engineers in the firm believe that they have all the answers and are reluctant to work with external partners and sceptical of marketers.

This is a problem for Joe as the major challenge to F&G is the extensive changes to its market. Pumps are often components of systems in buildings, factories, power stations, and sewerage works. Customers require the firm to learn to integrate its products into the various systems of assemblers or contractors, sometimes overseas and often operating to different technical standards. The pump manufacturer must sustain continuous dialogue with the firms coordinating the creation of the systems—the systems integrators—to produce creative solutions. F&G must improve its capacity to integrate its CAD system with these firms through the sharing of databases and design practice. It is beginning to develop closer links with its suppliers in, for example, electronic control systems in order to be aware of any advantages to its customers that might derive from their developments. F&G sees its investment in CAD as providing the basis for it to develop skills in designing and integrating new product systems.

Joe Fuller has to decide whether F&G will remain a supplier of components or modules to these systems. Or, rather than being the passive instrument of the systems integrators, whose control over the system ensures them substantial profits from their negotiating strengths, whether it can become a systems integrator itself. Whatever direction the firm takes, Joe Fuller is aware that all F&G's activities must be driven by a clear strategy such that all efforts fit together to cumulatively develop a distinctive advantage over competitors in innovation. The firm has to establish a clear reputation in the marketplace for innovation as a component supplier or a systems integrator. It has to become an employer attractive to highly skilled, creative, and committed workers. He knows an international approach is needed for both market and technology as many customers and suppliers have overseas operations. Offshore production has to be considered as an option, even if it adversely affects employment in the home factory.

## Summary and conclusions

This chapter has defined MTI, analyzed its importance, and illustrated some of its key elements. It has shown why MTI is a major contributor to the construction and maintenance of competitive advantage and the ways in which managers meet their objectives. Whether considered at a national or regional level, in a particular industry or firm or from the perspective of individuals, technological innovation and its effective management is important.

MTI includes the ways managers create and deliver value from innovation strategy, R & D, innovation in products, services, operations, and processes, and commercialization, within innovation networks and communities. These activities can be complex, involving technological and organizational integration, and risky, with high levels of uncertainty, concern to control costs, and manage appropriability. In all considerations of technological innovation, learning is essential and this is a major underlying theme of this book.

As our examples have shown, and as will become clear as the book proceeds, MTI is a broad-ranging and challenging process, and even companies that have been highly successful at it in the past are continually being confronted by new difficulties. These challenges range from the day-to-day operational issues of how to make supportive technologies, such as CAD systems and CIM (computer-integrated manufacturing), more efficient, or dealing with government agencies to meet regulatory requirements, or major strategic issues determining the future of the company. The British pump firm needs to make innovation a core element of its business strategy, develop its innovative capabilities, and reconsider its business model: should it become a systems integrator? The US biotech firm similarly needs to consider its business model and decide whether

it becomes a research services company or an integrated pharmaceutical company or something in between—is it in the market for products or ideas? It also needs to manage its intellectual property more effectively. The Taiwanese firm must decide how it is going to access key technologies in the future, and develop design and new product development teams that can work quickly and effectively. The Japanese laboratory needs to reconcile its strategic, long-term function with short-term financial constraints and better manage its external and international relationships. The Indian software firm needs to decide how it is going to manage its future growth by producing more creative, higher value-added services in collaboration with international partners and local networks. The Mexican automotive supplier needs to upgrade its strong operations capabilities to offer innovative products, using Internet-based intermediaries.

The challenges of MTI can be seen to include far more than technological issues. They include managing organizational, financial, human resource, marketing, and collaboration issues. They also encompass major strategic issues, concerning the business models used to deliver value. Many of these challenges result from broader changes occurring in industry and business and it is to these that we now turn.

# **2 The Business Context for the Management of Technological Innovation**

## **Introduction**

Managing technological innovation requires an understanding of both the broad industrial and business context in which it occurs and the nature of the innovation process itself. Managers need to know what drives innovation and the different forms it takes. This chapter examines the changing nature of industry and business, with sections on technological change, the knowledge economy, business and innovation systems and networks, the changing nature of management, and globalization. Chapter 3 examines the innovation process.

## **The changing nature of industry and business**

A US car worker in the 1930s might have some basic recognition of the way cars are produced at the beginning of the twenty-first century at Fiat in Turin, or Nissan in Sunderland (and the prevalence of robots might confirm some long-held apprehensions about the future), but he would have little comprehension of the industry as we know it. If the 1930s car worker were transported to a contemporary US car plant, he would be amazed to learn that the cars were all designed, and some major components tested, by computers in electronic offices. The range of new materials being used in automobiles, their instrumentation, the efficiency of their engines, and the range of safety designs and aids offered would probably confound him. He would almost certainly be surprised to learn that the car bodies were designed in Germany, the engines in the UK, while other components were made in Mexico, Spain, and Australia. Most perplexing of all, no doubt, would be his discovery that he was working for a firm whose organizational and production practices were essentially Japanese.

A British insurance agent of the 1930s might have some basic appreciation of present-day principles of writing insurance policies, but would have little recognition of contemporary practices in Swiss Re in London, or AMP in Australia. She would, of course,

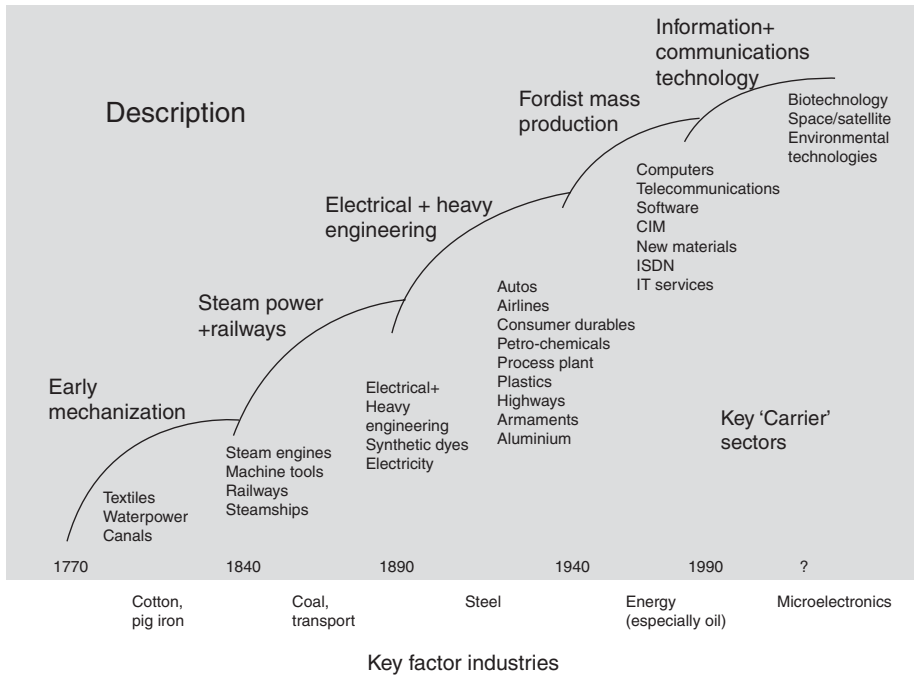
be overwhelmed by the ubiquity of computers in the office. She would be astounded at how easy it is to access detailed information on clients and the huge range of the company's available products, how simple it is to calculate the likely risks and returns of various policy configurations and options, and how data mining techniques can provide a flow of ideas for new service offerings. She would be very pleased to learn how documents are replicated and stored with previously unimaginable ease. She would be surprised to learn about the complex system of underwriting and financing in her company, deriving capital from pension funds in Brazil and South Africa. She would be delighted to see women in her industry no longer working only in the typing pool, but actually running the company. The way the combination of government and corporate policies and her own in-demand skills have created a working environment where she and her partner have access to maternity leave, and a company creche, may well leave her flabbergasted.

As industry and business continually change and, in some cases, alter radically in the course of one generation, it is necessary for managers to understand the historical forces shaping their conduct and organization. One of the forces with a significant impact on industrial and business development is technology, and an in-depth appreciation of the forces of technological change is vital for effective management.

## TECHNOLOGICAL CHANGE

In the 1930s Joseph Schumpeter noted that technological innovations were not evenly distributed over time or across industries, but appear in periodic clusters. According to one analysis, since the Industrial Revolution it has been possible to identify historical waves of intense technological change ('technological revolutions') characterized by rapid economic growth opportunities and radical social changes (Freeman and Perez 1988). These revolutions (which are described by Freeman and Perez as changes in *techno-economic paradigm*) depend upon clusters of mutually supporting technological innovations being accompanied by social innovations in areas ranging from organization and management, to taxation and employment law. Figure 2.1 illustrates these historical waves in simplified form and describes the key 'factor industries' associated with each wave. Factor industries, such as cotton, steel, oil, and information and communications technology (ICT) are typified by continually reduced costs, readily available supply, and an impact across wide areas of the economy.

According to this theory we are presently in the fifth wave of technological development, the ICT wave, with microelectronics being the major factor industry. Some speculate that we are entering a sixth wave, the life sciences wave, with biotechnology the key factor. The theory may help explain why some economies grow faster than others. As Freeman (1994: 88) described, those nations that prove most adept in making



**Figure 2.1.** Waves of technological development, 1770–1990

institutional innovations that match the emerging new techno-economic paradigm are likely to prove the most successful in growing fast, catching up, or forging ahead. So, for example, the economic growth of East Asian economies, such as Korea and Taiwan, has been based on the development of their technological capabilities (Kim and Nelson 2000). Those, on the other hand, that suffer from institutional ‘drag’ or inertia may experience a prolonged mismatch between their institutions (including management systems at firm level as well as government structures), and the growth potential of new technologies.

This theory is disputed in some circles, with particular concerns about the accuracy of periodicity and the relative contributions of particular technologies (Edgerton 1999, 2004). The cumulative effect of incremental innovations over extended periods may look revolutionary in retrospect. There are also questions about the impact of the revolutions on economic growth. As the concept of ‘waves’ of economic activity implies in this analysis, periods of economic growth are followed by recession and depression. Thus, the first wave, the Industrial Revolution in the late-eighteenth century, was followed by recession; the second wave, beginning in the 1830s and 1840s (‘Victorian prosperity’) was followed by a deep recession; the third wave in the late-nineteenth century, the *‘belle époque’*, was succeeded by the Great Depression; the fourth wave, with the post-Second World War economic growth and full employment, was followed by a crisis



of structural adjustment and high unemployment. Economists differ in their views of the length of the waves, whether they are shortening in duration (Perez 2002), and whether or not the fifth or future waves will be followed by downswings as severe as those experienced in the past, but many of the century's leading economists, from Keynes to Samuelson, believe that these waves of economic activity occur and are driven by changing investment patterns allied to technological change (Freeman and Louca 2001).

Despite criticisms of the theory of changing techno-economic paradigms it valuably emphasizes long time horizons in both the development and diffusion of technologies and the economic and social returns from them. It shows how technological innovation is a profoundly disruptive and uncertain process—changing techno-economic paradigms are genuinely 'revolutionary'. In this context, these revolutions themselves occur over what might appear to be relatively long periods of time: it can take several decades for a new general-purpose technology to become a core driver of economic growth. And the theory shows the immense social and economic transformations that occur during each new techno-economic paradigm. These are described by Freeman and Perez (1988) as involving new:

- 'Best-practice' forms of organization in the firm and at the plant level.
- Skill profiles of the workforce, affecting both quality and quantity of labour and corresponding patterns of income distribution.
- Product mixes, with new technologies representing a growing proportion of gross national product.
- Trends in innovation (both incremental and radical) as substitution of factors occurs.
- Patterns of location of investment both nationally and internationally as the new factors change relative comparative advantages.
- Waves of infrastructural investment to encourage diffusion of the new technologies.
- Waves of entrepreneurship and small, start-up firms in new technologies and industries.
- Tendencies for large firms to concentrate—by means of growth or diversification—in the novel factors.
- Patterns of consumption of goods and services and types of distribution and consumer behaviour.

Just as these transformations have occurred in the past, so they are still strongly in evidence at present.

Table 2.1 outlines some of the key features of major industrialized nations found in the 1950s and 1960s and contrasts them with the present situation. All these changes have profound effects on MTI.

**Table 2.1.** Major features of industry, 1950s–1990s onwards

1950s and 1960s ‘Convergence & aggregation’ (the 4th wave?)	1990s onwards ‘Divergence & disaggregation’ (the 5th wave?)
Dominance of large-scale, vertically integrated firms	Decentralized, network-based, flexible firms
Mass, production systems, dedicated machinery	Lean Production systems, flexible machinery
Mass stable, standardized markets	Niche, rapidly changing markets, customer sovereignty
Centralized management	Decentralized management
Monopoly and oligopoly	Intense competition
Strongly directive government, state-owned utilities and telecoms, protectionist industry policies, tripartisanship between government, unions, and employers	Non-interventionism, privatization and deregulation, government as regulator not provider, free-trade policies
Strong role of trade unions: from policymaking to demarcation decisions	Declining power of unions, employers’ concern for ‘employees’, multitasking
Separation of management and ownership	Share-owning incentives and Management buyouts
Full-time secure employment	Significant part-time, contractual employment
Some internationalization of industrial production	Globalization of business
Nationalism in trade and industry policies	Pan-nationalism in trade and industry (EU, NAFTA, APEC)
Predominance of Western models of management	Integration of international best practice in models of management
Science and research undertaken in universities and large firms	Substantial increase in scale and scope of science and research and diversity in provision (‘the new production of knowledge’)
Technology development a feature of individual firms; not-invented-here syndrome; antitrust legislation	Technological collaboration a feature of government policies and corporate strategies
Clear distinction between manufacturing services, and resources sectors	Blurred boundaries in the knowledge economy
Competitiveness derived from tangible assets: capital, land, and labour	Competitiveness derived from intangible assets: skills, capabilities, creativity

The significance of all these changes is summarized by Lester (1998: 322) as follows:

During periods of rapid change, investment in intangible assets—knowledge, ideas, skills, organizational capabilities—takes on special importance. The results of these investments—ideas for new products and processes, knowledge of new market possibilities, more competent employees, nimbler organizations—give the economy the flexibility to keep adapting and reconfiguring itself to new supply and demand conditions. They are the lubricants of the economic machinery.

Just as significant is the likelihood that the extent of the changes that have occurred since the 1950s will be matched by similarly dramatic changes in the 2030s and 2040s.

It is the change in techno-economic paradigm created by biotechnology that has provided business opportunities for start-up firms like the one described in the case study in Chapter 1. The USA has led the world in the commercial development of biotechnology, and its universities and government research laboratories have undertaken the basic research to create the seed corn for new businesses, some of which have emerged in a new organizational form: the biotechnology firm (Shane 2004; McKelvey 2000; McKelvey,

Rickne, and Laage-Helman 2006). Economies that are adaptive and have the capacity to promote and support entrepreneurship and industrial growth often reap advantages from the new technology. Government policies for intellectual property protection, and regulations that facilitate rapid and safe drug development, have encouraged the growth of the biotechnology sector. A large and highly technology-conscious venture capital industry has provided another form of institutional support. Industry has adopted new forms of organization, such as the close relationships between large pharmaceutical and small biotechnology firms.

Our entrepreneurial biotechnology firm was created by a new wave of technological development. Its operations are encouraged by a supportive national innovation system (NIS) (see the discussion below). Its growth relies on novel sources of finance, organization, and management. And its business future depends less on tangible products than on intangible knowledge, protected by patents. Although its original knowledge base was derived from traditional, if interdisciplinary, research in a university, much of its present knowledge is self-created, resulting from its leading edge R & D. The sources of knowledge production in this technology have been dispersed and expanded, features of what is called the knowledge economy.

## THE KNOWLEDGE ECONOMY

Political scientists and economists have long known that knowledge is central to economic growth. Friedrich List in 1841 wrote that ‘national wealth is created by intellectual capital’, and Alfred Marshall in 1890 argued ‘knowledge is our most powerful engine of production’. There is growing contemporary recognition of the contribution of knowledge in the economy and appreciation of the increasing importance of knowledge within it. The World Bank (1998: 1), for example, argues that ‘knowledge has become perhaps the most important factor determining the standard of living—more than land, than tools, than labor. Today’s most technologically advanced economies are truly knowledge-based’. The knowledge economy is not only about new creative industries and high-tech business, it is relevant to traditional manufacturing and services, and to businesses ranging from construction and engineering to retailing and banking. The OECD offers the following definition:

The knowledge-based economy is an expression coined to describe trends in advanced economies towards greater dependence on knowledge, information and high skill levels, and the increasing need for ready access to all of these by the business and public sectors.

Investments in knowledge by the OECD nations are estimated to account for 9 per cent of GDP (OECD 2005) and investments in knowledge including spending on R & D and on software, and public expenditure on education—are increasing faster than GDP

**Table 2.2.** Modes of producing knowledge

Mode 1	Mode 2
Problems set and solved in a context governed by academic community	Knowledge created in the context of application
Disciplinary	Transdisciplinary
Homogeneity of producers	Heterogeneity of producers; encouraged by information and communications technology
Hierarchical and continuing	Hierarchical and transient
Quality control through peer review	Socially and economically accountable and reflexive quality control
Emphasis on individual creativity	Creativity a group phenomenon

growth. These, and other indicators, such as the increasing proportions of high-tech goods in world trade in manufacturing industry, illustrate the growing ‘knowledge intensity’ of the developed economies. Between 1995 and 2004, for example, real expenditures on R & D increased by over one-third in the OECD countries (OECD 2006) and annual growth rates in internationalization of high-tech industries largely outstripped growth in manufacturing industry as a whole (OECD 2005). Measuring the market value of a company against its book value (Tobin’s  $q$ ) provides some indication of the intangible assets or knowledge in a company. A measure greater than 1 suggests the market value of a company is greater than its recorded assets, and therefore includes recognition of unrecorded intangible assets. According to one estimate, the  $q$  value of knowledge-based companies such as Zeneca in the UK measured 5, while the US-based Microsoft registered at 15 (DTI 1998).

There are a number of drivers behind the move to the knowledge economy: first, the increasing knowledge intensity of the processes of generating, producing, and commercializing new goods and services; second, the almost exponentially extended capacity of ICT to store, process, and transfer vast amounts of information; and third, the process of globalization of knowledge work (Defillippi, Arthur, and Lindsay 2006).

In addition to the changes in the extent of the importance of knowledge, the ways of producing new knowledge are also changing. Gibbons et al. (1994) argue that increased competition in industry has led to increased supply and demand in a market for knowledge. They distinguish between ‘traditional’ and ‘new’ modes of producing knowledge. Alongside traditional, disciplinary knowledge (which they call Mode 1), a new, broader, transdisciplinary and highly contextual form of knowledge is emerging (Mode 2) and supplementing Mode 1 (see Table 2.2).

According to this thesis, knowledge production occurs in an increasing variety of organizations, in firms and consultancies, as well as traditional universities, and in an increasing number of ways. Consequently, the form of the links between knowledge-producing and using organizations becomes important and may follow patterns different from those in the past.

## Business and innovation systems

Analysis of the ways contemporary business is conducted and innovation occurs has led to an appreciation of the importance of various forms of *systems* and *networks* combining the activities of firms and institutions. Rather than being autarkic, atomistic organizations, firms are part of numerous systems and the form of these has many implications for MTI. Chapter 4 of this book focuses on the MTI within such communities and networks. Studies have identified the range of actors and institutions involved in business and innovation systems and networks, the way these combine competitively and cooperatively, and the social and cultural basis of these interactions (Carlsson et al. 2002; Lundvall 1992; Edquist 1997; Lundvall et al. 2002; Gu and Lundvall 2006). By highlighting the systemic nature of business and innovation, they can usefully identify weaknesses that can then be addressed to enhance systemic strength.

Business and innovation systems and networks are themselves changing with the international transfer of good practice, seen, for example, in the transfer of Japanese production and new product development methods to the West, and US R & D management practices to countries like Japan, Korea, and Taiwan. Nevertheless, there are some characteristics of these systems that are nation specific—in social, cultural, and institutional terms—that are sufficiently important to support a form of analysis known as NIS.

The intellectual father of the systems of innovation perspective was the German economist Friedrich List. List wrote *The National System of Political Economy* in 1841 as a critique of classical economics and as a manifesto for the planned industrialization of Germany, which was an industrial laggard at the time. He argued that for Germany to become a major world power like England, a national programme would be required to improve its systems of production rather than reliance on the ‘invisible hand’ of the market. This programme, he concluded, must include the protection of ‘infant industries’, mobilization and extension of the education system, and government assuming the role of creator and nurturer of the innovative potential of the nation.

## NATIONAL INNOVATION SYSTEMS

The system of innovation that has received most analytical attention is a country’s NIS. National influences on innovation have an important bearing on how successful an individual firm is likely to be. Recognition of the systemic nature of innovation led, during the 1990s, to international work on NIS as part of the search for the sources of national competitive advantage. Studies of NIS began with Freeman’s (1987) analysis of the Japanese system. Since then, the NIS approach has been used in a number of country studies, most successfully in analysing the phenomenal growth of the Korean

economy towards the late 1990s (Kim 1997). The approach has been adopted by a range of governments. In South Africa, the concept was used to help set up the National Advisory Committee of Innovation (NACI). In Sweden, the main government ministry supporting innovation was renamed Innova, based on the concept.

There are a number of analytical approaches to NIS. Without oversimplifying, one of these approaches can be described as the ‘institutional approach’. It examines the relationships between the national institutions of finance, education, law, science and technology, corporate activities (particularly those that are research oriented), and government policies, and their influence on the propensity for innovation (Nelson 1993). Another form of analysis can be described as the ‘relational approach’. This analyses the nature of business and social relationships in nations, manifested, for example, in the way links between suppliers and users of technology encourage shared learning (Lundvall 1992). This approach focuses on the importance of socially embedded knowledge and learning. Patel and Pavitt (1994: 79) define NIS as ‘the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change-generating activities) in a country’. Included in this approach is the role of incentives such as temporary monopoly profits to encourage basic research. Also included are the strategic capabilities of firms, whose differences have considerable impact on technological innovation and competitiveness.

Although studies of NIS correctly point to the activities of firms as the key determinant of success, they also highlight the importance of government. This means that MTI managers need to be acutely aware of the regulatory systems in which they operate, particularly in respect of IPR, standards, and environmental issues, and the ways these are changing (See Box 2.1 and Chapter 9). They also need to understand government procurement and outsourcing policies. Many governments around the world are looking for increased contributions to national R & D efforts from the private sector, and for faster financial returns from their investments. Managing the linkages between public- and private-sector R & D has become a major management challenge.

As there is an increasing number of institutions with specialized knowledge of very different kinds—firms of various sizes, consultancies, research organizations, and universities—the ability to access different sources of knowledge and to apply these to their own needs becomes crucial for innovation. It is the configuration of these institutions and the (resulting) flows of knowledge that characterize different NIS and underlie the innovative performance of countries.

The NIS approach suggests that technological innovation is both more frequent and better managed, leading to more substantial national competitive advantage when the elements of the broader environment surrounding firms’ activities are well articulated into a system than in situations where each element works largely in isolation. Thus, the NIS approach brings a major new form of analysis to industry. The overall innovation

**Box 2.1 Regulations and innovation**

Government regulations are sometimes seen as a hindrance to innovation, limiting the scope and nature of firms' technological activities. There are, however, many examples where regulations stimulate the emergence and diffusion of new innovations, for example in environmental technologies. Government restrictions on emissions from new cars have played an important role in stimulating innovations in engine design and aerodynamics by automotive manufacturers (Jaffe and Palmer 1997; Porter 1991).

Statistical evidence supports the importance of regulations for innovation. In surveys of European firms, regulations were amongst the most commonly cited sources of information for innovation (see Chapter 5). For many firms, regulations contain information about new practices and help convince firms to adopt new processes they would not otherwise have considered. An example can be seen in the UK housing sector. Public sector social housing developments have been subject to increasing regulatory standards related to the use of environmentally sustainable materials and new technologies. New buildings in the UK, for example, must comply with stringent energy and emissions regulations and come equipped with broadband access.

The development of the new field of fire engineering provides a case study of the impact of regulatory changes on innovation. Making buildings safe for people in the case of extreme events is a challenging task for architects, engineers, firefighters, and regulators. Fires in buildings can spread rapidly and present severe threats to life and property. Traditionally, buildings' fire laws are managed through a set of codes and regulations. These codes are a set of rules that all new buildings have to meet, such as the minimum distance to an exit door. These regulations are based on considerable knowledge about materials, fire, smoke, and the movement of people during extreme situations, and they work well for simple, square buildings. In the design of an innovative structure, such as a new museum or tall building with an atrium, these regulations provide less guidance. In response to this problem, the UK government in the late 1990s shifted to 'performance-based' regulation for fire control and management. Under this new regime, if architects and engineers could demonstrate to regulators and firefighters that a building was safe, they could build it even if it did not follow prescriptive codes. This shift in regulation opened up great opportunities for innovation in the design of buildings, creating the new discipline of fire engineering. Fire engineers have become responsible for developing fire strategies, working collaboratively with architects, developers, contractors, regulators, and firefighters. The engineering of these strategies often requires the use of advanced simulation technologies to map and predict what will happen to the building and people during an extreme event. Simulations allow fire engineers to demonstrate building safety to regulators and firefighters prior to its construction, without recourse to existing codes. One innovation to emerge is the use of elevators for evacuation from tall buildings during fires. Fire engineers discovered if elevators could be made safe through pressurization and expelling of smoke, they could be used to evacuate people from buildings more quickly than stairwells. The elevators could also be used to bring in firefighters quickly to the location of the fire. In one tall building in London, this strategy reduced evacuation time from 22 to 12 minutes. The use of these new approaches to design could only have been possible with more flexible, performance-based systems of regulation. A new regulatory system created opportunities for novel fields of engineering to emerge and new, safer solutions to be implemented. These fire engineering solutions have also been used in projects around the world, including the Florence train station redevelopment, the Hong Kong subway, and the Freedom Tower in New York.

*Source:* Dodgson, Gann, and Salter 2007.

performance of an economy depends not so much on how specific formal institutions (firms, research institutes, universities) perform, but on how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, and legal frameworks).

A properly functioning NIS underpins the innovative capacities of firms, because the institutional structures provide collectively what firms cannot produce individually.



These factors include ‘public good’ research and the development of a broad range of expertise that is necessary for firms’ innovation strategies, but cannot be afforded by individual companies. This is especially true in small countries and for small firms whose resources are too small to meet the cost of basic research.

Effective NIS are continually changing. The importance of these changes can be seen if we return to our Taiwanese machine tool company case. The company’s growth was encouraged by a highly supportive system of research institutions and preferential government financing. But when the company moved to a new stage of technological innovation and arrived at the technological forefront, it had new requirements for the

### Box 2.2 League tables of NIS

As governments have become increasingly interested in the way innovation creates national wealth, more and more effort has been focused on creating league tables of innovation performance to enable countries to compare with one another. These efforts are not straightforward. First, it is not clear that countries are engaged in an ‘innovation’ competition. Under the right conditions, innovations can benefit all countries and therefore just because Finland has a higher rate of innovation than Ireland does not mean the Finns are happier or even richer than the Irish. Second, measuring innovation is complicated (as Chapter 3 shows) and many of the measures of innovative performance are imperfect, unreliable, and sometimes misleading. Third, since no single indicator of innovative performance is reliable, league tables almost always involve some weighting between several indicators. The results of these exercises are highly sensitive to the weighting system itself and the inclusion of some variables and not others.

Attempts to measure the innovation performance of countries or regions have been undertaken since the late 1960s. The collection of data on national R & D expenditure and patents, by the OECD, has allowed researchers to build rankings of countries, taking these indicators as a proxy for innovativeness. Over time, new variables have been added, including educational performance, expenditure on ICT, and Internet use. Takeoff in interest in league tables of innovation resulted from the publication of a report by Michael Porter and Scott Stern. This study, a later version of which was published in *Research Policy* (Furman, Porter, and Stern 2002), used number of US patents per capita as its measure of innovativeness and compared countries over time according to their ‘national innovative capacity’. In response to this work, the European Commission launched its own annual innovation league table—The ‘TrendChart’ or European Innovation Scoreboard. This is a more detailed and extensive attempt to measure innovativeness, and includes more variables than the Furman and Porter and Stern studies. These studies have been supplemented by a range of OECD reports that rank countries and regions by different measures of innovation. In addition, many countries and regions have conducted their own efforts at building league tables, adding new variables to those offered by others.

All these exercises are useful in generating debate and opening up questions about the performance of innovation systems. Governments use results from these tables to justify action (or even inaction). They should be interpreted with extreme care, however, as small differences between countries could be a result of measurement error. Furman, Porter, and Stern’s measure of patents per person, for example, is biased by the fact the number of patents produced by a country is likely to be a product of the industrial structure of the country. Some countries are specialized in industries where patents are effective means of protecting innovations, such as electronic and electrical products, whereas other countries focus on services and non-patenting manufacturing industries, such as food products or resource industries, where patents are largely ineffective (see Chapter 9 for a discussion of differences across industries in patenting).

For more information about League Tables of Innovation Systems, see the original Porter and Stern study at <http://www.compete.org/pdf/innovation.pdf>. The EU’s Trendchart or European Innovation Scoreboard can be found at <http://trendchart.cordis.lu/>. The OECD also publishes yearly statistics on science, innovation, and the knowledge economy at [www.oecd.org](http://www.oecd.org).



NIS. It now needed access to basic science, funding for long-term, more speculative R & D, and enhanced design skills. To assist this type of firm, the challenge for the Taiwanese NIS is either to change the strategies of existing, successful, institutions providing research, investment funds, and education and training, or to try to create new ones.

## REGIONAL SYSTEMS OF INNOVATION

The geographical proximity of firms developing and using similar and related products and technologies produces positive sum gains for business and innovation (see Box 2.2). Since the 1920s, when economist Alfred Marshall showed the importance of 'industrial districts' in providing various supports and synergies for firms, a great deal of research has examined the innovation-promoting potential of firms working and competing together in close geographical proximity. Michael Porter (1990), for example, argues that it is the geographical clustering of industries into systems connected by horizontal and vertical relationships, in combination with factor and demand conditions and firm strategies that creates innovation and international competitiveness. Industrial districts provide similar firms in proximity with 'aggregation benefits' that can be compared to the reduced transaction costs of integrated firms (Storper 1997).

There are several ways that technological innovation may be stimulated by geographical proximity. Cooke and Morgan (1994: 26) emphasize two. First, 'information, knowledge and best practice are rapidly diffused throughout the local milieu, raising the creative capacity of both firms and institutions'. Second, uncertainty is reduced through having a better understanding of the results of decisions. When there is great uncertainty about the future and nature of a technology or market, it is often necessary for individuals to meet face-to-face to exchange ideas (Storper and Scott 1995; Storper and Venables 2004). Geography shapes personal networks as distance constrains knowledge exchange (see Box 6.3). Regional areas may also be sustained by 'swift trust' between different actors (Brown and Duguid 2000). Within regions, informal traditions of reciprocity and understanding, and mutual concerns for maintenance of reputations, allow different actors with shared backgrounds to quickly form bonds with one another. Trust helps to mitigate the problems of opportunism and the time-consuming effort of writing contracts for cooperation or knowledge sharing (see below).

Differences in institutional norms and behaviours can provide regional competitive advantage. Since these institutional norms and behaviours have been built over time, they are difficult to imitate and therefore help a region sustain its advantage (Braczyk et al. 1998; Cooke 2001; Maskell 2001). Many advantages derive from the specific nature of the local labour market. Regions can be magnets for talent, attracting skilled and highly educated workers to them. They may be associated with the 'buzz' of a critical mass

**Box 2.3 The location of the creative class**

In 2002, the economic geographer, Richard Florida, published *The Rise of the Creative Class* (Florida 2002), raising awareness of the importance of cultural and social amenities in shaping patterns of regional innovation. Florida's book focused on the location of high-technology workers in the USA and the factors that shape why some regions (or cities) have more than others. Using a variety of data, including the quality of local cycle paths, the availability of kayaking and other water sports, as well as cultural festivals, Florida found a high correlation between these amenities and numbers of high-tech workers. In addition, Florida found that a large gay population (Gay Index) and high number of artists (the Bohemian Index) were correlated with a large share of high-tech workers. This finding led Florida to argue that such regions need the 'three Ts': talent, technology, and tolerance. Successful regions or cities offer dynamic, culturally diverse environments that appeal to those individuals with high professional and technical skills (Florida 2002). Florida's work has had a significant influence in the USA and elsewhere, by suggesting that governments should focus greater attention on the role of amenities in helping to support regional development. It would be unwise, however, to overextend the analysis. The mutual occurrence of these phenomena does not mean they are causally related. In other words, the concentration of high-tech workers may lead to the growth of gay and artist communities rather than the other way around. Regardless of the direction of this relationship (which remains the subject of considerable debate), this study opens a new window on the factors that might shape regional competitiveness, extending the analysis well beyond the usual measures of innovativeness, such as R & D expenditure and patents.

of people engaged in similar activities (Florida 2002). These environments may also provide opportunities for individuals to gain status and recognition for their achievements and in the process of doing so allow them to capture great returns from their knowledge or expertise. Our Indian software firm in Chapter 1 benefits significantly from being in the Bangalore region. Not only is it advantageous for its labour market, but it also provides the possibility for the firm actively to manage local software companies in a network where it acts as the systems integrator. Local availability of distinctive technological and research capabilities provide another source of advantage. Individual firms may gain considerable advantage from being located in the right place (Gertler 1995). Large multinationals—such as the Japanese electronics company described in Chapter 1, invest resources in setting up subsidiaries and R & D laboratories in locations where they can be 'in the know' about new technologies and ideas, allowing them to gain access to local networks (Bathelt, Malmberg, and Maskell 2004).

The importance of local labour market factors in encouraging innovation is seen in Richard Florida's research on the 'creative class' (see Box 2.3).

There are broad differences in regional business and innovation systems. Saxenian (1994), for example, compared what she calls 'local industrial systems' in California's Silicon Valley and Boston's Route 128 and found several key areas of difference (Table 2.3). Although both of these regions are renowned for their innovativeness, there are marked variations in the business structures and relationships that create it.

Regional governments are active supporters of innovation, investing funding in new research centres, technology parks, R & D tax credits, and a range of other policy measures in the pursuit of innovation (Eisenger 1988; Wolfe 1993). There has been

increasing use of the tools of economic, educational, and innovation policy by governments to help support firms in particular regions. In part, the government support for innovation regionally responds to the fact that many industries are highly concentrated in a relatively small number of locations. Many countries are characterized by huge differences between different regions, between ‘have’ and ‘have not’ areas, such as north and south Italy—discussed in Chapter 4. Kansas differs from California in relation to innovation. This polarizing trend appears also to be increasing. Indeed, ‘the more knowledge-intensive the economic activity seems to be, the more geographically clustered it tends to be’ (Asheim and Gertler 2004: 291). However, there are many regional differences in the type and level of government support, sources of science, technology and finance, industrial structures, and indeed innovation-supporting cultures. This is particularly evident in China, where over fifty new high-technology zones have been extremely successful in building high-tech industries precisely because they are exempted from many government restrictions and procedures applied in other regions of the country. The significant role of government in regulating and facilitating firms’ activities in globalized markets adds further complexity to the regional analysis of systems of innovation.

## SECTORAL SYSTEMS

National and regional systems are important influences on innovation, but many industries are remarkably similar across localities and countries. The film industry in Hollywood (Los Angeles) and Bollywood (Mumbai) are both organized around the delivery of films. Both rely on an entire ecology of different actors with dense and overlapping relationships, moving from one project to another in a moveable feast of people, projects, and organizations (Grabher 2002). The institutions and forms of organizing within an industry are often reproduced with only minor adaptation across a range of countries and regions. Hollywood and Bollywood are, of course, different in many respects, including the greater importance of family ties in India (Lorenzen and Taeube 2007), but in the development, production, and commercialization of films they share many common features. Indeed, there are fundamental differences between industries in their structure, institutional set-up, sources of knowledge, and use of different types of intellectual property that are relatively impervious to national and regional differences. In other words, the types and configuration of institutions that support innovation within an industry are often consistent or ‘invariant’ across countries.

Sectors involve much more than a set of producers with similar and competing products. Every sector is characterized by a range of actors that shape and influence patterns of innovation. To capture the full range of influences shaping innovation in a sector, Malerba developed the concept of ‘sectoral systems of innovation’: a ‘set of new and established products for specific uses and the set of agents carrying out market

and non-market interactions for the creation, production, and sale of those products' (Malerba 2002: 250). The concept of a sectoral system of innovation (SSI) encompasses a wide range of elements, including the knowledge and learning processes underpinning a set of product activities; demand conditions; a variety of actors, including firms, universities, and government; interaction within and across firms; competition and selection processes; and institutions such as standards, regulations, and labour markets.

An example of a SSI can be found in the footwear industry. In Italy, Brazil, and Spain there are large clusters of high-quality shoe manufacturers, designers, and specialist suppliers. In all these countries, shoe production is highly localized in a few areas. In Italy, women's designer shoe production is concentrated in the valleys between the three small towns in Marche (Sant' Elpidio a Mare, Porto Sant'Elpidio, and Montegranaro). In Spain, shoe production is concentrated in Valencia and Majorca. In Brazil, shoe production is based in the Sinos Valley in the state of Rio Grande do Sul (Rabellotti and Schmitz 1999). In each of these local clusters, there is an entire ecology of specialized firms, including sole makers, shoe box manufacturers, shoe making machinery producers, shoe designers, shoe buckle makers, and, of course, shoe manufacturers. Firms in these areas also rely on local institutions, such as shoe design centres, often sponsored by local or regional government and specialist professional service firms, which provide a range of unique services, such as advice on acquiring intellectual property protection for shoe designs. These clusters are supported by local traditions of shoe making, passed down from one generation to another. They are also helped by strong skills and training, both on-site and through local colleges and universities. The character and structure of one shoe cluster is remarkably similar to another. Making high-quality, designer shoes often leads to the creation of common institutions regardless of where they are formed, indicating that some elements of sectoral systems may be similar across countries.

SSI 'develop over time as a result of both conscious design and unplanned processes' (Malerba 2002: 262). Changes to sectoral systems are rarely smooth and costless. There is no 'optimal' SSI. Adaptation and evolution are important to ensure their successful development. Indeed, some sectoral systems are notoriously slow to change and adapt to new technologies and organizational practices. The construction sector often lags in the use and uptake of new technologies (Gann 2000). The 'backwardness' of the sector is partly related to its organization, with many small, cash-strapped producers of buildings. It is also a product of the fact that construction usually takes place on specific sites and there is therefore little opportunity to standardize products and processes. Most customers in the industry are inexperienced, risk averse, highly price sensitive, and usually one-time buyers. This means that the sector often lacks the 'tough customers' necessary for innovation (Reichstein, Salter, and Gann 2004). These factors have a tendency to 'lock' the construction sector into a low level of innovative performance when compared to others (Nam and Tatum 1988). This pattern of low performance is repeated across a

**Table 2.3.** Types of technology firm

	<b>Supplier-dominated</b>	<b>Scale-intensive</b>	<b>Information-intensive</b>	<b>Science-based</b>	<b>Specialized suppliers</b>
Typical core sectors	Agriculture Services Traditional manufacturing	Bulk materials Automobiles Civil engineering	Finance Retailing Publishing Travel	Electronics Chemicals Drugs	Machinery Instruments Software
Main sources of technology	Suppliers Learning from production	Production, engineering Learning from Design offices Specialized suppliers	Software and systems departments Specialized suppliers	R & D Basic research	Design Advanced users
Main tasks of technology strategy	Use technology from elsewhere to strengthen other competitive advantages	Incremental integration of changes in complex systems Diffusion of best design and production practice	Design and operation of complex information processing systems Development of related products	Exploit basic science Development of related products Obtain complementary assets Redraw divisional boundaries	Monitor advanced user needs Integrate new technology incrementally

Source: Pavitt (1994).

wide range of countries over time, illustrating the peculiarities that shape innovation at a sectoral level.

Pavitt (1984) developed a typology of technology-based firms and the sectors to which they belong (See Table 2.3). By differentiating between types of firm and sector he argued that the constraints, opportunities, and challenges for managers differ accordingly, highlighting their impact for MTI.

TECHNOLOGY SYSTEMS

Other perspectives on systems of innovation such as the ‘technology systems’ approach have developed in parallel with the geographical and sectoral perspectives discussed above. These also focus on systems, but emphasize the specific technologies of the constituent parts of national and international industrial structures.

Technological innovation is rarely a discrete, atomistic event. It invariably builds on extant technology or contributes an element to a broader technological system. Successful innovators integrate their operations with the technological systems of which they are a part. The ‘technology systems’ approach is in some ways similar to that of national and regional innovation systems, but also differs in a number of ways. First, the systems are defined by technology rather than national boundaries and although they are affected by national or regional culture and institutions, they can also be international

in nature. Second, technological systems vary in character and extent within nations. Thus there are different technological capabilities within nations: Japan is strong in electronics and relatively weak in pharmaceuticals, whilst Britain is the reverse. Third, this systems approach emphasizes technology diffusion and use rather than creation. It is particularly valuable when considering the existence of public-sector research and 'bridging institutions' for the development of different technologies (Carlsson 1994).

The CoPS approach briefly described in Chapter 1 provides another form of analysis. CoPS are essentially large-scale, highly integrated projects and their very complexity point to a number of interesting challenges related, for example, to mastering systems architecture, to managing knowledge accumulation in one-off projects, to building trust in temporary coalitions of firms, and to learning, when project teams are often disbanded and quickly realigned. These complex products, which are now designed, produced, and operated as discrete or small batch projects, have led to a growth in firms specializing in project-based activities (Acha et al. 2004; Davies and Hobday 2005; Gann and Salter 1998; Hobday 1998).

Considerations about business and innovation systems add considerably to the complexity of managing MTI. The challenges for MTI are to understand fully the systems of which firms are a part, and to integrate firms' activities into these systems effectively. To relate this discussion to our earlier example of the British pump firm, the firm faces diverse options for its future, which can be clarified with analysis of systems. It can concentrate on simply being a manufacturer of a single product, the pump. Or it can integrate its pumps into larger systems, comprising valves, controllers, gauges, and sensors, which might constitute a subsystem of a larger system, such as a building, a ship, or a refinery. At its most ambitious it could become a systems-integrator itself, taking responsibility for the design and manufacture of the whole system. This decision should be based on a clear understanding of its position within the business system (its relationships with suppliers, customers, and sources of research and finance) and its technology systems (how is the system configured and where does the greatest value lie in being a part of the system).

## **The changing nature of management**

New industrial structures and organizational forms require new ways of managing. Innovative, flexible, and imaginative management are needed to deal with the wide range of challenges facing firms and governments in technology, organization, finance, skills, and training, and in their increasingly complex and intimate external links. To deal with some of the challenges outlined above, companies are using many of the practices

**Table 2.4.** Two paradigms of management

Old paradigm	New paradigm
Organizational discipline	Organizational learning
Rigid organization	Flexible organization
Low trust	High trust
Command and control	Empowerment
Hierarchies	Markets and networks
Strategy as prescriptive plans	Strategy as process, building consensus, and unity
Not-invented-here syndrome	Receptivity to external inputs
Technology driven by strategic business units	Technology driven by core competencies
Functional structures	Business process structures
Knowledge is periodically useful and resides in few staff	Knowledge is a key source of competitiveness and its creation and diffusion is encouraged throughout the firm

of what we will call the new management paradigm, aiming to produce more openly communicative and flexible ‘learning’ organization structures.

There are some deeply pessimistic views about the future of management, typified by Anthony Sampson’s analysis of the changing nature of corporate life. Sampson (1995) argues that past certainty of occupation and security of employment are shattered. His ‘company man’ is insecure, powerless, and totally dominated by overpaid, unaccountable, and centralized top managers, who are themselves helpless in the face of increasingly aggressive corporate raiders. ‘Management’ is associated with reduced autonomy, increased control, and an inability to defend valuable, hard-earned, and unappreciated assets against dangerous external threats. This view of contemporary corporate management is exaggerated and builds on examples of old-style management rather than on emerging modern management practices.

The old, ‘scientific management’, command and control models of management are no longer considered to be effective or efficient. What matters to new-paradigm managers is attracting and retaining intelligent, highly motivated, empowered staff, and organizing them into coherent and cohesive work groups and networks. Good management encourages high-trust organizations where devolved authority and responsibility ensure fairer and more transparent decisions about resource allocation. Coordination and communication occur as natural features of the organization’s structure and culture rather than by management fiat. Alternatives to ‘bottom-line’ evaluations of success are becoming more common, as lessons are learned about the value of models of management more oriented towards growth and stakeholder satisfaction.

Some of the major contrasts between the old and new paradigms of management are shown in Table 2.4. MTI in the new paradigm will be discussed in the following chapters, but four of the most germane contextual issues—strategy, learning, knowledge, and trust—will be discussed briefly here.



## STRATEGY

Nowhere are changes in management clearer than in the role of strategic management. As Henry Mintzberg (1994) points out, in the old style of management, strategy meant the development of plans and prescriptions to be followed slavishly. In the new style of management, value lies in the process of developing a strategy such that all stakeholders are involved in assessing, understanding, and defining the firm's distinctive competencies. The aim is to define the activities of the firm such that it has a clear identity and purpose in a complex and changing world of seemingly infinite threats and opportunities. These identities and purposes derive in many instances from historical adherence to core values underpinning the organization, and the vision of what the company wants to be as a business (Collins and Porras 1995).

Having the organizational structures and processes that encourage participation in strategic formulation, and ensuring that internal organization facilitates communication across functional and other boundaries, also helps the efficient implementation of strategy. Herein lies a major purpose of strategy. The innovations and changes that occur in all successful organizations are disruptive and dysfunctional unless their purpose is well articulated and communicated, they are coordinated, and those affected by them feel a sense of ownership and influence over their nature and outcomes. Strategy in this sense helps build consensus and unity; it empowers rather than directs.

Strategy determines the extent to which the firm is prepared to undertake risky investments. As we shall see in subsequent chapters, there are advantages in having a balanced research portfolio with some high-risk/high-return projects. It is incumbent upon managers with strategic responsibilities to ensure that the longer term is not ignored when short-term pressures are strong. Our pump firm's expensive, and hence, risky investment in CAD showed a long-term perspective and was based on a strategic decision related to what the firm wanted to be in the future. The risk in entrepreneurial start-up firms, such as our biotechnology firm, is high. As we saw, it initially focused on the wrong product. Acceptance of that level of risk is determined by the strategy of the company's owners (in this case, the professional risk-taker, the venture capitalist). The ways firms develop innovation strategies are analysed in Chapter 4.

## LEARNING

Learning has been described as the defining characteristic of successful firms: the 'learning firm' (Senge 1990). Learning occurs in firms by means of investments in resources, and policies towards employees, other stakeholders, and other organizations with which they have business relationships. The literature on learning in organizations and firms reveals a number of features:



- Learning is a long-term activity and needs to be directed by cogent strategies.
- It is expensive.
- It can be encouraged by a variety of external linkages. Our Japanese R & D laboratory, for example, learns extensively from its overseas links and our Mexican supplier learns from its US customers.
- The organizational challenge for firms is to transfer individual learning into group practices and corporate routines and for positive organizational learning to inform the behaviour of individuals.

A feature of technological learning lies in the way its development is cumulative and path-dependent. That is, as far as a company is concerned, history matters and what you do today and tomorrow depends in large part upon what you did in the past. Learning is a key element of MTI, and is examined in greater detail in Chapter 4.

## KNOWLEDGE

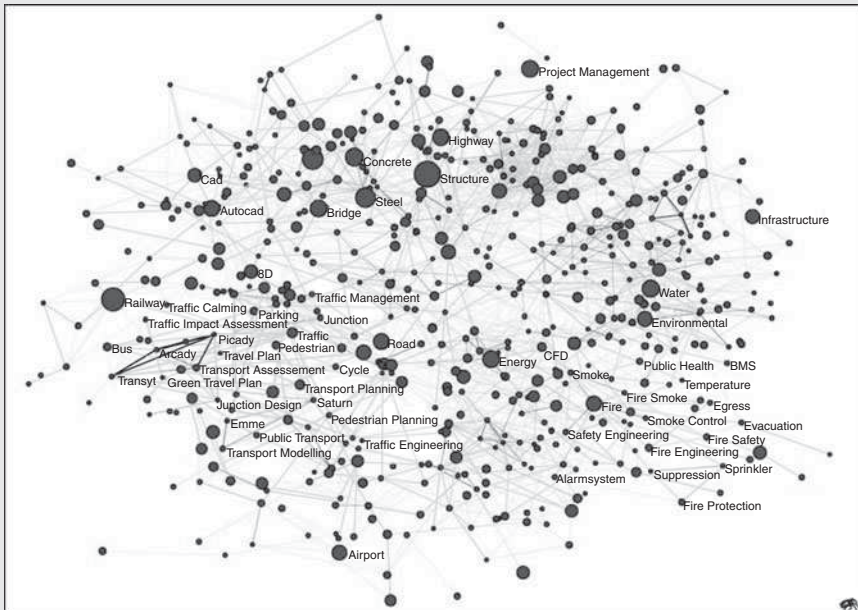
Like learning, knowledge has been described as a central defining characteristic of firms and their ability to compete. According to Kogut and Zander (1993), '[F]irms are social communities that specialize in the creation and internal transfer of knowledge.' It is argued to be increasingly important, as capital- and labour-intensive firms, and routine work, are replaced by knowledge-intensive firms and activity, and knowledge work (Starbuck 1992; Amin and Cohendet 2004). Four aspects of knowledge that affect MTI will be outlined here.

First, knowledge is something that needs to be managed (Argote, McEvily, and Reagans 2003; Davenport and Prusak 2000; Dixon 2000). According to Leonard-Barton (1995), knowledge-building activities are crucial elements in the definition of core technological capabilities, which are in turn integral elements of competitive advantages. These activities include shared problem-solving, experimentation, prototyping, importing and absorbing technological and market information, and implementing and integrating new technical processes and tools. As knowledge is an asset, it is something that needs to be accounted for, and a number of efforts are being made to develop procedures for measuring it (Sveiby 1997) and assessing how knowledge flows in an organization (see Box 2.4).

Second, knowledge has some distinctive characteristics when it is considered as something that is marketable. Economists describe knowledge as being non-rivalous (i.e., once it is produced it can be reused by others) and non-excludable (i.e., it is difficult to protect once in the public domain). It is also indivisible—that is, it must be aggregated on a certain minimum scale to form a coherent picture before it is applied (Johnston 1998). These features of knowledge have major implications for the management of intellectual property, and are discussed in Chapter 9.

### Box 2.4 Mapping knowledge at Arup

One of the great challenges faced by all organizations is knowing what staff know and can do. Managers often find it hard to map and track different activities across the organization. An example of how managers might seek to better understand their employees' innovative capabilities is seen in the use of knowledge maps in the engineering design company, Arup. Arup has 71 offices in 50 countries, and employs close to 7,000 full-time staff. It has been involved in some of the twentieth century's most significant building projects, which has helped cement its reputation in the industry for creative and innovative problem-solving. Every year, Arup undertakes over 30,000 projects annually for hundreds of different clients. The firm comprises over fifty specialist groups, such as environmental consultancy, acoustics, and structural engineering. The organization has highly advanced information and knowledge management systems involving a range of tools. IT-based systems are complemented by a range of human resource practices designed to encourage knowledge sharing, such as mentoring, job rotation, and experience sharing. As part of this system of sharing knowledge, each member of the organization is encouraged to complete an expertise text box in his/her company staff profile, and keep it updated. Their pages highlight areas of expertise and interest, and relevant publications. These skills descriptions are self-declared and voluntary. There is no checking of entries, and there is a strong belief that individuals will be honest and accurate. These pages are reviewed annually as part of the personnel appraisal process. About two-thirds of the firm's employees have completed profiles. These can be analysed by staff looking for help with a problem by using a powerful search engine. This information also provides a window into the innovative capabilities of the organization: What skills are being developed? What are the emerging interests of different staff? Using a combination of semantic and social network analysis (see Chapter 5), it is possible to build an overall picture of skills inside the organization. Figure 2.2 outlines the knowledge map for Arup, using skills descriptions. This approach allows the firm to gain insights into capabilities which are core to the firm and how they are being combined to deliver projects to clients.



**Figure 2.2.** Arup knowledge map

Source: Criscuolo, Salter, and Sheehan 2006.

Third, knowledge is not just information that can be stored, transported, and accessed electronically. It includes subjective, considered, and personal assessments of the value, meaning, and use of information (Nevis et al. 1997; Brown and Duguid 2001). Knowledge is, therefore, personally and socially embedded, and this is an issue challenging managers relying on electronic media as sources of knowledge advancement (see Box 6.3).

Fourth, it is necessary to distinguish between codified and non-codified (or tacit) knowledge. This distinction, identified by Polanyi (1967), separates knowledge that is easily communicated by, for example, being written down in papers or blueprints, and knowledge that cannot readily be described, such as craft knowledge, and that is learnable only by observation and imitation. The differences between tacit and explicit knowledge, and the links between them, provide the basis for Nonaka and Takeuchi's (1995) approach. Tacit knowledge, they argue, is developed in the individual, and they identify a 'knowledge spiral' by which it is translated into explicit forms.

## TRUST

Trust facilitates learning within the firm and in external relationships between organizations. Fukuyama (1995) suggests that national prosperity depends more on communitarian behaviour of shared values and sociability than on the rational selfish interest ascribed to humankind by so many economists. This emphasizes, of course, the importance of the relational approach to NIS. Trust has been seen as a key feature in facilitating continuing relationships between firms and individuals (Macauley 1963; Arrow 1975, McEvily, Perrone, and Zaheer 2003), and it can underpin economic relationships, particularly in the form of buyer-supplier relations (Sako 1992; Sako and Helper 1998), networks (Saxenian 1991; Sabel 1993; Nooteboom 2002), and technological collaboration (Dodgson 1993a) (see Box 2.5).

An example of the extent and benefit of trust was seen in Saxenian's (1991) study of successful Silicon Valley firms during the 1980s. She illustrated how firms exchanged sensitive information concerning business plans, sales forecasts, and costs, and had a mutual commitment to long-term relationships. Saxenian (1991: 428) argued that this involved 'relationships with suppliers as involving personal and moral commitments which transcend the expectation of simple business relationships'. A recent example of trust between firms can be seen in the framework agreement that unites the project team responsible for building Terminal 5 at Heathrow airport with the client, British Airports Authority (BAA). In 2006, T5 was Europe's largest construction project with a build-value of around \$8 billion. The client, BAA, knew that such a large project required innovation in design, products, and processes of delivery, but that to innovate in the UK construction industry using traditional forms of contract could lead to risks being

passed along the supply chain, major cost escalation, and delays. It therefore developed a collaboration framework in which all parties signed a risk–reward-sharing agreement, based on trust and which rewards innovation. In early 2007, the project was close to completion, on time and within budget.

In addition to trust being the cement in the relationship between firms, it is also essential within them (Fox 1974). Trust is necessary, according to Sabel (1993: 332), because, as markets become more volatile and fragmented, technological change more rapid, and

### Box 2.5 The extent of trust in industry

Trust, like innovation and learning, is by no means a straightforward concept. Sako (1992: 377) argues trust to be ‘a state of mind, an expectation held by one trading partner about another, that the other will behave in a predictable and mutually acceptable manner’. She argues that three types of trust can be distinguished. ‘Contractual trust’ such that each partner adheres to agreements, and keeps promises. ‘Competence trust’, which is the expectation that a trading partner will perform its role competently. ‘Goodwill trust’ which refers to mutual expectations of open commitment to one another.

Someone who is worthy of “goodwill trust” is dependable and can be credited with high discretion, as he can be expected to take initiative while refraining from unfair advantage taking...trading partners are committed to take initiatives (or exercise discretion) to exploit new opportunities over and above what was explicitly promised. (Sako 1992: 379)

Sako’s studies reveal the advantages firms (primarily Japanese firms) enjoy in subcontracting relationships that are not arm’s length, and are ‘obligational’. The form of the subcontracting relationships adopted by our Indian software company from Chapter 1 will be critical to the success of its network.

Trust is, therefore, central to a number of elements of the innovation process, in particular in inter-firm relationships and creative, committed organizations. But how trusting are inter- and intra-firm relationships? Hofstede’s (1980) analysis of comparative national cultures examined, amongst other issues, the question of individualism versus collectivism. Individualistic cultures are loosely knit and people look after themselves and their immediate families only. Collectivist cultures are characterized by a tight social framework where groups enjoy strong loyalties and are expected to demonstrate substantial mutual commitments. Hofstede’s (1980) analysis of thirty-nine countries found that the most individualistic was the USA. The Asian economies, by contrast, had generally low individualism. Whilst not equating collectivism with trust, this indicator might point to a propensity among many western countries to avoid cohesive networks and groups, while this is one of the features that has provided many Asian economies (such as Japan) with a considerable source of strength. In contrast, however, Gu and Lundvall’s (2006) study of China’s evolving NIS argues that it is the absence of trust between different actors that is constraining the development of innovation in that country.

High-trust networks exist in many countries and industries. In Australia (also individualistic according to Hofstede) there is a very cohesive network in the mining industry, and it is one of the most successful mining industries in the world. Such networks cannot exist without high levels of trust and the award of considerable discretion to other parties. Contracts encompassing the complex and diverse activities undertaken within the network would be virtually impossible to draft, let alone police. The efficiency of the system might also be enhanced by the existence of goodwill trust where parties offer more than was expected of them in the expectation that the favour will be reciprocated in the future. Throughout his studies of outsourcing in the Australian mining industry, Quinn (1992) was continually surprised by how little was actually written down in formal contracts (outside prices and broad parameters of performance). Such networks can also possess self-regulating aspects inasmuch as sanctions can be applied if a company misbehaves—that is, it can be excluded from further work with the other firms in the network.

product life cycles correspondingly shorter, it is too costly and time consuming to perfect the design of new products and translate those designs into simply executed steps. Those formerly charged with the execution of plans—technicians, blue-collar workers, outside suppliers—must now elaborate indicative instructions, transforming the final design in the very act of executing it.

The challenge for MTI in all the case-study companies described in Chapter 1 is to move away from the pessimistic Sampsonite view of management, and towards the new paradigm of management. Whether working in a manufacturing firm in the UK, Taiwan, or Mexico, a science-based firm in the USA, a Japanese multinational, or an Indian services company, the challenge is to use strategies that focus on learning and knowledge and are based on trust. It is the ability of firms to be flexible, to empower their workers so as to encourage the creation and diffusion of knowledge, engage effectively with external parties, and to use strategies to develop unity of purpose, that will make these firms effective organizations and ensure their future competitiveness.

## Globalization

Globalization is a broad term encompassing a wide range of issues and developments. It includes changes in corporate strategies in relation to production, marketing, finance, and R & D; from the corporate perspective, it can be conceived as the search for competitive advantage across national borders. General Motors (GM), which operates 365 facilities in over 50 countries, defines being global as ‘taking advantage of your global resources to do a better job of bringing customer-valued products to market, faster and for less money than your competitors can’. An indicator of raised levels of globalization is the threefold increase between 1960 and 2000 in the value of all the USA’s imported and exported goods over the rate of GDP, to exceed 20 per cent of GDP by 2000, and the increase in cross-border investments from 1.1 per cent of GDP in 1960 to 15.9 per cent of GDP in 2000 (Dam 2002—quoted in Gritsch 2005). Another indicator of globalization is the rise in number of start-up firms that are ‘born-global’ and evidence to suggest that entrepreneurs who start their businesses simultaneously in a number of different countries are more likely to reap spectacular rewards, although they also run higher risks of failure (Autio 2000; Sapienza, Autio, and George 2006; Liesch et al. 2007).

There are various drivers behind globalization.

- *Greater participation in, and integration of, world trade.* An increasing number of nations are becoming involved in world trade and are subjecting themselves to the conditions and disciplines required to participate actively in it. Membership of the World Trade Organization (WTO), and its predecessor, the General Agreement on Tariffs and Trade (GATT), increased from 62 countries in 1967, to 130 in 1997,

and 150 in 2007. As part of this expansion, the Asia-Pacific has become a centre of international production and exports, and its increasingly affluent markets are important components of world trade. Similarly, but to a lesser extent, the Latin American countries and transforming East European nations have also expanded their international trade links.

- *Liberal government policies.* Governments internationally have followed the paths of deregulation and tariff reductions, encouraged by the WTO, and have lifted the constraints of protectionism and facilitated greater investments from overseas in important areas such as telecommunications and banking.
- *Changing corporate strategies.* Companies are increasingly internationalized. The stock of Foreign Direct Investment (FDI) in 2004 was estimated at \$9 trillion, attributed to some 70,000 transnational corporations and their 690,000 foreign affiliates, whose total sales amounted to almost \$19 trillion (United Nations 2005). Multinationals are more prepared not only to invest overseas, but to form strong partnerships and joint ventures with overseas companies. The Asian strategy of the German chemical company BASF, for example, includes nine joint ventures in China (one shared with DuPont) and a joint venture in Korea. It is the largest shareholder in the Japanese pharmaceutical company Hokuriku. It is constructing a major manufacturing plant in Malaysia, and is forming a joint venture with Malaysia's largest company, Petronas, to create another. FDI can occasionally involve the transfer of technological and managerial expertise, which can then diffuse through the economy and improve the nation's capacity to operate in global markets (see Box 2.6).
- *Creation of global capital markets.* Liberalized capital markets have encouraged cross-border capital movements. Capital is increasingly available internationally as major financial markets, such as Wall Street and the City of London, become more global in orientation. Daily foreign-exchange turnover increased from \$15 billion in 1973 to \$1.2 trillion in 1995 and an average of around \$1.9 trillion in 2004.
- *Capacities of ICTs.* Technologies such as satellite and broadband communications systems and the Internet have provided firms with the potential to facilitate communications across borders. The cost of a three-minute telephone call between New York and London fell from \$300 in 1930 (in 1996 dollars) to \$1 in 1997 (*The Economist*, October 18, 1997). By 2004 it cost around 20 cents. Companies such as GM use common computer and networking protocols to deal with the complexity and scope of product development on a global scale.
- *Increasing market homogeneity.* While it is important not to exaggerate the extent to which cultures and markets are becoming alike, the ubiquity of certain brands and images—Disney, Coca-Cola, Sony, McDonalds, Nike—reveal a certain convergence in international tastes and experiences.



In addition to these factors, the creation, use, and sale of technology provide a major reason why firms are globalizing. The United Nation's 2003 *World Investment Report* estimates that 76 per cent of all international royalties on technology involve payments between parent firms and their foreign affiliates, showing that multinationals play a key role in disseminating technology around the globe. OECD data show that R & D performed abroad by foreign affiliates represent, on average, over 16 per cent of total industrial R & D in the OECD in 2003 (OECD 2005).

Early research on the international diffusion of technology argued that firms developed technology in their home markets, then exported their products, which led to overseas production and eventually to some simple R & D activities to adapt products to local tastes and requirements (Vernon 1966). It was subsequently recognized that some firms, particularly in high-technology sectors, undertook R & D concurrently in different markets (Vernon 1979). In the 1990s, firms became more globalized in their orientation towards technology development and use. There continues to be a debate about the extent to which R & D has become internationalized. Some argue that R & D is such an important strategic activity that it essentially remains controlled in corporations' home nations. Others argue that increasing amounts of R & D derive from foreign investment.

The following research findings indicate the extent to which R & D and patenting are globalized:

- From 1990 to 2002, R & D expenditures in the USA by majority-owned affiliates of foreign-based multinationals rose from 8 to 14 per cent of total US industrial R & D performance. R & D expenditures by US-owned companies abroad rose from about \$12 billion in 1994 to \$21 billion in 2002 (National Science Board 2006).
- Companies, such as Nortel, Nokia, Lucent Technologies, and Dow Chemicals, each have more than ten research centres located overseas. Intel's 20,000 R & D employees are located in more than thirty countries.
- 45 per cent of US patents are registered from abroad (NSB 2006). 15.8 per cent of all patented inventions in the European Patent Office (EPO) were owned or co-owned by a foreign resident in 2000–2, an increase from 10.8 per cent in 1990–2 (OECD, STI Outlook 2006).
- Between 1995 and 2001, R & D investments of foreign affiliates rose in value from \$29 million to \$51 billion in the OECD, and R & D performed abroad by multinational companies has increased since 1995 relative to R & D performed at home (OECD, STI Outlook 2006).

A case of just how globalized technology can be is provided by a Daewoo telecommunications product. Daewoo Telecom, the Korean company, developed a new switching system for the Korean telecommunications network. The development cost roughly \$25 million over three years, and involved around 350 engineers. Much of the background

work was done in Korea; however, substantial software coding was done in New Delhi. An important technical requirement in which Daewoo had no expertise, the advanced intelligent network, was developed in Daewoo's US Telecom Research Center. This centre is headed by an American, previously from Bell Labs, who sourced some of the required technology from a company located in Princeton, New Jersey. The product was considered for purchase by Russia, Uzbekistan, Ukraine, Kazakhstan, India, and Burma.

In all discussions about the extent of globalization of R & D, it is clear that there are broad differences between countries. European firms tend to be more internationalized in their overseas R & D investments than US firms, which, in turn, are more globalized than Japanese firms. Firms based in smaller countries, such as the Scandinavian nations and the Netherlands, do not have a large domestic market, and if they are to undertake substantial R & D projects, they have to exploit the results internationally.

One of the major explanations of the greater globalization of technology is the greater balance in international contributions to R & D. The US share in the seven largest industrial nations' R & D reduced from 70 per cent in 1960 to less than 50 per cent in 1994. Recent estimates suggest that the USA accounts for approximately 44 per cent of the R & D expenditure of the OECD countries (UNESCO 2005). Countries such as Korea and Taiwan, which have grown rapidly in terms of their technological expertise, are undertaking greater levels of R & D and patenting in the USA. Another reason for increasing globalization is that governments invariably welcome and encourage overseas R & D investment and may have incentives to encourage that investment. Singapore, a classic example in this regard, offers a range of government grants and incentives. Despite some concerns voiced in the USA about the negative consequences of overseas companies accessing US science cheaply, a number of reports have revealed the benefits of overseas R & D investment, particularly through the encouragement of highly skilled employment. Whilst this globalization of technology is occurring, it is important to note that it is primarily in Japan, Europe, and the USA that it is most advanced.

Another aspect of globalization is the way science is increasingly internationalized, with a large proportion of academic publications being derived from international collaborations, particularly in basic research. Between 1988 and 2003, internationally co-authored articles doubled in share from 8 to 20 per cent (NSB 2006).

Firms have different motives for globalizing their technological activities. These are described as: (a) global exploitation of technology; (b) global technological collaboration; and (c) global generation of technology (Archibugi and Michie 1995). The global exploitation of technology is considered to be akin to export flows, and is primarily the incorporation of technology embodied in products and services. This would occur if our Taiwanese machine tool company or British pump firm sold its products in Japan in configurations that met national standards requirements. There may be some limited MTI considerations in respect of adaptation of these products to local requirements either at a local level or in the home market. Global technological collaboration and its



**Box 2.6 Globalization and national innovation systems**

Despite increases in globalization, the nation remains the most important innovation arena. What happens inside national borders largely determines the success of the national economic endeavour. It is still within the national arena, for example, that the majority of regulations are determined, and that policies for research, training, protection of intellectual property, access to finance for development, and so on are decided. Furthermore, research shows the importance of national, cultural differences in approaches to product development and innovation (Ettlie et al. 1993; Zhang and Dodgson 2007). Archibugi and Michie (1995) confirm this analysis from another point of view. They present evidence that, although transnational firms exploit technological opportunities in a global context and collaborate internationally, they also rely heavily on home-based technological infrastructure for the generation of technology. They conclude that national innovation policy remains an important determinant of the international competitiveness of nations, despite the globalization trend.

This reliance is partly due to the crucial importance of innovation ‘speed’—the reduction of lead times for innovations to reach the market if they are to be profitable. This speed is significantly affected by conditions in the home market, which impact on the ease of creating and operating various technological developments (Teubal 1996). If the home market is not appropriate (has the wrong industrial and, especially, customer mix, a poor R & D base, or poor provision of finance) initial marketing, sales, and product testing cannot be carried out effectively.

It is for reasons such as these that Porter (1990: 19) concludes that while globalization of competition might appear to make the nation less important, instead it seems to make it more so. With fewer impediments to trade to shelter uncompetitive domestic firms and industries, the home nation takes on growing significance because it is the source of the skills and technology that underpin competitive advantage. This point is developed by Meyer-Krahmer (1999: 3), who argues that:

[T]he winners in a closely interlinked world economy will probably be those locations which, owing to competence and openness, become centres of information, communication and knowledge application. It is the overall attractiveness of a location which is important. Future national innovation policies will have to increase this attractiveness, not only by encouraging individual breakthroughs, but also by supporting innovative networks, while at the same time optimising a number of other locational factors in order to facilitate leading edge markets.

management would be a major issue if the US biotechnology firm began collaborating with a European pharmaceutical firm. This is considered in detail in Chapter 5. Global generation of technology is probably occurring to a much lower extent than the other categories. It would be an important element of the activities of the Japanese R & D laboratory as it tries to develop and source technology from overseas. This has many implications for MTI that will be explored in Chapter 6.

## Summary and conclusions

This chapter has described some of the major changes occurring in business and industry that affect MTI. It has analysed how revolutionary changes in technology require concomitant changes in industrial structure, firms’ business models, management, and organization to take advantage of new technological opportunities. The changes have led some analysts to argue that we are moving to a ‘knowledge economy’. These changes

can be profound and require firms to adjust to them rapidly. The chapter analysed the importance of various kinds of systems and discussed the value of the new forms of analytical frameworks that enable firms to understand their position within, or integrate themselves in, these systems and networks so as to benefit from their membership. A new paradigm of management was outlined and its importance for the new industrial structures described. MTI has to reflect these changes and contribute to them in creating a more efficient and empowered form of management. The relationship between globalization and innovation, and how this poses new challenges for MTI, was also examined.

Effective MTI requires decision-makers to be very aware of the context in which they operate. Managers need to understand the positions of their firms within their surrounding business and innovation systems. They need to comprehend the opportunities and challenges brought by broad technological and managerial changes and by globalization. And they need to possess deep knowledge about technological innovation itself, which is discussed in Chapter 3.

# 3 Technological Innovation

## Introduction

Managers of technological innovation have to know about the broad and aggregate features of technological innovation itself, as well as the context in which MTI occurs. They need to know about the different types and levels of innovation. They need to appreciate the strengths and weaknesses of the major measures of innovativeness, such as R & D investments, patenting performance, and innovation surveys. Managers need to understand how the innovation process is changing and how firms can search amongst the many different sources of innovation. And they need to appreciate the various outcomes of innovation, including how they are diffused and adopted by individuals and firms. These issues are the concern of this chapter.

As we saw in Chapter 1, innovation is ubiquitous and is a management priority for a wide diversity of businesses. It is also something of a moveable feast, changing in both *outcome* and *process*, which adds to its challenge for management. The changing innovation process is analysed in this chapter and the emergence of a ‘fifth-generation’ innovation process is discussed. Innovation outcomes—new products and services—are continually changing, and are discussed in Chapter 6. To illustrate the defining feature of technological innovation as a continuous quest, Box 3.1 describes the unremitting efforts of inventors and innovators to produce a better mousetrap. Essentially, innovation is as much a journey as a destination (Van de Ven et al. 1999). The more that is known about the journey—its means, circumstances, and purpose—the more rewarding it is likely to be. The better-informed managers are about the nature, process, source, and outcomes of technological innovation, the more likely they are to be able to use it to deliver value.

## Types and extent of innovation

The type and extent of technological innovation varies, with consequences for its management. Researchers have analysed extent and type of innovation according to whether it is:

- *Radical* or *incremental* (Freeman 1974)—that is, the extent to which a technology has changed, or the degree of novelty of an innovation. Radical innovations include breakthroughs that change the nature of products and services, such as

**Box 3.1. Continuous innovation: The quest to build better mousetraps**

Some technical challenges perennially confront and taunt inventors and innovators. One such challenge is the design and manufacture of mousetraps. Mice are a common pest. In London, mice outnumber people and in developing countries they are major carriers of disease. Humans have long struggled to find the most effective mechanism for catching mice. The oft-quoted phrase ‘build a better mousetrap, and the world will beat a path to your door’ is attributed to the nineteenth-century essayist, Ralph Waldo Emerson. It suggests that when an inventor is ingenious, great opportunities arise. The history of innovation in mousetraps, however, suggests ingenuity alone may not suffice. There are some 4,400 mousetrap patents registered with the US Patents and Trademarks Office (USPTO). Yet only a small number have ever been successfully commercialized. This has not deterred would-be inventors from developing even more elaborate and sometimes effective mousetraps. Indeed, some 400 people a year apply for mousetrap patents in the USA. The most successful design was developed in 1899 by John Mast of Lititz, Pennsylvania. This is the familiar snap trap, with a spring steel wire that swings down on the mouse. Mast’s design has been widely copied ever since. It remains a cheap and effective mechanism for catching mice. It has several advantages over other traps in that it is easy to use, cheap to manufacture, and highly efficient. The 1900s saw a range of competing approaches to Mast’s, including the use of poison, lobster pots that enticed mice into buckets of water where they drowned, and even traps that hanged mice in little nooses. Electrocution was tried, but as it continued after the animal was dead, users had to deal with the increasingly pungent smell of fried mouse. In the 1980s, a trap using superglue was developed, but the operator had to unstick living mice stuck to the trap and it failed to gain much popularity. In the 1990s, issues of animal treatment came to the fore with a range of ‘humane’ traps that allowed people to capture mice and then release them into the ‘wild’. Consumers became more style conscious, leading to the development of chrome and coloured traps, matching the look of modern kitchen appliances. The snap trap, however, remains a design classic; its low price, simplicity, and effectiveness ensure it retains a dominant position among mousetraps, more than 100 years after its invention.

Source: Hope 1996.

synthetic materials, and may contribute to the ‘technological revolutions’ discussed in Chapter 2. Incremental innovations include the ‘million little things’ that involve minor changes to existing products, which cumulatively improve the performance of products and services. Radical innovation usually requires greater investment in basic research than incremental changes, and more links with research institutes, and may follow different diffusion patterns (this is discussed in Chapter 5, and see Box 3.2).

- *Continuous* or *discontinuous*—that is, whether it affects existing ways of doing things (Tushman and Anderson 1986), or whether it is *sustaining* or *disruptive* (Christensen 1997). Firms commonly find it very difficult to break away from previous technologies and ways of innovating, and managers may need to explore new ways of doing things that are destructive of existing successes.
- Change over *life cycles* (Abernathy and Utterback 1978)—that is, how it relates to early emergence of an innovation, a period of ferment and uncertainty, progress to a takeoff period of growth, and maturity in a satiated market. Chapter 4 discusses how the management of the early stages of innovation life cycles differs markedly from that required in latter stages.

- *Modular*—that is, occurs in components and subsystems without addressing the system of which it is a part; or *architectural*—that is, attempts systemic improvements without great attention to its component parts (Henderson and Clark 1990). The management of systems integration (SI) poses very different MTI challenges to innovation in modules or components. SI is discussed later in this chapter and modularity is discussed in Chapter 8.
- Results in the emergence of a *dominant design* (Abernathy and Utterback 1978). MTI changes once a dominant design—the winning product class in the market, the one competitors and innovators must adhere to (see Box 3.12)—is established, and this is discussed in Chapter 4.
- Occurs within *open* or *closed* innovation strategies (Chesbrough 2003). The management challenges of open innovation—where innovation involves different strategies for buying, selling, and collaborating—are discussed in Box 3.4.

### Box 3.2 Breakthrough innovations in tennis rackets

Radical innovations need to combine novelty and uniqueness and have a major effect on subsequent technological developments to be truly disruptive. The case of tennis rackets shows how business sectors can be transformed by radical or disruptive changes in technology. Tennis is a popular game with over 100 million active players worldwide. Tennis players enthusiastically consume new racket technology as they seek to gain advantage over competitors. It is a sport where technical changes in the design, materials, and manufacturing of rackets have had a major influence on the way the game is played. Between 1971 and 2001, 581 US patents for tennis rackets were awarded.

The 1960s was the age of wood rackets or ‘woodies’. These had become the dominant design in tennis rackets in the 1920s. All the great players in the early era of professional tennis—from Ron Laver to Arthur Ashe—used ‘woodies’. The 1970s saw innovations in design, especially in materials and shape of rackets. The first of these was the wire spiral-wound steel-frame racket which was adopted quickly by the then Wimbledon and US Open Champion, Jimmy Connors. This innovation led to a ‘materials race’ in tennis racket design and manufacturing, ultimately leading to the introduction of fibreglass and composites in the 1980s and 1990s. The shape of tennis rackets changed dramatically in 1976, with the introduction of oversized racket heads (increasing from 70 to 110 sq. in.). Few professional tennis players adopted these oversized rackets when they were first introduced, but within three years they had captured close to 30 per cent of the total market for their developer, Prince. Worried about the effect of this new design on the game, tennis officials introduced a size limit. The year 1981 saw a further innovation in a new stringing pattern with denser stringing closer to the sweet spot in the centre of the racket head. In 1987, the wide-body racket with thickened shaft portions was developed, providing stiffer rackets. This was invented by Siegfried Kuebler and licensed to Wilson. This innovation stemmed from research into the physics of tennis rackets, demonstrating how collision energy from the ball–string contact could be fed back into the ball. The stiff racket frame maximized energy applied to the ball from a hit, resulting in a faster return. Wide-body design soon became the standard, altering the nature of the professional and amateur game. In professional ranks, the 1990s saw the rise and dominance of hard-hitting serve and volley specialists such as Pete Sampras, Boris Becker, and Pat Rafter. Their game was based on exploitation of new technology to generate pace and power, limiting opportunities for competitors, and relying more on finesse. In the 2000s, with changes in court surfaces and the design of slower tennis balls, professional tennis has seen a rebalancing with players, such as Roger Federer, combining the power of new rackets with the finesse of the ‘woodies’ era.

Source: Dahlin and Behrens 2005.

## Managing incremental and radical innovation

Although in practice there are no hard and fast distinctions between incremental and radical innovation and they are best considered as different ends of a continuum, managing the extent and the various types of innovation requires different skills and resources. Incremental innovation is the most common form and tends to reinforce the position of established firms, allowing them to exploit what they know to help them do things better (Utterback 1994). It is what firms focus the bulk of their managerial resources upon. Much incremental innovation can be seen as fairly mundane, involving few of the great events that characterize radical innovation (Rosenberg 1982). Being a successful incremental innovator, however, requires skill and ingenuity and those firms that are successful at it are often able to gain significant economic advantage.

There are many examples of successful incremental product innovations. Kenwood's and Tefal's use of chrome covers on toasters created an incentive for customers to purchase a new toaster before the end of the working lives of their old ones. Espresso machine makers, such as Gaggia and Faema, introduced a range of new foam-making devices, making it easier for unskilled but aspiring baristas to produce cappuccinos at home. Imperial College London's new Business School building, although innovative in appearance, is based in shape and design on the library at Nimes, both designed by Lord Norman Foster. Incremental process innovations are often part of a firm's day-to-day activities (see Chapter 8). Few commercial processes are left unchanged from year to year, and improvements in processes can have an immense effect on productivity. The Nissan factory in Sunderland, UK, for example, is one of the most productive automobile factories in the world, and it aspires to achieve 10 per cent performance improvements annually, posing significant challenges for its employees and its competitors. Incremental process innovations can also be found in the service and cultural sectors. When the *Lord of the Rings* trilogy was filmed, it was decided to film all three parts at one time on location in New Zealand. This approach saved on costs by allowing the film company to fly expensive stars, such as Liv Tyler, to New Zealand only once instead of three times. It also ensured that the appearance of production sets and actors was similar across all three movies. The films were subsequently developed in sequence, incorporating considerable computer graphics, and released yearly between 2001 and 2003. Incremental service innovations, such as Amazon selling DVDs (digital video discs), are often extensions of existing lines of business or minor adaptations to existing systems. The Bank of America is progressively using simulation software to determine the optimal configuration of its new banks to ensure easy customer access and friendly reception for new customers. McDonald's has been continually innovative in extending and modernizing its product line by creating new ranges of hamburgers and, more recently, new lines of 'healthy' alternatives. It has also developed many minor process innovations, including the vertical cooking of hamburgers in Tokyo to save space. Tucker (2002) lists product, process,

and strategic innovations at all levels in McDonald's ranging from 'breakthrough' innovations in its 'Big Mac' and franchisee regulations, to incremental innovations in the cooking of chips and production of green milkshakes for Saint Patrick's Day.

Incremental innovators adopt a range of management strategies and practices to capture returns from their efforts, including:

- Seeking cost advantages over the competition.
- Making minor modifications to design.
- Creating organizational routines, procedures, and standards for more efficient and economic production.
- Adding features to existing products.
- Re-innovating—making changes to designs after their first introduction and then quickly introducing them into the market (Rothwell and Gardiner 1988).
- Branding.
- Developing a reputation for product quality.
- Learning from users and customers.

In contrast, radical innovations are critical events that reshape designs, knowledge, and the nature of competition in the product market (Utterback 1994; Dosi 1982). Most technical change occurs slowly and cumulatively until it is punctuated by a major advance. Radical breakthroughs are not common, occurring according to one estimate at thirty-year intervals in most industries (Tushman and Anderson 1986). McGahan (2004) estimates that one-fifth of all industries in the USA between 1980 and 1999 underwent a radical change. Such innovations may disrupt the position of established firms and open up opportunities for new firms to enter the market and overtake incumbents (Christensen 1997). When a disruption occurs, there is often great confusion about the nature of the market, with many firms experimenting with ranges of designs and options. The exploitation of these periods of fluidity often requires new sets of knowledge that are distant from the past experiences of incumbents. It makes firms ask new questions, draw in new technical and commercial skills, and employ new problem-solving approaches (Christensen and Rosenbloom 1995). Radical innovations are often associated with the emergence of new 'dominant designs'—the established ways that a product is configured or designed (Afuah and Utterback 1997; Utterback 1994). Radical innovation often leads to dramatic performance breaks with the past. A nominal measure of a radical innovation is that it alters the price–performance relationship of a product by a factor of 5 (Dahlin and Behrens 2005). One example was the development of float glass making by Pilkington Brothers in the 1950s. Float glass was more than ten times more productive than the previous method of continuous grinding. In the case of many radical innovations, a firm's current customers may be unreliable guides to the future. Such innovations often involve 'attack from below' as a cheaper, alternative technology is developed that reshapes the nature of competition in the sector (Christensen 1997).

Many firms fail to make the transition in response to radical innovation. Polaroid's response to digital photography is a good example of this inertia (Tripsas and Gavetti 2000). Throughout most of the post-Second World War era, Polaroid was the leading producer of instant cameras, and it had developed an extensive set of technologies that allowed users to print pictures instantly. Polaroid's business model was based on a 'razor-blades' approach, with most of its income derived from the sale of film rather than cameras (manufacturers of razors derive most revenue from selling replacement blades). In the 1980s and 1990s, Polaroid invested in digital photography and made the first working models of digital cameras. Further development would have required a reorientation of the firm away from its deep knowledge base and what it had been good at in the past. Polaroid decided not to invest in the commercialization of this technology, believing that few customers would want disposable, digital pictures (Tripsas and Gavetti 2000). Consumers, of course, rapidly adopted digital cameras. They proved popular because consumers like taking pictures more than having printed copies of them (Munir and Phillips 2005). Polaroid was unable to anticipate changing consumer behaviour. It was locked into older technologies, a misguided business model, and a misunderstanding of consumer preferences. As result of these failures Polaroid went bankrupt in 2002 and was purchased by a private equity company.

Radical innovations need not lead to the fall of established firms. Some radical innovations may actually enhance the capabilities and resources of incumbents, allowing firms to transfer lessons and experiences from one industry era to the next (Anderson and Tushman 1990; King and Tucci 2002; McGahan 2004). Such innovations are sustaining, allowing firms to extend what they know (Christensen 1997). Firms, such as Philips, were successful in the development of the CD (compact disc) players and the following generation DVD players. In the case of music players or MP3s, established firms, such as Sony, found themselves overtaken by outsiders, such as Apple, but remain very active in the market. The circumstances that determine whether a radical innovation becomes disruptive or sustaining are uncertain. It is difficult, if not impossible, to predict whether a particular innovation will shake out established firms or whether incumbents will be able to survive and even prosper in the new regime.

There is a range of management practices and strategies firms can use to prepare for radical innovations, including:

- Willingness to be open to new ideas from outside the firm and sector.
- Continuous searching and scanning of the technological and market environment.
- Taking options on different futures by investing in a portfolio of technologies.
- Creating new links and relationships within innovation systems.
- Reshaping organizational structures to ensure that some parts engage in exploratory work.
- Bringing in new capabilities through acquisition or hiring.



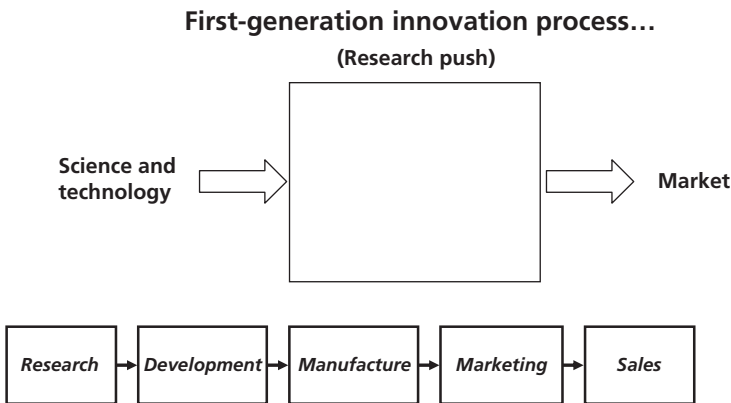
- Investing in new areas of technology somewhat distant from current practice.
- Building networks and alliances from outside the base industry.
- Being aware of new patterns of customer behaviour.
- Jettisoning old habits or ‘ways of doing things’ when required.

Although these practices and strategies may help firms avoid the fate of Polaroid, there is no recipe for survival in the face of great technological or market ferment. Some firms may succeed in changing their nature and culture to respond to these situations. Many firms will try to change, then fail and eventually decline. A few firms will not even try and choose death over struggle.

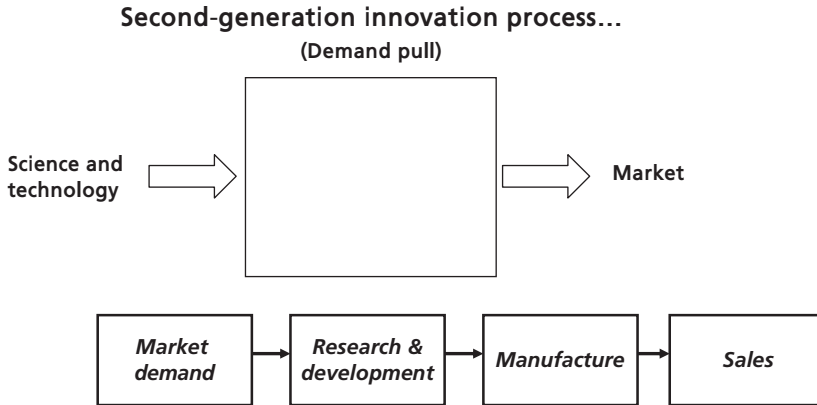
## The changing nature of the innovation process

The innovation process is the way firms marshal their resources to take advantage of scientific, technological, and market opportunities. Over the last twenty-five years or so analysts have developed a number of approaches that consider the innovation process, and these can be categorized into five generations of thinking (Rothwell 1992).

The first, prevalent during the 1950s and 1960s, was the *research-push* or first-generation approach (see Fig. 3.1). This approach assumes that innovation is a linear process, beginning with scientific discovery, passing through invention, engineering, and manufacturing activities, and ending with the marketing of a new product or process. Associated with the US government’s chief science policy advisor, Vannevar Bush, in his influential book *The Endless Frontier*, the approach was a legacy of the Second World War, where the power of science was demonstrated in the form of the nuclear bomb, and it was assumed that massive scientific investments would produce dramatic improvements in the energy sector, defence industries, and medicine. Until the 1970s, many



**Figure 3.1.** First-generation innovation process

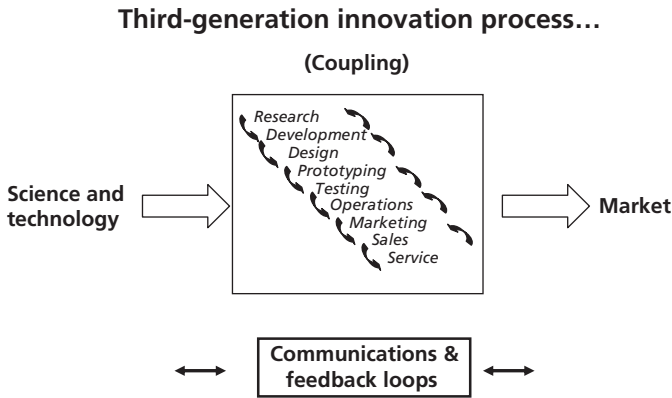


**Figure 3.2.** Second-generation innovation process

government policy-makers and managers of major industrial companies had accepted the view that a new product or process is the result of discoveries in basic science, brought to the attention of the parent organization by its research staff for possible commercial application. The management challenge in this process is simple: invest more resources in R & D. In this model there are no forms of feedback. The model was rapidly shown to apply only to science-based industries.

From the early to mid-1960s a second linear model of innovation was adopted by public policy-makers and industrial managers in advanced capitalist economies. This was the *demand-pull* or second-generation model (see Fig. 3.2). In this model, innovations derive from a perceived demand, which influences the direction and rate of technology development. Kamien and Schwartz (1975: 35) argue that in this model innovations are induced by the departments that deal directly with customers, who indicate problems with a design or suggest possible new areas for investigation. The solutions to any problems raised are provided by research staff. To some extent this approach reflected the corporate practices of the time, which emphasized planning and saw the creation of large centralized planning departments, believed to be able to predict future requirements. The rise of social science subjects, such as human and economic geography and the sociology of consumption, generated new ideas about markets and demand, informing and advising governments, which developed 'predict and provide' policies. It was also a time of growing consumer awareness and movements, such as those demanding greater automobile safety. The management challenge of this process is relatively simple: invest in marketing.

Both linear models of innovations are oversimplified. Rothwell (1992), for example, showed that at an industry-wide level the importance of research-push and demand-pull may vary during different phases in the innovation process, and also vary across sectors.



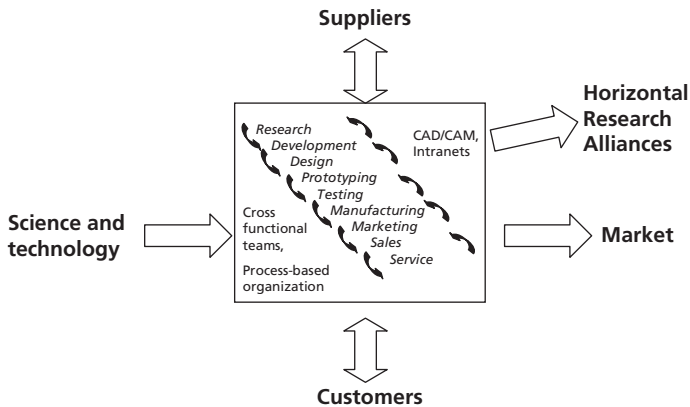
**Figure 3.3.** Third-generation innovation process

The third model, the *coupling* or third-generation model, (see Fig. 3.3) integrating both research-push and demand-pull, was centred on an interactive process where innovation was regarded as a ‘logically sequential, though not necessarily continuous process’ (Rothwell and Zegveld 1985: 50). The emphasis in this model is on the feedback effects between the downstream and upstream phases of the earlier linear models. The stages in the process are seen as separate but interactive. The management challenge of this process involves significant investments in cross-organizational communications and integration.

New models (the ‘fourth- and fifth-generation’ innovation models, as Rothwell called them) incorporate the feedback processes operating within and between firms. The high level of integration between various elements of the firm in innovation is captured in the fourth-generation, *collaborative*, or ‘*chain-linked* model’ of Kline and Rosenberg (1986), which shows the complex iterations, feedback loops, and interrelationships among marketing, R & D, manufacturing, and distribution in the innovation process (see Fig. 3.4). This process reflected growing understanding about the way innovation involved more than broad-based input from the science base and the market, but close relationships with key customers and suppliers. There was increased appreciation of the internal organizational practices that encouraged innovation, especially the move away from sequential departmental involvement towards a more fluid, inclusive, and process-based approach. The importance of technology in assisting the innovation process, by having common CAD/CAM (computer-aided manufacturing) platforms for example (see Chapter 8), was identified. Based on experiences with government policies and programmes encouraging collaborative R & D, such as Sematech in the USA, ESPRIT in Europe, and the Fifth Generation Computer Systems (FGCS) programme in Japan, the process recognizes the role that can be played by alliances with other firms and competitors. The management challenges and required resource commitments become significantly more widespread.

The fifth-generation innovation process includes the growing strategic and technological integration between different organizations inside and outside the firm, the way

### Fourth-generation innovation process... (Collaborative)



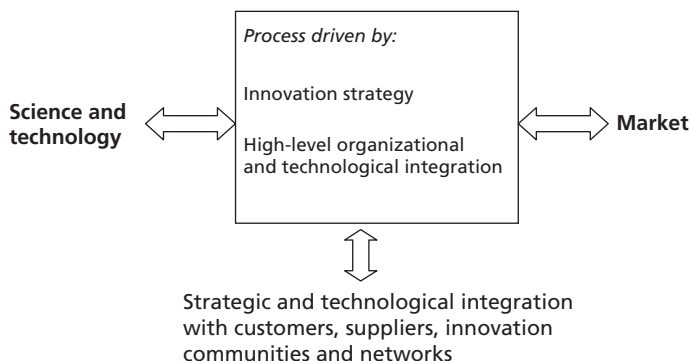
**Figure 3.4.** Fourth-generation innovation process

these are being enhanced by the ‘automation’ of the innovation process and the use of new organizational techniques, such as concurrent rather than sequential development (see Fig. 3.5). It moves away from the ‘silos’ of functional divisions towards organization according with business processes. This model represents an idealized approach to best practice and will be considered in some depth.

## The fifth-generation innovation process

While the analytical origins of the fifth-generation innovation process differs from the macro-perspective of the fifth wave of technological development (discussed in

### Fifth-generation innovation process... (Strategic and integrated)



**Figure 3.5.** Fifth-generation innovation process

Chapter 2), the challenges for management are similar, particularly with respect to dealing with high levels of risk and uncertainty. The major aspects of the fifth-generation innovation process are outlined in Fig. 3.5. Within the firm we see increasing concern with the organizational forms and practices and skill balances that enable the maximum flexibility and responsiveness to deal with unpredictable and turbulent markets. Research, development, design, and engineering take place in concurrent iterations, supported by 'innovation technology' in a fluid model called 'Think, Play, Do' (Dodgson, Gann, and Salter 2005; see Box 3.3). Some of these issues have already been discussed in relation to the new management paradigm, and others, like lean thinking, will be discussed in Chapter 8. The value-creating activities of the firm are linked with suppliers and customers, and all the technological activities in the firm are directed by increasingly coherent and effective innovation strategies (see Chapter 4). Two important features of the fifth-generation innovation process are the increasing extent of strategy and technology integration.

*Strategic integration* between firms is increasingly global and occurs across technological, market, and financial areas. When Boeing designed its 777 aircraft, it involved its customers and suppliers closely. Boeing created what came to be known as the 'Gang of Eight', comprising eight international airline customers who met over a twelve-month period to help specify the requirements for the new aircraft. United Airlines, which decided to purchase thirty-four of the new aeroplanes before they had even been designed, was intimately involved in its configuration (Sabbagh 1996). Boeing also had close involvement from suppliers. Important components, such as major parts of the fuselage and the rudder, were subcontracted to Australian and Japanese firms. Engine manufacturers, such as Pratt and Whitney, designed their engines in close conjunction with Boeing.

Since 1995, Ford has operated a Technology/Product Review Center in Dearborn, Michigan. This is a forum for suppliers to demonstrate their technological expertise to Ford engineers. These 'supplier showcases' typically last two days and have been replicated in the UK and Germany. A major problem for Ford has been integrating its suppliers' technology, and these centres are designed to overcome these problems by giving early feedback on suppliers' technology developments.

*Technological integration* occurs in various forms. An example would be the hybrid car, running on both electricity and petrol, and involving the merger of electrical and mechanical technologies. Kodama (1995) discusses the prevalence of 'technological fusion'. Thus, mechatronics involved the fusion of mechanical technology with electrical and material technologies, optoelectronics involves the fusion of glass and photonic technology with cable and electronic device technologies, and biotechnology involves the fusion of, amongst other fields, biology, chemistry, and engineering. Kodama argues that fusion is more than a combination of different technologies. It is the creation of a new technology where the whole is greater than the sum of the parts. Each fusion 'creates new markets and new growth opportunities in the innovation' (Kodama

1995: 203). There are many contemporary examples of new technologies emerging from the combination of different knowledge bases, such as bioinformatics and nanomaterials.

Another form of technological integration involves technologies that themselves enable the integration of various components of the innovation process. These have been described as a particular category of technology: innovation technology (see Box 3.3).

This increased strategic and technological integration often aims to improve competitiveness through the timely delivery of goods and services. Time-based strategies of rapid speed, such as 'first-to-market', are growing in importance (see the discussion on 'first-mover advantage' in Chapter 4). When Sony developed the camcorder, it believed that it only had a six-month lead on its competitors. One of Toshiba's laptop computer manufacturing plants introduces a new model to the manufacturing line every two weeks. For two years, Nokia introduces a new mobile phone every month. Speed is also evident in the pharmaceutical industry, where 'first-to-patent' is of crucial competitive importance, and the speed of the development process can provide distinct advantages. In online services, such as Amazon and YouTube, being first-to-market assists the development of brand recognition. To reduce the time it takes to develop new products, digital product data must be presented in such a way that they can be used effectively by all the different departments of the firm. Software companies, such as SAP, offer enterprise resource planning (ERP) systems that help integrate financial data with design, manufacturing, and inventory data (see Chapter 8). Product data management (PDM) systems can be part of ERP systems. PDM stores all the information and data about products in an easily available format, allowing continual changes to be made in a controlled manner. Although very complex, when fully operational ERP enables each department in a firm to have access to the information it requires in a format that is understandable.

All our case-study companies are affected by aspects of the fifth-generation innovation process. The biotechnology firm has to be particularly closely integrated with its major partner, with whom its future strategy is entwined. The Taiwanese machine tool firm and the Japanese R & D laboratory need close affiliations with overseas research laboratories. The British pump firm requires close strategic integration with others involved in the design and manufacture of its systems. The Indian software company aims to act as a systems integrator, coordinating inputs from suppliers to meet customer needs. The Mexican supplier needs to work hand-in-hand with its US customers. High levels of technological integration are required of all the firms. The biotech firm is using a number of automated systems for gene-sequencing and this enables the electronic 'design' of molecules. The pump firm has a CAD/CAM system linked to its suppliers and customers. The machine tool company uses a range of computerized design databases, enabling it to store all information on existing products and test results and electronic prototyping of new parts. The Japanese laboratory uses its intranet and a wide range of Internet-based communications to link with its internal customers and external scientific partners. The Indian software company uses computerized project management

### Box 3.3 Innovation technology

Technology is being used to improve the speed and efficiency of innovation in new ways, providing considerable challenges and opportunities for managers. Companies such as Ricardo and Dassault are using virtual-reality suites to help customers design next-generation products. GSK is using simulation and modelling tools to substantially improve the speed of new drug design. E-science, or Grid computing, is building new communities of scientists and researchers in Rolls Royce and other companies, helping them to manage collaborative projects. Wal-Mart uses sophisticated data-mining technology to help understand its customers and manage its supply chain. Firms in industries as diverse as Formula 1 racing, and fashion, are using virtual and rapid prototyping technology to improve the speed of innovation. Together these technologies comprise a new category of technology, what Dodgson, Gann, and Salter (2005) call 'innovation technology' (IvT). IvT is being used to make customers on the one hand and scientific researchers on the other more central in decisions about new products and services.

Many IvTs are becoming ubiquitous (Thomke 2002; Tuomi 2002; Schrage 2000). There is evidence of extensive use of IvT in a wide range of sectors, from pharmaceuticals to the mining and construction industries and across many different types of organizations. IvT functions alongside Information and Communication Technologies (ICT) and technologies used in operations and manufacturing, such as automated materials handling.

Pharmaceutical companies are increasingly using IvT in fields such as gene-sequencing and combinatorial chemistry. Pfizer has developed automated techniques for rapid screening and dispensing of thousands of chemicals using robots. GM uses what it calls 'math-based design and engineering', which provides digital representations of vehicles for design, engineering, and testing. This system is used routinely in areas such as:

- 3-D simulations for modelling vehicle structures, crashworthiness, and safety restraint.
- Computational fluid dynamics codes for designing and analysing engine combustion systems, transmissions, interior climate-control systems, and vehicle aerodynamics.
- High-level systems for automated design of integrated chips and electromechanical components.
- Virtual-reality prototypes for vehicle exteriors, interiors, components, and production tooling.

Use of these systems has led to developments in stability control systems, electronically enhanced steering, continuously variable suspensions and engine controls, with virtual-reality prototyping reducing the need for costly physical models. IvT allows firms to experiment cheaply and 'fail often and early'. IvT is also very important in the design of large, complex systems, such as utilities, airport infrastructures, communications systems, where it is not usually feasible to test full-scale prototypes.

One of the most important aspects of IvT is how it assists the representation and visualization of knowledge and its communication across different domains, disciplines, professions, and 'communities of practice'. By way of illustration, the use of IvT in the design of a new building makes complex data, information, perspectives, and preferences from diverse groups visible and comprehensible. Virtual representation can assist architects in their visualization of the eventual design and help to clarify clients' expectations by giving them a good understanding of what a building will look and feel like before work begins; it informs contractors and builders of specifications and requirements, and enables regulators, such as fire inspectors, to confidently assess whether buildings are likely to meet regulatory requirements. IvT can allow various players in the innovation process, suppliers and users, contractors and subcontractors, systems integrators, and component producers, to collaborate more effectively in the delivery of new products and services. The adoption of IvT is leading many organizations to reconsider the way they conduct and manage innovative activities. They provide a useful aid to the digital integration of the innovation process.

It is possible to think of IvTs as the new 'capital goods' of innovation. It could be argued that their effective integration with other technologies will become one of the critical issues for technology-based competitiveness in the future. (For a discussion on the way IvT are used in architectural design, see Box 7.16.)

systems and software-writing tools. The Mexican automotive company relies on Internet-based intermediaries for developing and commercializing its components.

The external orientation of the case-study companies, and the extensive innovation communities and networks described in Chapter 5 are features of what is increasingly known as ‘open innovation’. This model of innovation, and the question of how open firms should be, are examined in Box 3.4.

### Box 3.4 Open innovation

Researchers have suggested that firms need to adopt more plastic and porous models of innovation by being open to external sources of ideas and routes to market and engage with a larger number and wider range of collaborators. Chesbrough (2003) refers to this as the shift from ‘closed’ to ‘open’ innovation. This perspective argues that the innovation process has become increasingly complex and to innovate firms must involve a greater number of actors more closely and intensively to realize the commercial potential of their ideas. This research is often highly prescriptive and is based on case studies of leading practices in firms such as Lucent, Intel, 3Com, IBM, and P&G (Dahlander and Gann 2007; Dodgson, Gann, and Salter 2006; Huston and Sakkab 2006).

The basic principles put forward by Chesbrough are derived from a critique of the dominant twentieth-century model of corporate innovation where most activities associated with new product and service development were deemed to be within the sphere of internal R & D. Chesbrough describes this model as the traditional *closed innovation* approach, underpinned by six main principles:

1. An assumption that because the firm invests in its own R & D it has been able to recruit appropriately qualified people to carry out innovation: ‘the smart people all work for us’.
2. To profit from R & D, firms must invent, develop, and sell the product or service by themselves.
3. If the firm’s R & D department is able to discover, or invent, a new idea, it will be in the best position to get it to market first.
4. Bringing a product or service to market before competitors provides the best return on investment in innovation.
5. Firms that come up with more and better ideas will beat their competitors.
6. Firms should control their IP themselves and prevent their competitors from profiting from it.

The *open innovation* approach challenges these principles. Open innovation is characterized by more fluid interactions between internal and external innovation activities, in which ideas, people, and resources flow in, around, and out of organizations. In this approach, the boundaries between internal and external activities and the firm’s general operating environment are more porous, and it is therefore important to extract as much knowledge from the external environment as possible (Chesbrough 2006; Chesbrough, Vanhaverbeke, and West 2006). The following six points encapsulate the open innovation approach:

1. It is not necessarily possible to employ all the best people in the firm’s R & D and innovation centres, and there are many talented people with good ideas outside the firm, who could provide useful inputs. The business needs to find a way of connecting with them.
2. The R & D carried out by other organizations can create value from which the firm can profit. It needs to carry out R & D internally to create the absorptive capacity to capture some of the benefits from ideas generated externally (Cohen and Levinthal 1990).
3. The firm does not need to originate ideas from its own research to profit from new ideas if it makes the right connections to networks of innovators.
4. Building a better business model to exploit new ideas will provide a better return than focusing purely on first-mover advantage (see Chapter 4).
5. The firm will succeed if it can improve the ways it uses ideas generated internally across the whole organization, not just in R & D or design departments.



6. Firms that are successful *open innovators* are able to profit from the ways other firms use their IP, and also to buy-in IP from external sources to advance their business objectives.

Since the publication of Chesbrough's *Open Innovation* in 2003, these ideas have become influential amongst innovation managers in many businesses (Christensen, Olesen and Kjær 2005). P&G has changed its strategy from one focused on R & D to an approach known as 'Connect and Develop' (C&D) (see Box 6.1). Philips has renamed its R & D department the 'Open Innovation Unit'. Box 6.2 describes how GSK has created a 'Centre of Excellence in External Drug Discovery', using an open innovation model. The concept of open innovation has grown in importance across businesses in many sectors and amongst policy-makers with responsibility for encouraging and supporting innovation in governments, for example, by promoting an increase in the amount of collaboration between universities and industry (Bessant and Venables 2007).

One of the problems with the open innovation concept is that whilst it has become a popular term, the idea of systematically using external sources of innovation is not particularly new. Josiah Wedgwood, the Staffordshire potter, organized collaborative technological networks and sought inputs from lead customers in the 1700s. Hargadon (2003) shows how Edison recombined ideas, drawing on a network of innovators, financiers, suppliers, and distributors in the development and commercialization of the electric light bulb towards the end of the 1900s. This case study and many others show that there has always been a degree of openness in innovation processes. The contemporary environment has one important additional factor supporting the open innovation approach: innovation technologies (Dodgson, Gann, and Salter 2005, see Box 3.3). These include a range of third-party brokering services to enable exchange of IP (see Box 9.6), and e-Science, which enables firms and research organizations to participate in collaborative R & D. The questions that innovation managers need to resolve are how much should they engage in open innovation, in what ways, and how should these be managed effectively. Dahlander and Gann (2007) argue that there are at least three types of openness that need to be considered:

1. Openness in appropriability regimes and the different degrees of formal and informal protection of IP (see Chapter 9).
2. Openness in the number and type of sources of external ideas for innovation.
3. The extent to which firms rely on informal and formal relationships with other actors in the generation, development, and commercialization of new ideas.

### Can firms be too open?

Innovation managers need to recognize the advantages and limitations of engaging in development and commercialization of ideas across traditional boundaries. There is controversy in the innovation literature over how open firms should be to external partners in their search for new innovations and in developing new routes to market (Dahlander and Gann 2007; Helfat 2006; Chesbrough 2006). There are times when openness may turn from virtue to vice. Laursen and Salter (2006) found there were decreasing returns to openness. Firms that were too open had lower performance than those able to balance openness with internal activities. There are several reasons why firms need to be careful in opening themselves up to external partners. These include:

- The danger of theft: openness can lead to unplanned disclosures, and secrecy is often an effective method to protect innovative ideas (see Chapter 9). Ensuring the firm has sufficient means to protect its ideas is often a prerequisite to openness (Laursen and Salter 2005).
- Managerial time demands and transaction costs associated with managing a wide range of different partners can be high and may distract firms from internal activities.
- Over-reliance on external parties may increase the risk and uncertainty of product development processes.
- Negotiating and managing many external relationships can slow down the innovation process by increasing coordination costs.

These factors, together with the need to develop new business models, may lead to misallocation of managerial attention towards building external relationships, to the detriment of internal activities, and lead to a reduction in innovative performance. Managers need to balance the requirement to be open to external actors with the need to commercialize their ideas using their own resources.

## Sources of innovation

Understanding the sources of innovation is one of the most important elements of MTI. If managers know where to find innovations they can dramatically increase their innovation efforts. Schumpeter describes how the fundamental character of the search for innovation requires firms to find and carry out ‘new combinations’ among technologies, knowledge, and markets. ‘To produce other things, or the same things by a different method, means to combine these material and forces differently’ (Schumpeter 1934: 65). In this respect, search for innovation can be defined as ‘an organization’s problem-solving activities that involve the creation and recombination of technological ideas’ (Katila and Ahuja 2002: 1184). For Drucker, ‘... most innovations... result from a conscious, purposeful search for innovation opportunities...’ (Drucker 2002: 96). Firms invest considerable time, money, and other resources in their search for these opportunities (Cohen and Levinthal 1990; Zahra and George 2002). One manifestation of these search efforts is expenditures on R & D that can allow firms to conduct ‘off-line’ learning away from the pressures of delivering existing products and processes (Lippman and McCall 1976; Nelson 2003). As we have seen, however, R & D expenditures represent only one element in the search processes of firms and may account for only a small portion of private investment in the search for innovations.

The search for new combinations often requires ways of integrating knowledge from many different parts of the firm and working with various actors outside the firm, including consultants, customers, suppliers, and universities. Such search processes require managerial capabilities to build relationships with and absorb knowledge from external sources, and to bring together knowledge from inside the firm, combining experiences and ideas from different departments, divisions, and disciplines. As such, the search for innovations requires investment in the formation of networks and social capital inside the firm and with external actors (Powell, Koput, and Smith-Doerr 1996). Managers need to deal with different actors’ ways of working, routines, norms, and habits (Brown and Duguid 2000). The importance and nature of search activities for firms are explored in Chapter 4.

The importance of different sources of innovation varies by industry and by country. The most recent data from the European Community Innovation Survey (CIS), including responses from fifteen EU countries as well as Norway and Iceland, is presented in Table 3.1 (European Commission 2004). This survey shows how internal resources, clients, and customers are the most important sources for innovation in European firms, followed by suppliers and competitors. In comparison, few European firms indicated that they gain information for innovation from universities or government laboratories: less than 5 per cent of innovation-active firms. These results are relatively consistent across industries and with surveys in other countries, including Canada, Australia, Brazil, Chile, Argentina, and South Africa.

**Table 3.1.** Information sources for European firms. Proportion of enterprises with innovation activity indicating that selected sources of information were considered as highly important for innovation, EU, 1998–2000 (%)

<i>Sources</i>	<i>Manufacturing</i>	<i>Services</i>
Within the enterprise	37	40
Other enterprises within the enterprise group	7	13
Suppliers of equipment, materials and components	19	20
Clients and customers	27	31
Competitors	11	14
Universities and higher education institutes	4	6
Government and non-for-profit research labs	3	3
Professional conferences, meetings and journals	9	15
Fairs and exhibitions	17	14

## SUPPLIERS

Each of the five generations of innovation process described earlier requires a firm to form ties and work with individuals and organizations externally. Firms using fifth-generation innovation processes draw ideas from a wide range of customers, suppliers, universities, and even competitors. Von Hippel (1988) divides these interactions between vertical sources (i.e., between firms and their customers, and between firms and their suppliers) and horizontal sources (i.e., with competitors through informal knowledge trading). The role of customers and users as a source of innovation is well established and will be examined in more detail in Chapter 6. For many innovations, however, especially in production and operational processes, vertical relations with suppliers are often critical. Systemic links between users and suppliers in the automotive industry, for example, are known to be particularly important for innovation (Womack, Jones, and Roos 1990). In Germany, the component supplier, Bosch, is the major source of technological change in electronic automotive systems (developing the stabilizing system for all Mercedes cars, for example). A key factor determining the possibilities for innovation in that industry is therefore the closeness and quality of the links between the car assemblers and Bosch.

A number of studies have found that process innovators draw particularly on knowledge from suppliers (Cabagnols and Le Bas 2002; Reichstein and Salter 2006). Indeed, capital goods manufacturers' product innovations may create process innovations among their customers. Regardless of whether a firm sells its products directly to the retail market, or to other businesses, it is often necessary to work closely with suppliers to understand and utilize the full potential of a new technology.

## INDIVIDUALS

The Cambridge/MIT innovation survey of over 3,600 UK and US firms (Cosh, Lester, and Hughes 2006) confirms the CIS finding that the most important sources of

**Box 3.5 IBM's 'InnovationJam'**

IBM has for a number of years been undertaking simultaneous brainstorming sessions amongst its research laboratories around the world, searching for new ideas. They worked so well that in 2006 the company asked all its employees worldwide to post their ideas on how IBM's technologies could be applied to problem-solving and identifying new market opportunities for the firm. In all, over a 72-hour period, more than 150,000 people from 104 countries contributed to the 'InnovationJam'. Apart from IBM employees, there were family members, universities, business partners, and clients from 67 companies who contributed more than 46,000 ideas. These ideas were clustered, judged, and refined, and eventually top-ten ideas were identified, with a mixture of short, medium, and long-term time horizons. IBM has dedicated a budget of \$100 million for over two years to pursue the ten business opportunities, and appointed a vice-president to oversee their progress. IBM's Chairman and CEO, Sam Palmisano, in speaking about the Jam, said 'Collaborative innovation models require you to trust the creativity and intelligence of your employees, your clients, and other members of your innovation network... [and they] are greatly accelerating our ability to innovate' (IBM Press Release: November 14, 2006).

For more details on IBM's 'InnovationJam', see [www.globalinnovationjam.com](http://www.globalinnovationjam.com).

knowledge for innovation derive internally from within the company. Innovations can come from many different sources within the firm. A study of Canadian firms found the most common source of innovation within the firm was management and production workers (Baldwin and Da Pont 1996). This was followed by sales and marketing, and then R & D staff, indicating that the R & D department is not necessarily the main source of innovation inside a firm. Indeed, the sources of innovative ideas are often individuals working with users or involved in using new technology, such as shop floor workers.

The challenge for firms is to harness the knowledge of all employees to generate innovations. Many firms have created 'suggestion' or 'idea' boxes, rewarding staff who generate ideas that can be commercially realized or implemented. In some organizations, ideas are very well rewarded. In IBM, for example, employees receive bonuses on a points system for idea generation, including patents, technical disclosures in IBM's technical journals, and new product ideas. Reaching a critical threshold of points can lead to a significant bonus, equal to or more than a year's pay (also see Box 3.5). Companies such as Toyota thrive because of the ideas generated by employees, which, on average, submit more than one new idea per week per employee, totalling more than 1 million ideas per year. Many of these are implemented in continuous improvement innovations, while some feed into more radical research and development activities. The same thing happens in smaller firms: in WSP, a UK-based engineering consultancy, innovative ideas are collected monthly from staff, graded by a committee, and decisions made about which ones to implement. An individual whose idea is implemented, receives a financial reward and, perhaps more importantly, recognition from colleagues and peers.

The use of financial incentives for innovative ideas needs to be handled with care as they can lead to unanticipated outcomes (Osterloh and Frey 2000). The use of an

electronic network called 'ShareNet' for sharing knowledge in Siemens led to some staff creating problems and getting their friends to 'solve' them to win cash prizes. In some cases, cash prizes were greater than salaries, leading to attention being shifted from working to prize winning (Voelpel, Dous, and Davenport 2005).

Central to the development of new ideas inside the firm are networks and, as we show in Chapter 5, firms are making increasing use of various kinds of networks to generate and commercialize new ideas (Cross and Parker 2004). Networks provide opportunities for individuals to bring together different pools of knowledge (Burt 2005). They allow individuals to reach across disparate groups and make new connections and also to gain insights and new ways of seeing a problem. To harness the power of networks, leading firms have developed extensive knowledge management systems to encourage organizational knowledge-sharing (see Box 3.6). Such systems help bring together different individuals and teams to share experiences and ideas to solve problems. These 'communities of practice' (Brown and Duguid 2000) are found in firms, such as Hewlett Packard, which invest considerable resources in building up and managing their operations between different divisions, geographical locations, offices, and functional groups (Lesser and Storck 2001; Wenger, McDermott, and Snyder 2002).

### Box 3.6 Arup's skills network

As a leading international engineering company, Arup faces a major challenge ensuring its engineers learn from each others' experience. It has created twenty-seven skills networks or communities of practice to support knowledge-sharing. Each community operates independently and arranges meetings, workshops, and other activities to help develop and share knowledge. The communities are supported by an electronic network for sharing knowledge. Individuals can post questions and receive answers from colleagues. Individuals formally register to join a skills network and registered members receive an email prompt whenever a question is posted. However, anyone in the firm can access any network and contribute to it either by posting a question or providing an answer. The message threads are visible to all members of the organization and are archived for future use. A search engine scans the content of messages and identifies relevant information exchanges. Individuals may belong to multiple networks, and can join or leave any of these networks with impunity.

An example of the power of these networks can be seen in the Structural Skills Network, the largest and most active inside Arup. Between January 2003 and August 2005, there was a total of 3,060 messages (808 questions and 2,243 answers) posted on the network by 468 individuals, of whom 360 were members of the network. It is an open network which attracts interest from a large number of employees, mostly structural engineers, but also individuals working in areas such as bridges, fire, and façade engineering. Most exchanges in the network take place across countries, time zones, and business areas. The level and vibrancy of the structural skills network indicate that these electronic networks can be effective mechanisms for knowledge transfer and exchange. As suggested by Davenport and Prusak (2000), firms would be well advised to adopt these systems to unlock the latent potential of the knowledge and skills of their staff. These networks provide project staff with the opportunity to gain insights from the wider community inside the firm, and may be a source of competitive advantage for professional service firms.

*Source:* Criscuolo, Salter, and Sapsed 2007.

## UNIVERSITIES

Compared to other sources of innovation, universities may not appear to be important, and there is major debate about how they can best support innovation activities in firms. They are the source of graduate employees and have always been a key source of ideas for radical innovation. They are undisputedly the most important source of scientific discoveries (see Box 3.7). British university research over the last fifty years, for example, has discovered DNA (deoxyribonucleic acid), IVF (in vitro fertilization), animal cloning, MRI (magnetic resonance imaging), global warming, and the 'big bang' theory of how the solar system was formed (EurekaUK 2006). Universities are the primary source of basic research, and their discoveries can have major consequences for business and industry. The discovery of DNA, for example, was the fundamental breakthrough for the development of the biotechnology sector. Also, the development of scientific instruments, designed to help scientists do their research better, has major consequences for innovation (Rosenberg 1992). The computer, the laser, and the Internet all began life as scientific instruments. Innovation depends on well-educated and qualified engineers, scientists, business and management students, lawyers, and financiers.

### Box 3.7 The sources of major breakthroughs in science

What sort of scientific environments produce major breakthroughs? In a study of 290 major discoveries in life sciences that were awarded or nominated for awards (including the Nobel, Copley, Arthur and Mary Lasker, Louisa Gross Horwitz, and the Crafoord Prize), Hollingsworth, Hollingsworth, and Hage (2007) examine the organizations that helped individuals make their discoveries. The study looks at the research environments of biomedical and life sciences departments around the world, focusing on their scientific diversity, levels of bureaucratic control, extent of visionary leadership, and a range of other factors. Detailed case studies of different organizations provide a picture of the environments that supported prize-winning research. They differed considerably from traditional discipline-based university departments. Organizations producing major discoveries were characterized by frequent and intense interaction between scientists working across different disciplines. They frequently had visionary leaders willing to shield staff from outside criticism, and extraordinary patience over the delivery of results from interdisciplinary research. Many major discoveries in the life sciences were made by scientists with relatively 'low' productivity in numbers of scientific papers over their careers, compared to peers focused on large numbers of incremental contributions. Large institutes organized into disciplinary areas, with little intense interaction, were unlikely to produce major breakthroughs, focusing instead on 'normal' science and the generation of a high number of publications. It was rare for an institute to be active in both high productivity incremental research and major breakthroughs. In addition, too great a cognitive distance between scientists in an institute was shown to lead to unfocused and unproductive research. Other organizational routines associated with environments developing major breakthroughs include a highly selective approach to recruitment and promotion of staff. At Rockefeller University, for example, a biomedical powerhouse with twenty-three Nobel Prizes, only one in twenty to thirty scientists was offered a permanent appointment. Individuals selected needed to have a high degree of curiosity and interest in other fields. This study offers insights into R & D management in large firms where problems of encouraging frequent and intense interaction between scientists and engineers in different disciplines is a major obstacle to the development of radical innovations.

Firms that are connected to the science system are able to gain access to ideas before they are published (Fleming and Sorenson 2004). They can become part of the ‘information network’ around the university, gaining access to talented graduates and being able to shape the research activities of universities around their own problems (Rosenberg 1990).

Currently, debate focuses on the direct role of the university in commercializing knowledge by conducting ‘industrially relevant’ research and creating spin-out companies. As Etzkowitz and Leydesdorff (1997: 1) put it ‘The translation of knowledge into economic activity has emerged as a recognized university function, alongside research and teaching.’ Governments throughout the developed world have demanded that in return for public investments in research, universities and their staff should become active in directly supporting innovation and technology transfer. The link between research and business is becoming demonstrably closer. The number of citations to academic research in US patents, for example, increased sixfold over the decade of the 1980s, indicating a tighter linkage between academic research and industrial innovation (Narin, Hamilton, and Olivastro 1997). In the UK, the government has a ‘third stream’ of funding to assist commercialization. Many universities, with varying degrees of success, have established industrial liaison or research commercialization and technology transfer offices. In the USA, 174 universities have business incubators. There is debate over whether these activities distract university researchers from their primary role of delivering excellent research. Mowery and Sampat (2005: 209) put the role of industrially focused research into context: ‘The research university plays an important role as a source of fundamental knowledge and, *occasionally*, industrially relevant technology in modern knowledge-based economies’ (emphasis added). Professor Michael Crow, when he was executive vice-provost in charge of technology transfer at Columbia University, put it even more clearly:

The university can be a driving force (for economic growth) if it’s a great centre for science—not if it’s a great centre for technology transfer. Technology transfer is... a secondary objective at best, probably even a third-level objective. Anybody who moves it to a higher objective than that is foolhardy. Because it will corrupt the university for sure. (Crow, quoted in Washburn 2005: 187–8)

One of the most influential pieces of legislation affecting the links between universities and industry was the USA’s Bayh–Dole Act, 1980. This legislation for the first time allowed US universities to patent and license federally funded research. The legislation made US universities more active in protecting and licensing their technology and creating spin-out firms, and encouraged firms to collaborate more with universities. Between its passing and 2005, US university patenting has increased ten times, and industry funding for academic research has increased by 8 per cent annually. Washburn (2005) cites evidence that industry funding now directly influences 20–25 per cent of university research. She shows that 180 US universities own stakes in 886 start-ups, and



in 2002 they generated nearly \$1billion in licensing and royalty income. Whilst this evidence might suggest that university research is linking more effectively with industry, the Bayh–Dole legislation remains controversial. It has been argued to have positively fuelled growth in biotechnology and IT in the USA, but is believed by some to be destroying public-interest research and weakening the USA’s NIS (Nelson 2004). There are also problems from the universities’ own parochial perspective as: ‘It is almost a sure thing that many universities are paying significantly more to run their patenting and licensing offices than they are bringing in license revenues’ (Nelson 2001: 17).

Governments efforts to push universities closer to industry should also be assessed in the context of what industry actually wants from universities. Research addressing this question show their requirements to be: (1) well-educated, talented graduates; (2) creative, fundamental research; and (3) distinctive research cultures (different from the business’s own).

Universities play a multifaceted role when it comes to supporting innovation, which is captured in Fig. 3.6. It can be seen that the elements that government policies are currently focusing on constitute only a small portion of the overall ways universities contribute to innovation.

Universities and research laboratories are important sources of radical innovation, but the transfer of knowledge between them depends upon effective interpersonal connections (see Box 6.4). This is illustrated in the case of a successful science–business collaboration described in Box 3.8.

<b>Educating people</b> <ul style="list-style-type: none"><li>• training skilled undergraduates, graduates and post-docs</li></ul>	<b>Increasing the stock of ‘codified’ useful knowledge</b> <ul style="list-style-type: none"><li>• publications</li><li>• patents</li><li>• prototypes</li></ul>
<b>Providing public space</b> <ul style="list-style-type: none"><li>• forming/accessing networks and stimulating social interaction</li><li>• influencing the direction of search processes among users and suppliers of technology and fundamental researchers</li><li>• meetings and conferences</li><li>• hosting standards-setting forums</li><li>• entrepreneurship centres</li><li>• alumni networks</li><li>• personnel exchanges (internships, faculty exchanges, etc.)</li><li>• visiting committees</li><li>• curriculum development committees</li></ul>	<b>Problem-solving</b> <ul style="list-style-type: none"><li>• contract research</li><li>• cooperative research with industry</li><li>• technology licensing</li><li>• faculty consulting</li><li>• providing access to specialized instrumentation and equipment</li><li>• incubation services</li></ul>

**Figure 3.6.** The multifaceted role of the university

Source: Cambridge/MIT Institute.



**Box 3.8 Beauty is skin deep**

Consumer products companies know that it is increasingly important to find ways of getting closer to science to develop high-quality goods. Dr. Symon Cotton, a British computer scientist working at the University of Birmingham on skin imaging technologies, completed a Ph.D. on image and pigment-based analysis of skin lesions with the aim of diagnosing malignant melanoma. In 1998, he founded Astron Clinica to develop products based on his Ph.D. work, to enable doctors and skincare specialists to non-invasively see beneath the surface of the skin. This led to two patents DERMETRICS and SIAscopy. This technology examines the main components of the skin—haemoglobin, melanin, dermal melanin, and collagen—providing a detailed set of images to be used as a tool in diagnosis and monitoring.

In 1999, Cotton attended the American Academy of Dermatology conference in San Francisco, taking equipment to present results from his research on screening for skin cancer. He left the SIAscope machine in his hotel room, inviting conference participants to come and view it—the machine weighed some 90 kg. Several companies attending the conference expressed an interest, but it was Dr. Paul Matts, P&G's beauty division principal scientist, who saw the promise of the invention. P&G make skin products under the Olay brand and they saw the potential of SIAscope to measure skin colour and appearance. Cotton and Matts agreed to work together and developed a small hand-held version of the SIAscope, which they branded jointly. The collaboration resulted in the use of the technology in stores, and the development of new beauty products by P&G, including a range of applications for different skin conditions, wound management, and cosmetics. The relationship that started in a conference hotel bedroom, evolved with P&G and Astron Clinica jointly developing a number of new scanning technologies. Astron Clinica benefited by having their products co-branded and marketed by Olay, whilst P&G brought science to its consumers.

**OTHERS**

Firms also draw on ideas from government technology transfer agencies, trade and academic publications, trade and professional associations, exhibitions, conferences, regulations, and standards (see Chapter 9), and the various networks and communities described in Chapter 5. The analysis of patents can also be a source of innovative ideas (see Box 3.9).

**Measuring innovation**

One of the greatest challenges to managing innovation is its measurement. Governments and firms have expended considerable effort on measuring and mapping innovation activities. Many of these attempts have ended in confusion and failure.

Innovation is difficult to measure for a number of reasons. First, the benefits of an innovation often do not appear until some time after its introduction. Innovations frequently need a long period of development before they become user friendly or cheap enough to be widely adopted. Second, what is meant by the term innovation can be disputed and there can be disagreement over what is and what is not an innovation. A company might promote a product as 'innovative' when it has simply changed its colour. Third, it is difficult to separate process from outputs: some measurement systems measure inputs to the innovation, while others only measure outputs; measuring the

### Box 3.9 Patent analysis

To be awarded a patent an inventor must disclose information about his/her technology. This provides an important source of information for innovation. It is possible to learn about new areas of technology prior to the launch of new products and see how groups of patents contribute to a particular product. During examination, patent officers assign patents to a range of detailed technology classes. This information can be mined to find relationships between technological developments in different areas. It can be used to reveal promising or emerging areas of technology where invention is increasing at above average rates. In other words, it can allow researchers and managers to see 'hot spots' in technology development long before they are translated into products.

Patents need not only disclose the nature of invention, they must also establish links between the patent and prior technology. Inventors often cite other patents and academic papers to justify and explain the origin and novelty of their invention. This information is extensively analysed by industrial firms and researchers. There are two common methods of patent analysis: backward and forward (Jaffe and Trajtenberg 2002). Backward citation analysis involves reviewing citations by the patent to prior patents or articles in scientific journals. This helps uncover the science and technology that underpin a major breakthrough. Forward citations track the number of times and by whom a patent has been cited after its award. Forward citations are used to assess quality of a patent and gain a sense of its economic importance. Citation analysis can involve large-scale examination of millions of patent records, examining the extent and frequency of relationships to gain insight into the nature of and contributors to technological development.

Patent analysis is a widespread tool in industrial practice. Specialist firms have become expert data miners, hunting for patterns and relationships within patent data and providing strategic advice to companies based on their research. This work often involves searching to ensure technology developed by a firm is not already patented. It may also involve searching for technology that may be useful, exploring who owns it, and who has cited it: that is, who else thinks it is important. Such information can be very valuable in preventing firms from developing technology that already exists and signalling promising areas of technology. It is possible to explore the technology capabilities of competitors using patent analysis. Financial advisors evaluate patent data to gain insights into the technologies of a firm before advising clients to invest. Patent analysis tells investors which companies are good buys.

Chapter 9 discusses the management of patenting.

intervening process is notoriously difficult (Dodgson and Hinze 2000). Fourth, ascertaining the source of an innovation may be complex. It may be difficult, for example, to measure the relative contribution of R & D, marketing, or customer demand to the creation of an innovation, or the contribution of third parties such as suppliers.

The main indicators used to measure innovation are R & D statistics, patent data, innovation surveys, and product announcements. Each of these measures has strengths and weaknesses. Some additional methods used by firms to audit and benchmark their innovation performance are discussed in Chapters 6 and 7.

## R & D STATISTICS

R & D statistics are an important measure of social and private investments into the innovation process. The concept of R & D emerged in the 1900s, with the systematic organization of scientific and technological expertise in laboratories. Menlo Park

(1876–1884) was one of the first research laboratories, providing services to Edison's companies in the electricity and other industries. It aimed to produce 'a small thing every ten days and a big thing every six months', providing contracted-out research services to other firms. It filed 400 patents in seven years.

Research laboratories also emerged in the chemical industry, especially in Germany, enabling firms to develop new products and systematize production processes. In the 1930s, J. D. Bernal, one of the fathers of science policy, embarked upon an examination of investments in R & D in the UK. Bernal attempted to account for the total R & D activities of UK firms and government by contacting laboratories and asking them directly how much they spent on research and how many research staff they employed. By 1935, Bernal was able to estimate the share of the UK's economy that was devoted to research (Freeman 1999).

The idea of collecting information on research activities was picked up by other countries with the US National Science Foundation taking the lead. Problems arose because there were no commonly agreed definitions of what R & D was and therefore measurements were often incompatible across countries. To remedy this situation, the Organisation of Economic Cooperation and Development (OECD) developed a set of guidelines for the collection of R & D statistics. These guidelines were presented in their *Frascati Manual* (named after the Italian town where the conference establishing the indicators was held), first published in 1963. This manual has become the key source advising the systematic, consistent, and widespread collection and documentation of R & D activities by governments and industry. It has been substantially revised over the last forty years and the sixth edition was published in 2002 (OECD 2002).

The OECD's *Frascati Manual* states that R & D comprises 'creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture, and society, and the use of this stock of knowledge to devise new applications' (OECD 2002: 30). It suggests that R & D falls into three areas:

- Basic research: experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
- Applied research: original investigation undertaken to acquire new knowledge, primarily directed towards a specific practical aim or objective.
- Experimental development research: systematic work, drawing on existing knowledge gained from research and practical experience, directed to producing, improving, and installing new materials, products, and services.

The OECD has subsequently developed a family of manuals, including the Oslo and Canberra manuals, to guide governments in the development of indicators of innovative activity. These manuals provide advice on collection and interpretation of information

on a range of inputs and outputs into the innovation process, including patents and human resources.

There are significant problems with the measurement of R & D. Whilst the *Frascati Manual* provides detailed advice about what activities should and should not be included, there are still definitional problems and few firms have the time, willingness, or energy to scrutinize the manual. The traditional model of R & D based on the experiences of the large companies of the twentieth century saw separate R & D laboratories responsible for new product and process development. Increasingly product and process development is undertaken by different parts of the firm and only some of these activities are recorded in official statistics. R & D is simply an input into the innovation process, and in many industries several departments are responsible for innovation within firms. Indeed firms in a wide range of sectors do little or no formal R & D and yet are highly innovative.

In theory, R & D activities cease when the firm completes the necessary modifications to a working commercial prototype. Expenditures on marketing, preparing the product for production, and tooling the factory are not included in R & D statistics. Furthermore, with the advent of virtual and rapid prototyping (see Box 3.3), there is no clear delineation of when prototyping finishes. Product, service, and process innovations rarely fit into completely clear-cut categories or stages, which adds to the difficulty for firms to separate out R & D activities. In addition, small and new firms often tend to under-report their expenditures because they are performed informally or subsumed within other activities of the organization.

Although R & D in services rapidly increased in the 1990s and 2000s, its measurement is a major challenge for statistical agencies. Considerable effort has been made to help service firms better understand what elements of their activities should be counted as R & D. This often involves educating managers in service firms about the nature of R & D and working with them to help define rough estimates of the scale of activities. In South Africa, the individuals responsible for R & D data collection undertake site visits to service companies to help gain an insight into their informal R & D activities and assist their estimations. Software projects are also hard to categorize using traditional R & D measures. In theory, all software projects that involve uncertainty and create new functions should be included in R & D. Yet, the level of uncertainty involved in a software project is based on the judgement of its author. It is not an objective measure.

Given these limitations and others, R & D remains a blunt input measure whose boundaries are fuzzy. OECD reports often caution industry and governments to treat R & D statistics with a degree of scepticism, questioning their implications for policy and strategy. Nonetheless, public information on R & D expenditures has a major impact on corporate practice and public policy. Many firms report R & D expenditures in their annual reports based on the Frascati definition. This information is useful for managers because they can be used to benchmark relative performance, and firms often seek to

**Box 3.10 Bibliometrics—mapping science**

To gain insight into how science systems are structured and evolve, considerable effort has been made to map and measure their performance. This work is based on the analysis of scientific papers, exploring where they are published, who cites them, and who collaborates with whom in producing them. It involves statistical analysis of large-scale databases on scientific publications. One of the largest of these belongs to Thomson Scientific's Institute for Scientific Information (ISI) based in Philadelphia, USA. It includes 8,700 of the world's most important international scientific journals. Although this source is widely used for searching information about particular publications in the 'Web of Science', it can also be systematically analysed to gain insights into scientific productivity and collaboration. Recently, Google Scholar has become a widely used tool for bibliometric analysis with several specialized programmes now freely accessible, including, 'Publish or Perish' available at [www.harzing.com](http://www.harzing.com). Bibliometrics is the term used to describe the study and measurement of this information.

Bibliometric analysis has become a common tool in studies of innovation, especially in science policy. Early work in bibliometrics sought to find 'laws' of scientific behaviour. This work showed that much of the focus of attention in the scientific system was concentrated on a small number of journals and an equally small number of papers. Indeed, most academic papers receive no citations by others. Science can be a lonely business.

As the field has developed, researchers have increasingly used bibliometrics to measure the contribution of scientific research institutes and researchers (Hicks et al. 1994; Katz et al. 1995). This entails comparing the numbers and author addresses of papers published by different institutes and researchers. In particular, a considerable effort has been made to understand citations to papers, a measure of the impact of the research on the scientific community. Highly cited papers signify that a researcher has produced research that is valued or noticed by the scientific community. There is, however, no simple equivalence between citation frequency and research 'quality'. Many papers are cited simply because they can be disproved or even are incorrect. There are also marked differences between research fields in the propensity to cite journal articles.

Bibliometric data are used to map the performance of a national system of scientific production. This explores the 'Wealth of Science' across countries and in particular fields (May 1997). Such exercises allow governments to compare the performance of their national science systems. In general, the USA performs well in these studies, followed by the UK, Sweden, and Denmark. When controls are applied to the cost of producing the science by dividing the number of papers or citations by funding received, other countries, such as the Czech Republic and Hungary, move up the league table. Recent analysis across countries also indicates rapid improvements in the scientific performances of China and India.

Bibliometric tools are used by industrial firms to understand emerging areas of science and technology. Using techniques such as key or co-word analysis—that is, the frequency of jointly occurring keywords between abstracts of different papers—it is possible to map a new knowledge domain, exploring linkages between a field and other areas of science (Callon, Courtial, and Laville 1991; Leydesdorff 2005). Considerable efforts have been made to understand the emergence of nanotechnology as a field of research, for example, by examining links between it and chemistry, materials, biology, and other areas of science. Such efforts provide insights into promising future areas of scientific development.

It is possible to map the scientific publications of industrial firms. Some large firms, such as GSK, produce thousands of academic papers every year (Hicks 1995). This information is useful in understanding the capabilities of these firms for science-based innovation.

To learn more about bibliometrics, see the journal *Scientometrics*.

obtain a government tax credit for their expenditures. Governments have programmes to encourage firms to commit greater resources to R & D. Politicians use the percentage of Gross National Product (GNP) accounted for by R & D expenditures as indicative of economic vitality and vigour. Virtually all OECD nations have established R & D expenditure targets. The EU, for example, has established a target of 3 per cent of

GNP to be spent on R & D by 2010. In 2006, EU spending on R & D was 2 per cent of GNP.

Essentially, R & D remains an imperfect but useful measure of a major input into innovation. It provides one metric by which firms in the same sector can be compared regarding their commitment to technological innovation and the extent of and relative balance between basic and applied research and experimental development work.

## PATENT DATA

Patent data are another source of information on innovation. Patents have several advantages as indicators. They require codification of technology, describing its form and function as well as its novelty. As such, they contain considerable information about a firm's technological activities. Patents are examined by patent offices and therefore an awarded patent is seen to provide independent evidence of the novelty of a new technology over prior technologies. Information in patents can be used to map the sources and nature of technology in an industry or a firm and this can be very useful for managers (see Box 3.9). In some countries, firms have to pay to renew their patents and this provides information on which patents are considered by their owners to be the most useful. The disadvantage of patents as a measure of innovation is, as we saw in the case of mousetraps, that most patents are not commercialized. Patents are therefore better seen as a measure of invention rather than innovation. In addition, industries differ in their use of patents. In some industries, such as pharmaceuticals, patents can be an effective instrument to appropriate the benefits of an innovation, whereas in other sectors, such as services, there are few patents of commercial value (see Chapter 9).

## INNOVATION SURVEYS

A third approach to measuring innovation is the use of innovation surveys and databases (Smith 2005). Early studies used what is called the 'object-oriented' approach, that is, they focused on counting innovations. The most significant early survey of this kind was performed by the Science Policy Research Unit (SPRU) at the University of Sussex in the 1970s and 1980s, resulting in the SPRU Innovation Database (Pavitt 1984; Pavitt et al. 1987, 1989). The approach involved scanning technical journals and identifying announcements of major innovations. Each innovation was classified by its sector of origin, use, and type. This approach yielded a database of some 2,100 innovations in the UK over the period 1945–80. The approach was adopted by other countries. In Finland, VTT, an independent research organization, created the *Sfinno* database, which includes all major Finnish innovations over the last 100 years (Palmberg 2004; Pentikäinen et al. 2002). Other studies use industry-level research to document the sources of innovation

in particular sectors, such as construction and scientific instruments (Slaughter 1993; von Hippel 1988).

The 'object-oriented' approach to innovation measurement is limited by being time consuming and the information is difficult to collect. In the case of the Finnish study, for example, it required researchers to read over three million pages of technical publications (Saarinen 2005). It is also necessary to ensure that identified innovations are commercialized, rather than simply announced, to explore their use and diffusion.

A related approach is to use new product announcements made in the trade and technical press as a measure of innovative output. Such indicators are good for capturing information on small, incremental product developments, especially in consumer goods industries. Several companies, including Thomson Scientific, offer this service to researchers and firms seeking to learn more about innovation in a sector (see Box 3.10). This information is rather 'noisy' as many announcements are related to marketing existing products and not the introduction of new products. Using this method it is difficult to tell a major new product from a minor change in packaging. Firms introducing many new product varieties may be doing so from a position of weakness rather than strength, as seen in Sony's launch of many new MP3 players in an effort to catch up with Apple's iPod. Other product introduction surveys include Profit Impact of Marketing Strategy (PIMS), which emerged from research in GE in the 1960s. PIMS is a large, and often criticized, survey of over 3,500 firms which, nonetheless, includes useful information on new products.

Innovation surveys improve understanding about the sources of innovation. One of the most influential studies of innovation, Project SAPPHO, was conducted in the 1970s at the Science Policy Research Unit using an innovation survey (Rothwell et al. 1974; Rothwell 1977). SAPPHO examined fifty-eight innovations in the chemical and scientific instruments industry, pairing twenty-nine successful innovations with twenty-nine unsuccessful inventions. The study explored the factors that explained why some innovations were successful and others were not. The study found innovations with different performances were similar in the technology, organization of R & D, and training undertaken to make them work, but differed in the attention to users. Unlike unsuccessful innovations, successful innovations involved high levels of user involvement and user education. User engagement is therefore a key factor in determining success. Lessons from SAPPHO were used by Hewlett-Packard to redesign its product development processes to engage users more directly in the innovation process (Leonard-Barton 1995). In Chapters 5, 6, and 7, we discuss the ways firms integrate users into their innovation processes.

The 1980s and 1990s saw the emergence of a range of innovation databases at international, national, and sectoral levels. These databases focus on the number of innovations in a firm, industry, or country over time. They rely on expert opinion or lists of innovations generated by literature reviews. Scholars use these lists to investigate the incidence



and sources of innovation. Early studies showed innovation tended to be concentrated in high-technology industries and within large firms (Pavitt 1984, 1987), although others emphasized the advantages of smaller firms (Wyatt 1984). Innovations also tended to emerge from areas with strong R & D and other scientific and technological resources (Acs and Audretsch 1990). In addition, national surveys of innovation were undertaken to understand how many firms in a country were innovative and from where they received their ideas for innovation (Smith 2005).

Since the early 1990s, there has been a strong movement towards the use of innovation surveys, such as the EU CIS, to measure and map innovative activities comparatively across countries. These surveys are referred to as 'subject oriented' because they ask firms directly about their innovative activities (Kleinknecht and Mohnen 2002; Smith 2005). The first generation of surveys was conducted in Europe, Canada, and Australia in the early 1990s and the approach diffused rapidly around the world. In the late 1990s, many of the countries of South America—Brazil, Argentina, Chile, Peru, Uruguay, and others—and South Africa launched innovation surveys. The EU countries are required by law to implement the CIS every two years. India and China are planning to launch innovation surveys in the next few years. All these surveys are based on the OECD's *Oslo Manual*, now in its third edition. The *Oslo Manual* sets out guidelines for the survey, outlining questions, and sampling strategies (OECD 2005).

Innovation surveys ask firms to report whether they have developed a product or process innovation and indicate whether they were new to the market, new to the firm, or simply minor modifications. They also ask a number of questions about innovative activities, such as what sources of knowledge firms draw upon for innovation, and how innovations are protected from competitors.

Surveys have a number of advantages as indicators of levels of innovation in an economy. They draw on large samples of firms across all sectors. Surveys in the UK and Italy have had more than 16,400 and 29,000 respondents respectively. They help to capture information on innovative activities missing from R & D statistics. They enable researchers and governments to explore determinants of innovation at the level of individual firms and how a firm's ability to be innovative shapes its business performance. One additional advantage is that they allow international comparisons, enabling countries to compare the proportion of their firms that are innovative.

Like other indicators, however, innovation surveys have severe drawbacks as a measurement tool (see Box 3.11). They rely on firms themselves to report whether they were innovative. These statements are not checked and therefore their data rely on the knowledge and honesty of respondents. This can lead to biased data, especially in cross-country comparisons where notions of novelty and innovation differ. In addition, innovation survey data remain poorly established in the minds of managers. Unlike R & D data, which have become part of the management tool kit, innovation surveys are difficult for managers to understand and relate to their own businesses. As these surveys become a



**Box 3.11 Measuring the economic contribution of technological innovation**

Measuring the relationship between technological innovation and economic growth is difficult because of data shortcomings and the complexity of innovation itself. As Christopher Freeman (1994) argues, however, while it is difficult to measure the precise contribution of technical change to the growth of industries and countries, no one doubts that innovation is essential to this process.

There are many econometric studies of the returns to R & D investment but, like all efforts to measure an activity that is complex, socially based, and long term, they are bedevilled with methodological problems and inadequacies. Many of these studies measure the 'social' rather than the 'private' rate of return, because often the firm (or government agency) that undertakes the research does not accrue all the benefit. Once a technological breakthrough has occurred, it is replicable in one form or another by others who also accrue benefit (termed a 'spillover' in the economics literature).

Amongst the best studies of private returns are those of Griliches (1986), whose firm-level estimates of the gross rate of return to industrial R & D range between 25 and 40 per cent; Odagiri (1985), whose study in Japan estimated returns of 26 per cent; and Mansfield (1988), whose industry-level analysis shows returns of 38 per cent in Japan and 27 per cent in the USA. Coe and Helpman (1993), in a study of the twenty-two OECD nations plus Israel, show a rate of return of between 100 and 120 per cent. While there is some inconsistency in the econometric research, there is a general consensus that R & D investment produces advantageous rates of return with benefits that considerably outweigh the costs.

Despite the measurement difficulties, we do know that R & D expenditure and patenting activity is positively associated with growth in productivity and exports (Fagerberg 2005). Furthermore, the evidence points to a rapidly growing world trade in R & D-intensive products and knowledge-intensive services and to these products and services accounting for an increased proportion of world trade. Those economies that can expand their level of economic activity and exports in high-technology goods and in knowledge-intensive services will be best placed in the global economy.

regular part of national data collection, however, it is likely that, like R & D surveys, they will become part of how managers see themselves and measure performance relative to competitors.

No single indicator of innovation is totally satisfactory. Innovation can be measured, but only partially and indirectly. Any measurement of innovation should come with a caveat.

## Outcomes of innovation

Innovation can create many benefits for society, firms, and individuals—building wealth, increasing the quality of life, and even sustaining personal happiness. Some specific returns to innovation for individual firms are discussed in Chapters 6 and 9. An innovation commonly produces wider social contributions beyond the value captured by the innovator. Successful innovations diffuse widely across society. A virtuous circle can develop between an innovation and its diffusion. As an innovation is launched onto the market, its purchase or consumption by others stimulates new demand. This allows the producer of the innovation to make more of the product or service, lowering its cost for subsequent users. As well as producing profits to be

reinvested in innovation, falling cost curves enable access to products and services previously beyond the reach of many consumers. These falling cost curves are a product of greater scale of production and efficiencies that derive from learning how to make something through repetition (learning by doing, see Chapters 4 and 8). As in the case of the personal computer, such economies have created tremendous productivity gains for society. In addition, innovations may have uses in a number of different fields, and subsequent use in related areas can help create economies of scope, allowing firms to make a greater variety of products for their customers. Lower costs and greater variety ensure that products are widely available to consumers in a range of styles to suit most tastes. Such is the efficiency of the modern production, distribution, and marketing system that innovations often become quickly available to large numbers of people.

To help capture consumers' interest in innovation, firms can compete on branding and appeals to lifestyles. Such efforts often require building up the image of a product or service as contributing to the consumer's aspiration for a better life. These endeavours are fundamentally the domain of sales and marketing, but given their impact on innovation MTI requires awareness of both. Building new markets often requires considerable marketing imagination. When BMW was preparing to launch its new 1 Series in 2004, it used text messaging as a way of creating excitement about the new product. The text messages offered potential customers a chance to sign up for a test drive before it was launched on the market. This approach elicited responses from 150,000 people and helped ensure that the sales of the 1 Series were strong when it was launched later that year (Edmondson 2006). In Chapter 5 we examine some examples of how communities of people actively and enthusiastically engage with the development of innovations.

The outcomes of innovation are not always positive, of course. Schumpeter's description of innovation as a process of 'creative destruction' highlights the way it can devastate existing industries and firms, with all the associated social consequences. Technological innovations include military weapons, toxic chemicals, and the means of increasing personal surveillance and control by the state. Many innovations are ambiguous in their contribution. Cheap electricity and international air travel contribute hugely to economic wealth and social welfare, but also to global warming. The enhanced social engagement with the innovation process discussed in Chapter 10 may be one means of alleviating some of the negative consequences of innovation and making better judgments about the risks associated with them.

Another negative feature of innovation is that the objectively best technology may not be the one broadly adopted. Instances such as Sony's Betamax system losing out to a less advanced technology, are described in Chapter 7. The ways 'dominant designs' can be constructed from sub-optimal technologies is described in Box 3.12.

**Box 3.12 QWERTY**

The ubiquitous use of the QWERTY keyboard layout in the English language remains an historical puzzle. The layout is neither efficient nor logical. There is some debate, for example, as to whether a system devised by August Dvorak in 1936 is more efficient as it balanced frequently used letters between the two hands and loads strong fingers more heavily (Utterback, 1994). One explanation for the emergence and dominance of the QWERTY keyboard has its roots in an understanding of the early days of the typewriter (David 1985). A Wisconsin printer, Christopher Sholes, built the first typewriter, obtaining a patent for the device in 1867. The original typewriter had a number of design flaws: the print was outside the sight of the typist and typebars often clashed and jammed. In trying to solve these and other problems, Sholes developed the QWERTY keyboard layout. It separated the most frequently used keys, helping to slow the typists, ensuring that the typebars did not collide. Significant improvements in mechanics were achieved by working with the arms manufacturer Remington. But the machine itself was expensive, sold slowly and many early adopters, such as Mark Twain who wrote *Tom Sawyer* using a Remington typewriter, were frustrated as the costs of learning how to use the new machine were high. A range of competing machines, with different keyboard layouts and alternative printing mechanisms emerged. Edison patented a print-wheel in 1872, which became the standard for teletype machines. In the period 1895–1905, however, the QWERTY keyboard dominated and became part of a complex production system. David (1985) suggests three mechanisms by which QWERTY became ‘locked-in’ to the economic system. The first was *technical interrelatedness*, concerning the need for system compatibility between hardware and skills of the people using it. Typists trained on QWERTY ensured their skills were portable from job to job. By investing in one design, employers limited technical variety and allowed themselves to acquire ready-trained typists in the labour market. The second factor was *system scale economies* through economies of scale and expectations about the adoption decisions of others creating a strong momentum or bandwagon for its use. The third factor was the *quasi-irreversibility of investments* as the investments made by individuals and organizations to learn to use the QWERTY keyboard were high. It was also easy for other hardware makers to shift to the use of QWERTY.

The case of QWERTY shows premature standardization is possible around a sub-optimal system. As David (1985: 333) suggests:

The agents engaged in the production and purchase decisions of today’s keyboard market are not prisoners of custom, conspiracy, or state control. But while they are, as we now say, perfectly ‘free to choose,’ their behaviour, nevertheless, is held fast in the grip of events long forgotten and shaped by circumstances in which neither they nor their interests figured.

The QWERTY case improves understanding of how economic and managerial decisions are shaped by history. The choices that face managers about whether or not to adopt a technology may be profoundly conditioned by past events. History does not always produce ‘efficient’ or ‘optimal’ solutions. Technologies are often chosen because they provide network effects, crowding out alternatives that in hindsight would have been more efficient or technically superior (Shapiro and Varian 1998). Indeed, as David (1999) states,

[There is] nothing in the process that guarantees an outcome governed by forward-looking consideration of which among the available options would turn out to be ‘best’ from the viewpoint of the whole collective of technology users, let alone optimal for economic welfare in society at large.

Our modern civilization rests on many vintages of older technology, and one of the key challenges for managers is to improve or ameliorate some of the negative consequences of older technologies.

## THE DIFFUSION OF INNOVATION

Diffusion is the process by which innovations get adopted and used by people and organizations. The most influential model of the diffusion process was developed by

Everett Rogers in the 1950s and 1960s and has been subsequently used by many others, such as Moore (2002). Rogers's model of diffusion has become a key analytical tool in marketing, organization, and innovation studies. The model's focus extends beyond technological innovation; it is a general model of diffusion of new ideas, practices, and habits. Rogers defines the innovation-decision process as the way in which an individual or other decision-making unit passes from first knowledge of an innovation, to forming an attitude towards it, deciding to adopt or reject it, implementing and using it, and confirming the decision. It involves five stages: knowledge, persuasion, decision, implementation, and confirmation.

At the core of the model is the attempt to explain the S curve (see the discussion in Chapter 4 on the Product Life Cycle). The S curve is simply the shape of the pattern of an innovation's adoption over time, showing an initial slow period of awareness building, a period of acceleration as the innovation becomes popular, followed by a levelling-off as saturation and maturity occurs. The Rogers model of diffusion is based on two main elements: the technical features of the innovation itself and the social factors that shape the decision to adopt. These two aspects interact and mutually shape each other, determining the diffusion path.

Rogers emphasizes social factors. Social processes—including the cognitive and psychological attitudes of individuals and groups—shape the willingness to choose to adopt an innovation. Different individuals or groups may attach varying degrees of importance and value to an innovation. Rogers' model highlights how social networks, persuasion, and word of mouth all influence choices. The decision to use a new technology or innovation can be determined by factors such as an individual's sense of well-being or status within a community and the ways they act within institutions (Munir and Philips 2005). What other people think and do shapes decisions to adopt. Most people are susceptible to peer pressure and fashion. Young people, in particular, are especially conscious of their social standing with peers. New technologies and fashions move quickly through teenage social networks, making life difficult for young people and their parents as they seek to keep up with the behaviour of others. Companies make elaborate efforts to keep track of the new fashions and tastes that emerge, often employing firms that specialize in spotting trends among young people. They may also seek to positively influence this sector of society by offering free products to high-profile figures and celebrities. These activities are all a part of marketing and play upon the social nature of diffusion.

Rogers suggests innovations differ fundamentally in their characteristics which in turn shape their potential for adoption:

- Innovations need to have significant *relevant advantages* over existing systems or technologies. The greater the advantages, the more likely and more quickly the innovation will be adopted.

- The *complexity* of an innovation can have a negative effect on adoption. Innovations that combine different systems often require greater efforts to construct and use them.
- Some innovations cannot be used before they are adopted and therefore the *trialability* of innovation can positively or negatively shape the decision to adopt.
- The benefits of an innovation over other technologies or ideas are often hard to determine and therefore the *observability*, or the ease with which the innovation can be evaluated after trial, can have an effect on the speed and extent of diffusion.
- The ability to adapt, refine, and modify an innovation or the *reinvention* of innovation can also shape its use.
- Innovations are often embedded in systems and how close the *innovation fits a system* can have an impact.
- There are often high levels of uncertainty about the outcome of an innovation and the greater the *risk*, the lower the level and speed of adoption.
- Users often have different needs and the ability of innovation to *fit the task* for users can affect its take up.
- Many innovations require considerable support from their producers before consumers can use them successfully. This level of *support* influences adoption.
- Some innovations require little or no knowledge to use. Others require users to undertake considerable formal or informal learning or education. The *knowledge required for use* is therefore a key determinant of diffusion.

The choice to adopt may also be related to other context-specific antecedents, such as whether the adopter has a degree of independence. Some innovations are forced upon reluctant users. Rogers also points out that the factors that shape these choices may be different across stages of the diffusion process, including pre-adoption, early use, and established use.

Rogers' model contains a description of traits of adopters, dividing individuals and organizations into six categories. They include:

- *Innovators* are characterized by venturesome or daring personalities that may seek activities that involve risk and high rates of return and failure. They are willing to act in circumstances of high levels of uncertainty. They are likely to have considerable financial resources. They may act as gatekeepers of new ideas into the system (see the discussion of technological gatekeepers in Chapter 6).
- *Early adopters* are often highly esteemed members of the community who are able to influence the opinions of others. They can validate or legitimate new ideas for others.

- *Early majority adopters* interact with opinion leaders, but are not themselves leaders. They provide interconnectedness in networks. They may delay adoption, and be not the first, but not the last to adopt. They have a willingness to adopt, but will avoid being the first to do so.
- *Late majority adopters* are often sceptics who are forced to adopt by necessity. They may also be cautious, focusing on safety first. They are, however, susceptible to peer pressure.
- *Laggards* are often isolated in a wider social network. They may be highly suspicious of innovation, peer pressure, or gatekeepers. They often lack the knowledge, skills, and resources necessary for adopting new practices. For these individuals the cost of failure may be high and therefore they may wait until they are forced by markets or regulators to adopt.

These categories are ideal types and individuals may not fit exactly into them. The negative terms used for late adopters do not suggest these individuals are less able, but that their attitudes and adoption patterns relative to others are more downbeat and slower. Individuals may fall in different categories for different types of innovations. Early adopters of, say, consumer electronics, may be laggards in the adoption of innovations in financial services. Such adoption patterns may reflect the social utility of an innovation for that person or organization, or its perceived influence on lifestyle and consumption culture.

Rogers' analysis contains a strong pro-innovation bias, reflecting the view that adopting an innovation is generally beneficial to its user. It also says little about the cost of an innovation and how choices to adopt are shaped by economic factors. It pays little attention to the way adoption decisions by one actor may limit or constrain the options of another. By contrast, economic models of diffusion focus more on factors that shape the choices and abilities of adopters (Lissoni and Metcalfe 1994; Stoneman 2002; Hall 2005). Here, diffusion shows adaptation and learning and therefore reflects the skills, motivations, and capabilities of adopters rather than the fundamental properties of the innovation itself. These approaches seek to understand individual calculations of adoption that weigh the incremental benefits of adopting a new technology against the costs of change in situations of uncertainty and incomplete information. These models also highlight the importance of externalities and network effects in shaping adoption. For economists, the choice is not simply between adopting or not, it is between adopting now or later. Given the uncertain nature of a particular technology, adopting later may be a good strategy (see the discussion on fast-follower strategy in Chapter 4).

Economic models of diffusion highlight the dangers of being locked into a particular technology, making it difficult for users to switch to new and better options in the future (seen in Box 3.12). They show the path-dependent nature in the development

and use of some technologies (Arthur, Ermoliev, and Kaniovski 1987). They also stress that adoption can be expensive. Indeed, the costs of using a new computing system may be many times the cost of initial investment. These costs of using or learning may make it a reasonable decision to postpone or not to adopt at all. These models raise awareness of several key cost issues for managers to think about when making the decision to adopt a new technology or innovation. They include:

- *Resources*—What scale of resources is available to a firm and how much will it cost to use the new technology? In general, large firms are more likely to adopt new technology than small firms because of their greater resources.
- *Role of suppliers*—How much information is available about the innovation? It is possible for suppliers to create lock-in to a particular technology? Can they control access to and price of the new technology?
- *Technological expectations*—What is the future for the innovation? Will its price fall dramatically in the next few years? If so, should we wait?
- *Search or learning costs*—What are the costs of learning about the advantages of new technology and then learning to use it?
- *Switching costs*—Will the time and effort required to learn to use the new technology include costs of breaking with the past? Does the firm have to develop new capabilities to use the new technology?
- *Opportunity costs*—Does adopting the new technology require the firm to lose or underutilize previous investments? What are the costs of not investing? What opportunities or options may be foreclosed if the technology is not adopted (see the discussion of real option values in Chapter 9)?

Studies of diffusion have shown there are national, cultural, and religious differences that might shape patterns of adoption. An international study of use of consumer goods, such as video recorders, washing machines, and dishwashers, found considerable differences across countries between the period the technology was first introduced and when its adoption became widespread (Tellis, Stremersch, and Yin 2003). Some technologies diffuse rapidly in many countries, such as the CD player, which had reached a high share of the populations in the OECD countries in 1.8 years. In contrast, clothes driers took more than 10.4 years to diffuse widely. Denmark is the fastest adopter of consumer goods, whereas Portugal is the slowest. Some differences can be attributed to wealth and national endowments (driers are much less useful in sunny Portugal than in cloudy Denmark), but they also reflect the share of women in the labour force and general receptivity to new technology among the population.

Mobile phones provide an interesting technology adoption pattern internationally. Hong Kong has the highest rates of mobile phone subscription and Taiwan has the



highest rates of adoption in the world. For every 100 people in Hong Kong there are 111 subscriptions, and almost 1.3 phones per person. By contrast, rates of adoption of mobile phones in the wealthy USA remain well below other advanced countries. China is the largest mobile phone user in the world. The number in use increased from around 20 million in 1998 to 300 million six years later.

Past attitudes and behaviours shape future diffusion patterns. Japanese consumer electronics customers, for example, are some of the most discerning in the world. Building upon the enthusiasm for new products, electronic firms often release early versions of their product in Tokyo to see how Japanese consumers react. This can provide insights into how customers think about the value of an innovation, including its design and functional performance. Lessons from these experiments in lead markets often need to be adjusted for less advanced markets. For example, Dixons, one of the largest electronic consumer goods stores in the UK, in the 1990s and 2000s found many products did not come with suitable instruction manuals for UK users. Unlike in Japan, where users were often keen to learn about all features of new electronic equipment, working through manuals after purchasing their products, UK consumers just wanted to 'plug and play' electronic products, following simple instructions. Few were willing to read instruction manuals. In response, Dixons worked with its Japanese suppliers to develop products that required no instruction manual to appeal to their 'lazy' UK consumers.

Studies of the adoption of technological innovations show they often require mutual adaptation between producers and users of a technology (Leonard-Barton 1988). Indeed, new technologies rarely fit seamlessly with users. They often need to be adapted to meet users' needs and requirements through iterations or re-innovations (Rothwell and Gardiner 1988). Thus, technology shapes the context as well as the context shaping the technology. This process of adaptation may not be simple resistance to new technologies; it also involves a positive process of reinvention. An example of the challenge of diffusion and mutual adaptation can be seen in diffusion of innovations in health care (Ferlie et al. 2005). When dealing with human health, it is important to establish the credibility of a new treatment. Evidence of the benefits of new treatments, however, is usually not definitive and may be open to interpretation by specialists. In these cases, the credibility of an innovation is negotiated between several active adopters. Professional communities often have to be created and need to win the support of other professionals in the system to move the treatment into use. In this case, the diffusion process is shaped by characteristics of communities and contexts within which the technology is located and the availability of evidence upon which decisions can be based. This was the case with the development of fire engineering described in Box 2.1. The use of the simulation technology used by fire engineers required an extended and cautious negotiation between fire engineers, architects, planners, builders, regulators and fire-fighters (Dodgson, Gann, and Salter 2007).



**Box 3.13 Does fortune favour the brave?**

In a study of over a thousand Canadian independent inventors, Astebro found only 7 per cent successfully commercialized their inventions. Of the inventions that actually made it to market, only 40 per cent made a profit. The average rate of return on all inventive activity was 16 per cent. Six inventions had returns of 1,400 per cent, however, and one had returns of 2,960 per cent! Once the amount of time and effort put in was accounted for, Astebro found that inventing was an expensive activity, producing negative returns for most inventors. In other words, most inventors received nothing for their efforts. So why do inventors bother if returns may be negative? One answer to this is that inventors are risk-seekers and enjoy high-reward, high-failure activities. They are excited by competing. Inventors are also motivated by the desire to see their ideas translated into products. In this sense, invention is driven by more than pursuit of monetary rewards; it satisfies basic human desires for creativity and risk-taking.

*Source: Astebro (2003).*

Most innovations do not succeed in becoming widely diffused. The rate of failure in innovative efforts remains high and the returns from innovations are highly skewed (see Box 3.13). It is only a few innovations in a portfolio that produce significantly above-average returns. Similarly, only a small number of academic publications are highly cited, a small number of patents account for most income from patents, and a small number of products account for the majority of sales. Although the performance of incremental innovations tends to be less skewed than that of radical innovations, the implications of these skewed returns are clear: as Frederic Scherer argues, the chances of success in innovation are such that an appropriate metaphor is that of a lottery (Scherer 1998; Scherer, Harhoff, and Kukies 2000). Spending more on innovation, or buying more tickets, provides more chances of success, but large expenditure does not guarantee a win.

Innovation can create options for the future. Many of these options will not be realized, but they may open up other unforeseen possibilities. Good ideas do not always spread, but they can often influence the next generation of ideas that might diffuse. In this sense, the innovation process remains uncertain, offering what Schumpeter called ‘the carrot of spectacular reward or the stick of destitution’ to those who embark upon it. Withdrawal from the effort, however, provides little advantage and may create even greater long-term risks. It is those firms that try, fail, learn, try again, and then perhaps succeed that are the successful innovators. They have the diligence, persistence, talent, and luck required to succeed.

## Summary and conclusions

Managers need to know about the different types and levels, processes, sources, and outcomes of innovation. The management challenges of incremental innovation are very different from those of radical innovation. The management challenge of the

first-generation innovation process requires singular attention to one, occasionally very complicated, issue: building up knowledge about scientific research and the opportunities it provides. Managing the fifth-generation innovation process is significantly more complex as it involves many more parties and balancing multiple inputs. Measuring innovation is a vexatious issue: available metrics are inevitably incomplete. Indicators of R & D and patenting are flawed, but can be useful. Innovation surveys are becoming more widespread and are improving in value. Information from these sources are valuable tools in the MTI armoury. The outcomes of innovation are widely varied. There are some useful approaches to understanding the diffusion of innovation, and especially the underlying social and psychological influences. These need to be complemented with economic aspects, such as costs, and management factors, and the existence of key capabilities to understand the diffusion of innovation.

The chapter has highlighted how the focus of MTI—technological innovation—is a broad-ranging, complex, and difficult issue. Subsequent chapters will examine how MTI deals with particular aspects of the challenges raised by the nature of technological innovation. Chapter 4 examines the most challenging issue: innovation strategy.

# 4 Innovation Strategy

## Introduction

Of all the aspects of MTI, innovation strategy is the most challenging. Firms can be very good at the various activities involved in MTI, such as R & D or operations, which are discussed later in the book, but this counts for little unless it is supported by a well-grounded innovation strategy that guides firms' choices, prioritizations, and sequences. There is little value in being highly efficient at developing or delivering new products and services if they are the wrong products and services for the firm and its markets. Well-chosen new products and services deliver value, build the technological base of the firm, develop its capabilities, improve its processes, and add to its reputation and brands. An innovation strategy helps firms decide, in a cumulative and sustainable manner, about the type of innovation that best match corporate objectives. It should react to the importance and challenges of MTI described in Chapter 1, reflect the contextual issues affecting MTI discussed in Chapter 2, and respond to the different features and aspects of technological innovation analysed in Chapter 3.

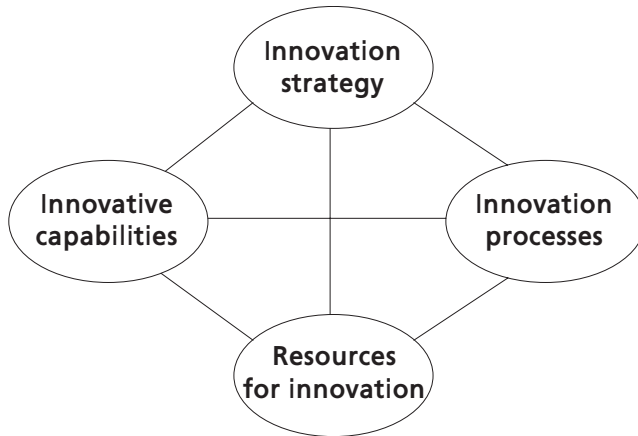
This chapter defines what an innovation strategy is, explaining why it is important, and how it relates to other aspects of corporate strategy in firms. Its primary focus is the formulation of an innovation strategy through the innovative capabilities of searching and selecting. It discusses the limitations of trying to use conventional corporate strategy frameworks and tools to define and guide radical, emergent, and unstructured innovation processes, such as those often found in new technology-based firms and in technological entrepreneurship generally. The implementation of strategy, involving configuring and deploying capabilities is explored more fully in subsequent chapters. In practice the formulation and implementation of strategy are undertaken iteratively and are intimately connected and informed by learning. The chapter begins by addressing the importance of formulating an innovation strategy. It then examines innovation strategies in practice by describing some types. This is followed by a discussion of searching and selecting capabilities. The chapter concludes with a review of the returns from innovation strategy, and consideration of the particular issues of innovation strategy in small and medium-sized firms.

## What is an innovation strategy?

An innovation strategy guides decisions on how resources are to be used to meet a firm's objectives for innovation and thereby deliver value and build competitive advantage. Its crafting is supported by a number of innovative capabilities that steer the configuration and reconfiguration of a firm's resources. It entails judgement about which kinds of innovation processes (discussed in Chapter 3) are most appropriate for the firm's circumstances and ambitions. An innovation strategy identifies the technologies and markets the firm should best develop and exploit to create and capture value. It does so within the limits of the resources available to the firm to support current and future innovation efforts and its evolving corporate strategy, organization, and culture.

When considering innovation strategy it is helpful to think of the military distinction between strategy and tactics (although it would be unwise to take the analogy too far—strategy is not warfare). In military parlance, 'tactical' refers to the specific means by which battles are won. 'Strategic' refers to how wars are won: whether, where, and when to fight battles; preparing for war by understanding the nature of external threats and opportunities; and ensuring that sufficient resources and capabilities are collected, organized, and deployed in a timely manner in order to succeed. Within an innovation perspective, tactical issues relate to how firms manage R & D activities, develop new products and services, and improve operations. At a higher level, strategic matters include analysis of the firm's competitive and technological environment, and assessment of its external challenges and opportunities and where its distinctive advantages lie. It involves prioritizing and developing the right technological innovations by ensuring that appropriate resources, capabilities, and processes are used to their best effect in delivering value. As with the understanding of the nature of corporate strategy vis-à-vis innovation strategy, it is not concerned with individual issues, but with comprehensive and coherent approaches to how business issues fit together (Hambrick and Frederickson 2001).

Innovation strategy is different to mainstream business strategy because it needs to comprehensively accommodate uncertainty. As such, and as discussed later, many common approaches to business strategy are inappropriate for innovative businesses. Continuing the military analogy, innovation strategies cannot simply follow an army field manual of prescriptive plans, but must function within Clausewitz's 'fog of war' with uncertainty about your own capabilities, and the capabilities and intent of adversaries. Some uncertainty (unknowable futures) is always present in strategic management of incremental innovation, but is a major strategic factor in radical innovation. Conventional strategy analysis tools such as Porter's five forces industry analysis (see discussion later) are useful for low levels of uncertainty but as uncertainty increases, the key elements of successful strategy become search and responsiveness, helping firms to react to unforeseen events (Courtney, Kirkland, and Viguerie 1997). Under conditions



**Figure 4.1.** A simple model of innovation strategy

of high uncertainty, the use of many common strategy tools can be misleading and even dangerous.

Figure 4.1 shows a simple model of four interrelated elements involved in innovation strategy, including:

- The enacted strategy itself, including its targets and ‘fit’ with overall company strategy, existing innovation efforts, and the context in which it operates. The identified targets are the technologies and markets that managers believe will create and deliver best value for their firms.
- The resources available for innovation: the assets a firm owns and to which it has preferential and secured access.
- The innovative capabilities that guide and enable those resources to be assessed, configured, and reconfigured.
- The innovation processes used to deliver results: the combinations of management and organization around R & D, new product and service development, operations, and commercialization that deliver innovation.

Innovation strategy helps to focus attention on how these resources, capabilities, and processes are best developed and deployed to meet corporate objectives.

There are often more opportunities for innovation than resources available, and choices have to be made. Choices should be linked to anticipated economic benefits and the ability to appropriate returns from innovation (see Chapter 9). They need to fit with overall corporate strategy, deciding whether or not innovation targets complement the firm’s available resources and existing innovation portfolio and whether ambitions match its organizational structure and culture. The choices made should include attention to issues of timing: whether, for example, a firm aims to be a proactive

innovator or to be a reactive follower. These decisions help prioritize resource allocation, providing a focus for marshalling and integrating different components of innovation processes and guiding them towards specific markets and customers within the competitive environment.

## RESOURCES FOR INNOVATION

A firm's resources used in innovation strategy include:

- Financial resources and appetite for and tolerance of risk.
- Human resources and their capacities for innovation.
- Technological resources, both physical (plant and equipment) and intellectual (knowledge, patents, trademarks).
- Marketing resources (ownership and market penetration of brands, access to lead customers, knowledge of markets).
- Organizational resources (the routines, procedures, practices, and policies within the firm, which, when combined, craft processes).
- Networking resources (partners, suppliers, customers, communities within which the firm operates, and the level of adhesion and trust within them).

## INNOVATIVE CAPABILITIES

There is a growing literature in the field of corporate strategy on the topic of 'dynamic capabilities', defined as the 'capacity of an organization to purposefully create, extend, or modify its resource base' (Helfat et al. 2007: 4). Innovative capabilities are similarly defined in this book as bundles and patterns of skills used by firms to formulate and implement an innovation strategy involving the creation, extension, and modification of those resources used for innovation. Numerous dynamic capabilities of firms are identified in the literature; here we consider four—searching, selecting, configuring, and deploying (Helfat et al. 2007)—that focus specifically on supporting innovation.

Innovative capabilities include:

- Searching—seeking and assessing market and technology opportunities and considering the threats changes in markets and technologies pose.
- Selecting—choosing amongst future options, based on an evaluation of available resources, the probability of value creation, and the results of search activities.
- Configuring—ensuring the coordination and integration of innovation efforts.
- Deploying—delivering internally generated and acquired innovations on time and to budget, and protecting and delivering value from innovation.

There is also a ‘meta level’ encompassing innovative capability:

- Learning—improving the performance of innovation processes through experimentation and experience.

## INNOVATION PROCESSES

Innovation strategy involves deciding upon the most appropriate innovation processes for the firm’s context and targets—whether these processes are relatively simple or complex (see the discussion later and Chapter 3 on the various generations of innovation process). An innovation strategy helps firms decide on the right things to do; their innovation processes help them do things in the right ways (see Box 4.1). Subsequent chapters of this book examine the various elements of the innovation process, including the development and maintenance of supportive networks and communities, technological collaboration, R & D, creating new products and services, operations, and generating economic returns through commercialization.

### Box 4.1 Dancing elephants

Even the largest and most cumbersome organizations can respond to changes in strategy. In his autobiography, Lou Gerstner, former CEO of IBM, describes how IBM undertook a fundamental strategic repositioning in the 1990s. The title of his book, *Who Says Elephants Can’t Dance?*, alludes to the way that even the largest, monolithic organizations can change strategies in a dramatic and effective fashion. In 1993, IBM was in deep trouble. Its annual net losses had reached a record \$8 billion. The computer market was focused primarily on desktops and it was extremely competitive. Gerstner joined IBM in 1993 and, with a strong customer-oriented background, he decided to focus on business applications across the enterprise. With help from his colleagues, he recognized that one of IBM’s enduring strengths was its ability to provide integrated solutions for customers, representing a total package of support, not individual parts or components. IBM successfully transformed itself into an integrated business solutions company, combining its strengths in solutions, services, products, and technologies. It sold its PC business and bought a major consulting firm. IBM accomplished a complete transformation in its strategy.

Sweden’s Ericsson is another example of a large company that radically changed its strategy (Davies 2003). During the 1970s and 1980s Ericsson was known as a broad-based manufacturer of public telecoms equipment. During the 1990s it focused on the mobile communications market and was so successful that by 1999, 40 per cent of the world’s subscribers were connected to Ericsson systems. During the mid-1990s, Ericsson manufactured and sold mobile handsets, mobile subsystems and systems, radio base stations, mobile switches, operating systems, and customer databases. In 1996, Ericsson’s Corporate Executive Committee completed the largest planning study in the company’s history. It pointed to the trends of deregulation and greater competition in telecoms forcing suppliers to get closer to customers. Telecom operators were demanding suppliers assume greater responsibility for network design, build, and operation.

As a result of this increased awareness, Ericsson’s strategy changed fundamentally from manufacturing into higher value-added services, systems integration, and operations.

The company now offers ‘turnkey’ solutions to design, build, and operate mobile phone networks (Davies 2003). It is a complete supplier and integrator of mobile systems. It also has a global services business, offering services and business consulting to support customers’ network operations. It has outsourced its products, including exchange equipment, 3G radio base stations, and mobile handsets to other suppliers such as Flextronics and its joint venture, Sony-Ericsson.

## Why is innovation strategy important?

The reasons why innovation is a strategic management issue is because it is intimately linked to the capacity of the firm to deliver value:

- Creating and appropriating returns from innovations is a key source of competitive advantage for a firm.
- Complex, risky, and expensive activities, such as R & D, product and services innovation design, operations, networking, and collaboration, can hamper a firm's competitive position and may result in piecemeal, short-term focused, and potentially conflicting outcomes unless they are guided by choices that build synergies and grow expertise cumulatively.
- Globalization of technology and markets, with many potential new customers, suppliers, partners, and competitors in different parts of the world, requires companies to take a strategic approach to their innovation activities to provide focus within an ever-expanding set of opportunities and threats.
- Organizational structures and innovation processes that firms adopt to encourage technological innovation need to relate to the corporate strategy pursued by the firm, and vice versa; for example, R & D can be organized according to whether the firm aims to support an innovation leader or follower position.
- Unless firms can articulate their long-term strategic aims for innovation, it is difficult for them to communicate with and benefit from public-sector science and technology policies in areas such as basic science, regulation, and standards creation. They are also less likely to be able to build long-term technological collaborations with partners or to find patient investors (see the discussion later and Chapter 9).
- A firm that identifies innovation as a strategic activity is more likely to attract creative workers in search of exciting opportunities in the 'war over talent'.

## Innovation strategy in practice

There are no blueprints for innovation strategy. Managers need to nurture the most meaningful approaches to strategizing for the specific circumstances within which they conduct their business. Innovation strategy development and use can vary markedly depending upon whether the firm is new or well established, large or small, centralized or dispersed in its organization, deals in simple or complex products and services, operates within well-defined or uncertain technological and market circumstances, with a major or minor impact on society, safety, and the environment. It also varies according



to the characteristics of the sectors and innovation systems in which it operates. The challenge for managers is to appreciate and work within the opportunities and constraints of being able to create and implement innovation strategy in their own specific circumstances, which, as we have seen in previous chapters, are often complex and uncertain.

In some firms, strategy is not written down, remaining implicit in the ideas of a few senior managers, and only partially communicated to staff, customers, and suppliers. In other firms, strategy is set out and documented explicitly, and communicated overtly within and outside the business. Explicit strategies for innovation describe objectives and targets and the specific resources, capabilities, and processes required to meet them. Such deliberate strategies are more commonly a feature of well-established sectors and stable business environments. Strategies that are less specific and more emergent are more commonplace in rapidly changing or emerging sectors and markets, in the context of radical innovation, or in the early stages of a product life cycle where there is a high degree of uncertainty. In all cases sound, enacted innovation strategies usually possess the following features:

- Statements on the role of innovation in meeting corporate strategic objectives, creating and delivering value, and building sustainable competitive advantage.
- As accurate as possible an understanding of market trends and technological and competitive circumstances and their impact on innovation positions.
- Articulation of the firm's innovation ambitions and long-term objectives.
- Recognition of gaps between current performance and future expectations in relation to innovation.
- Plans for developing and mobilizing resources and innovative capabilities in a timely manner.
- Appreciation of the most appropriate innovation processes for meeting objectives.

An innovation strategy usually involves a mix of approaches. Parts of the business, for example, may have a relatively straightforward innovation process, involving simple research-push or responding to customer demands. Other parts of the business may be far more complex and difficult to manage: for example, being a user of the fifth-generation process described in Chapter 3. It is important to recall that complexity of innovation strategy is defined here by the number of influential parties contributing to it and the emergent, unpredictable properties of outcomes. A 'simple' innovation process driven by huge investments in in-house science, for example, may turn out to be extraordinarily complicated, difficult, and risky (see Box 6.2). Greater complexity in innovation strategy definition is often found in large multidivision businesses where the development and implementation of strategy requires coordination if not consensus among corporate, divisional, and functional activities, as is demonstrated in Chapter 5 on R & D.

**Box 4.2 The move from technology strategy to innovation strategy**

Recognition of the broad corporate context within which innovation takes place is acknowledged in the MTI literature, which has evolved over the past twenty years from analysis of ‘technology’ strategy to analysis of ‘innovation’ strategy. This partly reflects the change in focus to looking at broader aspects than just technology, and partly a change in terminology—looking at the same things (technology) using a different language and set of dimensions. A number of books and articles in the 1980s and mid-1990s examined technology strategy from an organizational or operational perspective (Porter 1985; Teece 1987; Dodgson 1989; Pavitt 1990; Loveridge and Pitt 1990; Granstrand, Hakansson, and Sjolander 1992; Dussauge, Hart, and Ramanantsoa 1993; Goodman and Lawless 1994; Coombs 1994; Brown 1996). During the 1990s and 2000s, business schools adopted innovation as a core field of study because of its impact on competitive advantage. The focus on technological innovation extended beyond operations and engineering management and organizational matters to encapsulate associated changes in business models and corporate strategies (Burgelman et al. 1995; Dodgson 2000; Tidd, Bessant, and Pavitt 2005; Schilling 2005; Chesbrough 2003). During this time, innovation strategy became a more widely used and understood term, and has become encompassed by subjects such as marketing. It nevertheless retains its antecedents in being concerned primarily with technological innovation and the conditions that encourage its effective management.

Whether an innovation strategy is explicit or implicit, broad or detailed, prescriptive or emergent, and whatever its objectives and timing, its formulation and application are bounded by the firm’s culture, norms, and values. Strategy emerges from and is implemented within organizations that possess distinct beliefs and routines and, therefore, needs to fit with them. The continued success of 3M is attributed to its culture of supporting innovation, seen in the deeply engrained traditions and customs revealed in the following statement from its Chairman, William McKnight in 1948:

As our business grows, it becomes increasingly necessary to delegate responsibility and encourage men and women to exercise their initiative. This requires considerable tolerance. Those men and women to whom we delegate authority and responsibility, if they are good people, are going to want to do their jobs in their own way.... Mistakes will be made.... Management that is destructively critical when mistakes are made kills initiative. And it’s essential that we have many people with initiative if we are to continue to grow.

Given the high degree of failure in innovation, discussed in Chapter 7, a culture tolerant of failure and encouraging of learning from failure is a distinctive capability.

Developing an innovation strategy contributes to strengthening a firm’s knowledge about customers and markets, science and technology, regulations, competition, suppliers, and available finance. This knowledge in itself helps to improve awareness of what can and what cannot be embraced and underpins the innovative capabilities that shape and guide the formulation of an innovation strategy and the selection and use of appropriate innovation processes. The remainder of this chapter describes the types of innovation strategies firms can pursue, with analysis of the kinds of innovative capabilities needed by firms. A number of tools and techniques can assist firms in

defining their innovation strategies and building their innovative capabilities and these are described, together with a commentary on how to use them, and their likely benefits and limitations.

#### Box 4.3 Insights from corporate strategy and planning

There are several schools of thought on strategy and the ability to make meaningful choices about the future, ranging from those that think planning is a futile activity to those that believe that future events can be shaped, managed, and measured. It is generally useful for managers to assess the level of uncertainty surrounding their decision-making so they can tailor strategy accordingly. Courtney, Kirkland, and Viguerie (1997) identify four levels of uncertainty which affect the ability to develop meaningful strategy:

Level 1. Clear enough evidence about likely future markets and competitive environments for new technology is available, and standard analytical tools can be used with confidence.

Level 2. A number of alternative futures exist. These can be described in scenarios, and decisions can be made about the alternatives to which one might respond.

Level 3. A wide range of possible future outcomes exists and it is not possible to develop discrete scenarios with any degree of certainty. Managers glean whatever evidence may be available and make decisions based on past experience and their personal judgements.

Level 4. There is real ambiguity about the future creating high levels of uncertainty, so managers base their decisions mainly on qualitative judgements.

Uncertainty and ambiguity in many innovation activities can lead to the view that it is not possible to produce a systematic strategy with clarity of purpose. This position uses what might be described as a *judgment-based approach* to strategy. It is adaptive, focusing on experts' intuition to make adjustments to strategic orientations and operations in pursuit of results. In such case, the degrees of uncertainty surrounding the firm's operating environment are typically at Level 3 or 4. In the early stages of more radical innovation, the nature of uncertainty arising from unpredictable events can result in the best-laid plans failing. In such circumstances, why try to plan and develop strategies for the future? Attempts to use formal measurement tools and techniques (described later), can cause complications in the form of irrelevant data and mistaken diagnoses, and lead to what is often described as analysis paralysis. Under such conditions it may be better to leave decision-making to the judgement and experience of experts responsible for different parts of the innovation process with a loose set of orientations and guiding principles, thereby reducing the extent to which they are conceptualized in detail. Hirschman and Lindblom (1962) conclude that in many uncertain projects there is little point in detailed ex ante planning and at best we can develop the science of 'muddling through' (Lindblom 1959). Problems with this 'leave-it-to-the-experts' approach are that a lack of articulation reduces the possibility of engagement of a wider group of stakeholders (see Chapter 5 and the earlier discussion on why innovation strategy is important), and transparency and accountability in decision-making. Another problem with the 'adaptive' approach is that managers can sometimes abandon any attempt at analytical rigour, resulting in misinformed judgements and decisions (Courtney, Kirkland, and Viguerie 1997). Firms can deal with high levels of uncertainty by keeping their options open, investing in flexibility, allowing quick adaptation to opportunities, whilst still demanding rigorous processes for option of development and management.

At the other end of the spectrum lies the 'measure-and-act', *rational approach* to strategy and planning, or what Whittington (1993) calls the 'Classical' approach, which encompasses much of Michael Porter's work on strategy. It is intellectually linked with the study of economics and the military, based on a belief that managers can make rational choices in response to technical opportunities and social, economic, and environmental needs. The use of resources can be optimized to provide the best overall solution based on current knowledge and past experience. Application of this approach to innovation strategies sees the systematic definition of goals, with a schedule of resources and plans for the use of capabilities and processes needed to achieve them. This technocratic approach is often found in operations and engineering management using tools and techniques for measuring and improving performance against clearly defined benchmarks and milestones. It is appropriate to use such techniques where capital investment is intense—putting the firm at risk financially speaking, market uncertainty is

low, and risk can be contained, such as in incremental innovation and continuous improvement. Radical innovation is often inherently more multidimensional and uncertain, creating instability with unique and novel outcomes that conflict with such exercises of technical rationality (Lester and Piore 2004). There are, nevertheless, some circumstances where firms have the confidence of their market position and technological capability through detailed analysis to make ‘big bets’ on future developments with the aim of shaping the market to benefit from FMA (Courtney et al. 1997; see Box 4.4).

Another approach, associated with management scholars such as Mintzberg (1994), argues that strategy is emergent, evolving from decisions that are crafted as internal and external events unfold. This *rational-adaptive approach* accepts uncertainty and the difficulty of measurement, but believes in the possibility of developing plans and using techniques to collect evidence where it is practical to do so. This position is closely related to what Whittington calls the ‘Processual’ approach, which recognizes that in practice, strategy is a messy process of learning, failing, and compromising, emphasizing the crafted nature of strategy within a firm’s particular circumstances. An approach to innovation strategy formed from a combination of good judgement and practical techniques for gathering and analysing evidence is likely to be the most fruitful way forward in many situations, particularly where there are high degrees of uncertainty, as long as it leads to relatively rapid decision-making.

## Types of innovation strategy

Describing different types of innovation strategy is an inevitably crude exercise. In reality firms rarely comply with ideal types. They display different features in different businesses at different times. As we show shortly, strategies evolve between types. Nevertheless, there are some broad categories of innovation strategy that can be described and used for analytical purposes, although it is important to remember their limitations. One of the most useful distinctions is between firms that seek first-mover and fast-follower advantages—see Box 4.4.

Courtney, Kirkland, and Viguerie (1997) offer three basic positions that firms might adopt in uncertain conditions in the light of analysis of the industries within which they operate and the choices they make about timing:

1. Taking big bets, investing heavily in a single new area or development with the prospect of major returns. This may occur in emergent technologies where there are very high levels of uncertainty, or where an existing firm has strong technological leadership and wishes to capitalize on first-mover or very fast-follower advantages.
2. Hedging bets, investing in a number of different options where there are expected to be reasonable returns. This may occur in firms operating in relatively stable markets, able to benefit from fast-follower positions.
3. Wait and see, adopting a ‘watching brief’ to keep options open or maintain a position in a market whilst others bear greater risks by taking a lead in developments of uncertain new technologies. This option is usually taken by firms that follow behind industry leaders and fast followers, but have the ability to benefit by delivering cost-savings by producing cheaper goods and services.

**Box 4.4 First-mover/fast-follower advantages**

Lead times over competitors or FMA can provide key strategic advantages and means for firms to capture returns to innovation. Innovations may provide temporary monopolies to firms first into the market. First movers may be able to gain extra market share and capture high returns before the entry of competing products or services (Lieberman and Montgomery 1998; Suarez and Lanzolla 2005). They may also shape their customers' expectations of the form and function of a product or service, thereby influencing cost structures. In some industries, being first may allow the innovation to lock in customers to products or services and make it expensive for customers to switch to those of competitors. It may enable the firm to gain a head start over competitors in building up manufacturing, distribution, and provision of sales support.

Many successful firms specialize in being fast followers, able to learn from the experiences of the first generation of innovators and quickly follow behind them in the market (Schnaars 1994). Indeed, the names associated with numbers of well-known products are not those of the innovators: ballpoint pens, for example, were not developed by Bic, but by Reynolds and Eversharp; and 35-mm cameras were developed by Contrax and Exacta, not Nikon and Canon (Schnaars 1994).

There are some advantages in being a first mover, especially in capturing market share, but FMA vary across industries and geographic markets. These advantages also dissipate over time, but they can be enhanced by longer lead times before competitive entry. In particular, time of entry appears to be less important than access to complementary assets when assessing the potential of FMA to capture returns to an innovation (see Chapter 9).

Timing of entry in a market often depends on the existing resources and capabilities of the firm. Firms with many complementary assets may delay entry into a market for years and then successfully enter and overcome incumbents. This delay allows them to learn from the failures of others and wait until the market settles to the point that entry is likely to be highly rewarding. An example of delayed entry can be seen in Dell's move into printers. Originally Dell did not offer printers on its highly successful website. However, it eventually began offering Lexmark printers—renamed as Dell printers—as part of its computing sales package. This allowed it to utilize its extensive website to sell a wider range of products and capture a major share of the printer market. Another option for large firms is simply to acquire the first mover. An example of this approach can be seen in News International's purchase of MySpace in 2006. MySpace was one of the first successful social networking sites and its acquisition enabled News International to gain FMA.

A number of studies have developed more detailed typologies of technology and innovation strategy (Freeman and Soete 1997; Goodman and Lawless 1994). Here we distinguish *proactive strategies*, involving technological and market leadership with a strong research orientation, which are often pursued by firms that enjoy returns from FMA and are prepared to take big bets; *active strategies*, which involve defending existing technologies and markets, but with the preparedness to respond quickly once markets and technologies are proven and where bets are hedged; *reactive strategies*, which are usually pursued by 'follower' and 'imitative' firms who respond slowly to innovation and play the cost-cutting game; and *passive strategies* in which firms only engage in innovation once it is demanded by customers and is risk free—see Table 4.1.

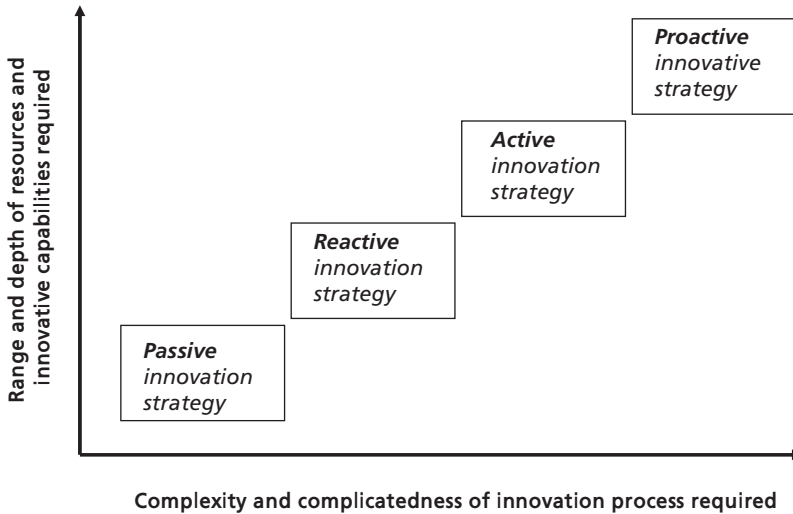
Examples of firms using proactive strategies include DuPont and Apple. DuPont has had over 200 years of technology leadership, including the development of cellophane (1923); nylon (1935); Teflon (1938); Lycra (1962); Dymel (which replaced chlorofluorocarbons, 1990); and solae (soy protein, 2001). Apple has produced the Macintosh and the iPod, and its offensive strategy was encapsulated in a statement by Steve Jobs in an

**Table 4.1.** Some ideal type innovation strategies

	Proactive	Active	Reactive	Passive
Objectives	Technological and market leadership	Not being first to innovate, but being prepared to follow quickly	Wait and see. Follow a long way behind	Do what is demanded by customers or dominant firms
Type of technological innovation	Radical and incremental	Mainly incremental	Entirely incremental	Occasionally incremental
Knowledge sources	Science; in-house R & D; Collaboration with technology leaders; demanding lead customers	In-house R & D; Collaboration with technology leaders, customers, and suppliers	Competitors; customers; purchase of licenses	Customers
Innovation expenditure	Basic and applied R & D; products and services new to the world; operations; education and training	Applied R & D; products and services new to the firm; operations; marketing; education and training	Focus on operations	No formal activities
Risk acceptance	High-risk projects included in portfolio. Take big bets	Medium-low risk projects. Hedge bets	Projects all low risk. Wait and see.	No risks taken. No bets.
Main forms of appropriability	IPRs; complementary assets; secrecy; speed	Complementary assets; speed	None	None
Typical firms	DuPont; Apple; Qantas; Singapore Airlines	Microsoft; Dell; BA	European and Asian budget airlines, such as Ryanair and Air Asia	Third- and fourth-tier automotive suppliers

interview in *The Times* (September 29, 2003: 23), when he said, ‘Our strategy is to innovate, that’s what we love to do. We’re the first with things most of the time. . . . Apple makes money because it innovates.’ Qantas and Singapore Airlines are proactive innovators—seen in their early introduction of flat beds in Business Class and ‘video on demand’ in in-flight entertainment systems.

Microsoft is a firm that conventionally uses an active strategy. Its Windows built upon Apple’s Macintosh and Xerox’s graphical user interface; Explorer copied Netscape; Xbox learned from Nintendo, Sega, and Sony’s products. British Airways has an active innovation strategy; for example, it introduced flat beds in Business Class relatively soon after its competitors did. Dell follows a classic reactive strategy in the technology used in its products, but its production and distribution model is highly proactive. Ryanair and Air Asia have successfully copied the model of the USA’s Southwest Airlines ‘no frills’ service, supported by Internet booking. Airbus is an example of a firm that changed its strategy from active to proactive. It was created in 1970 essentially to be a European imitation of Boeing. However, it developed a number of industry firsts, such as ‘fly-by-wire’ in 1984, and now competes head-to-head on innovation with Boeing.



**Figure 4.2.** Four levels of innovation strategy

Examples of passive strategies can be found amongst many supplier firms in the auto industry. Whilst some major so-called first-tier auto suppliers, such as Bosch in Germany, NipponDenso in Japan, and Magna International in Canada, can be highly active innovators, other firms further down the supply chain are usually entirely dependent on building to the specifications of others.

Figure 4.2 shows the relationship between these types of innovation strategy and the levels and range of resources and capabilities required and complexity and complicatedness of innovation process needed to support them.

## Formulating an innovation strategy

Processes of formulating and implementing an innovation strategy are iterative and dynamic, drawing on evidence from the external environment and appraisal of the opportunities, constraints, and limitations of internal resources, capabilities, and processes. Making choices about which creative ideas to pursue involves trade-offs which shape the direction of the firm and outcomes from particular investments. They involve choices about which technology paths to pursue and which customers to target, what is offered to those customers by way of solutions and value propositions, tasks to be performed by the business and those to be outsourced, and configuration of resources to perform these tasks to create, capture, and retain value. The formulation of an innovation strategy is assisted by the appropriate use of various kinds of tools and techniques, and a clear appreciation of which tools to use and when to use them—see Box 4.5.



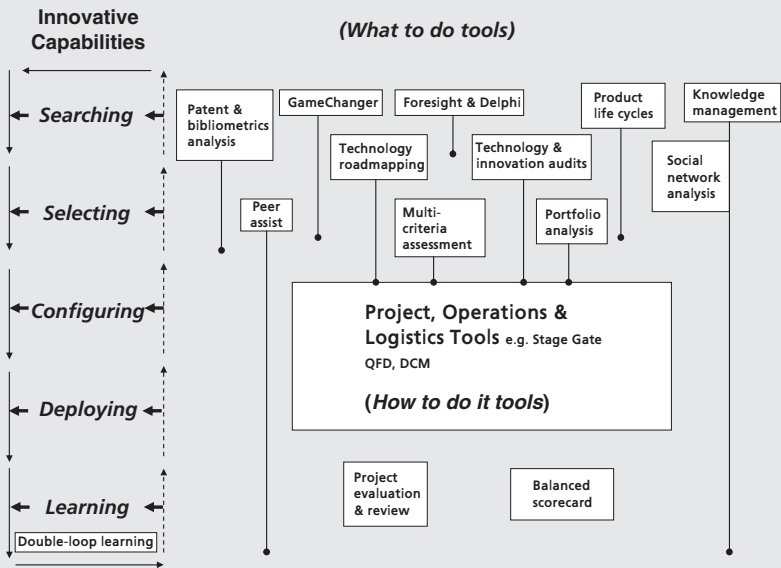
**Box 4.5 Choosing the right tools**

Innovation strategy formulation involves making choices about which tools to use and when to use them. This box provides some broad guidance on making sensible choices about gathering and analysing evidence and monitoring activities to inform MTI decision-making. As we have seen, however, innovation can be inherently uncertain and reliable evidence is often difficult to obtain and decisions usually involve judgement based on experience.

A plethora of tools and techniques is available to support decision-making, including techniques for performance measurement and evaluation of cost benefit. Many are adapted from general strategy and project management. Choosing the right technique, using it at the right time, and understanding the benefits and limitations of qualitative and quantitative data present major challenges in MTI. It must be remembered that the reliability of results from data-gathering and analytical exercises is likely to diminish in more radical innovation environments where novelty and uncertainty are higher. In contrast, the use of tools to set targets, measure and monitor performance in incremental innovation, and continuous improvement environments is commonplace—see Chapters 7 and 8. A distinction needs to be made between tools and techniques that assist decision-makers on what to do, as inputs into strategy, and those that assist with how to do it, which are more tactical and operational. A key requirement is for managers to have a well-grounded perspective on the level of risk and uncertainty in possible future courses of action. Failure to do so can lead to major mistakes in choice of tools and techniques.

Figure 4.3 provides some examples of tools and techniques used to assist innovation strategy. They are not exclusive; many different methods exist. The examples—which are described in more detail throughout this and following chapters—are selected to be broadly illustrative of the ways tools are used in innovation strategy. The particular tools depicted in the figure are in the ‘what to do’ categories, and those in the larger box are in the ‘how to do it’ categories. Some tools are used in several phases of the innovation process.

There are no hard and fast rules about which to use and when to use them, but some tools are more helpful than others at particular stages of innovation strategy development. Reliance on particular techniques and their results can focus managers’ attention narrowly on detailed issues that do not allow decisions to be made in a way that connects with the wider business context. In general it is better to



**Figure 4.3.** Some examples of tools and techniques supporting innovative capabilities



keep data gathering, measurement, and analysis as simple as possible and to see the results of tools as an input to decision-making rather than letting them drive the direction of future events. Overly elaborate instruments can use up scarce resources and may not provide results that are any better than simple approaches. In either case, firms need the capacity to absorb and make use of results in a systematic fashion. The choice of a particular tool therefore has to fit within a wider framework of decision-making and capability in the firm. Some tools will need to be used repeatedly in particular innovation processes; others evolve as the process develops.

In general, tools and techniques that support strategic thinking are useful if they provide a means for managers to reflect upon issues and decisions in what Schön (1991) describes as reflective development, using a common language across disciplines and functions involved in innovation processes. For this reason, the double-loop learning processes described later are particularly useful in helping firms develop capabilities and avoid investigating unproductive ideas again and again.

Developing an innovation strategy involves an assessment of a firm's position in the value chain (see Chapter 9) to understand what the firm is good at, why its customers like and buy its products and services, and how they value the ways it does business: that is, its value proposition. It is equally important to reflect upon why potential customers do not buy from the firm and how competitors gain market share. Wider analysis of market, technological, and sectoral trends is also an essential ingredient of strategy. Clear appreciation of current circumstances—ranging from whether they are entirely predictable or unpredictable—is a starting point for a firm's innovation strategy. This external analysis is usually crafted alongside the firm's understanding of its internal resources and capabilities and how well these are deployed in delivering its value proposition.

## Building innovative capabilities

The development and application of innovative capabilities is central to the definition and enactment of an innovation strategy. Table 4.2 indicates some examples of the analytical frameworks, concepts, tools, and techniques that can be used to assist the development and use of innovative capabilities.

## SEARCHING

As Chapter 2 showed, identifying future technological developments is a necessarily speculative exercise, but it is valuable nonetheless. Forward-thinking firms welcome any information, guidance, or advice on likely future developments or scenarios in their areas of science and technology, and on the trajectories their technology is likely to follow (Coombs 1994). As well as trying to understand the path that current technologies

**Table 4.2.** Innovative capabilities, analytical frameworks, and tools and techniques

<b>Innovative Capability</b>	<b>Key objectives</b>	<b>Analytical frameworks/concepts (some examples)</b>	<b>Tools &amp; techniques (some examples)</b>
<i>Searching</i>	Seeking and assessing market and technology opportunities and threats	Technological trajectories, Sustaining or disruptive innovation, Radical–incremental innovation, Lead customers/suppliers	Forecasting/Foresight, Delphi, Bibliometrics, Technology road maps
<i>Selecting</i>	Choosing amongst future options, based on evaluation of available resources and results of search activities	Life cycle analysis, Core competencies/technologies, Platform technologies, First-mover/fast-follower advantage	Technology and Innovation Audits, Social network analysis, Portfolio analysis, Peer Assist, Gamechanger, Multi-criteria assessment
<i>Configuring</i>	Ensuring the coordination and integration of innovation efforts	Lean Thinking, Integrated Solutions, Innovation brokerage, Balanced teams, Agile manufacturing	Technology Plans, R & D alignment tools, Quality Function Deployment, User tool kits
<i>Deploying</i>	Delivering internally generated and acquired innovations. Protecting and delivering value from innovation	Complementary assets, Dominant designs, Market for ideas or products, Appropriability regimes	IPR portfolio management, Standards setting, Real options
<i>Learning</i>	Improving the performance of innovation processes	Learning curves, High-level learning	Post-project evaluations, Strategic reviews, Balanced Scorecard

might follow, it is useful to assess which technologies in other industries might be usefully transferred. It is also necessary to think about how emerging technologies might affect the firm's position. Search is assisted by the conduct of basic research in companies, which, as discussed in Chapter 6, sends messages to external researchers that they are interested in a particular science or technology. Research investments create receptors for research being conducted externally. Some firms use scientific advisory boards with membership of eminent individuals who understand the nature of the firm's business and can balance their long-term views with more immediate business needs.

Assessment of the external context includes consideration of issues such as the systems in which firms operate, such as the NIS, and the networks to which firms belong, and the ways in which these are affected by globalization (see Chapters 2 and 5).

A number of analytical frameworks and concepts are useful in guiding search activities. Some were discussed in Chapter 3, including the notions of sustaining and disruptive innovations, and the differences between radical and incremental innovations. Other tools and methods that can be used include Foresight, Delphi, and Shell's GameChanger (see Box 4.6).

### Box 4.6 Foresight, Delphi, and Gamechanger

#### Foresight

Foresight brings together key people to assess ideas to look beyond normal planning horizons and identify potential opportunities from science and technology, together with recommendations for action. Foresight usually focuses on a particular topic, a broad thematic area of emerging science or technology, such as nanotechnology, or a particular social or economic issue, such as tackling obesity. It uses a range of techniques including trend analysis and modelling and simulation.

Foresight studies are used periodically for high-level planning and strategic development and include:

- Reviews of the scientific or technological domain, its current international position, and forecasts about the next stages of development.
- Vision statements about likely future developments based upon understanding key drivers, trends, and likely impacts.
- Recommendations for research funders, the scientific and technological community, and government and regulatory authorities.
- Creation of networks of experts capable of maintaining a watching brief on developments in the area.

The success of Foresight exercises is often evaluated according to the extent to which they have informed stakeholders and communities, and influenced policy-makers and businesses. Accurate predictions of science and technology future have always been elusive, and Foresight exercises will never provide completely reliable guides, but they help to raise awareness across different communities, gaining some convergence in expectations, and providing valuable insights for strategic planning.

#### Delphi

Delphi is a qualitative approach to technology forecasting based on eliciting, coordinating, and synthesizing expert opinion. It dates back to the mid-1940s and Project RAND, which later became the RAND Corporation. Project RAND included a commission for the US Air Force to forecast the likely impact of technological change in the military sector, with a particular focus on intercontinental warfare. RAND experts were asked to provide opinion on the probability, frequency, and intensity of enemy attacks and the consequences of the deployment of different technologies. Other experts were invited to provide anonymous feedback on initial results and the exercise was repeated until a consensus emerged.

The Delphi technique is mainly used to make informed, intuitive judgements about scientific and technical possibilities and their social, economic, and environmental implications. Organizations use it on a periodic basis, particularly when they are in a phase of strategy development or renewal. In its simplest form, expert opinions are elicited through carefully designed questionnaires interspersed with information to guide respondents' thinking.

The Delphi method aims to achieve a convergence of expert opinion on the likelihood of scientific or technological developments and their expected time horizons and resource requirements. In some cases—such as with climate change, investment in renewable technologies, and genetics—rather than achieving consensus, a range of opinions and polarized results emerges.

During the 1980s NEC successfully used an approach to technology forecasting that involved the identification of over thirty core technologies followed by attempts to predict developments in their underlying basic technologies. The core technologies provided the basis for future research and applications. For example, NEC identified pattern recognition as a core technology. It then attempted to predict changes in the underlying basic technologies of pattern recognition, and any new product opportunities which might emerge from those changes (Irvine 1988).

#### GameChanger

Shell's GameChanger provides a means for people inside and outside the business to come up with new ideas that 'change the rules of the game' for the company. The process encourages people to come up with new ideas and provides funds and advice to entrepreneurs on how to develop these ideas

further. It enables investment in radically new, early-stage ideas in the energy and transport/mobility industries, taking them, where appropriate, to the 'proof of concept' stage.

The GameChanger process began by exploring and supporting ideas that were generated by Shell's own employees. It has subsequently been used by academics, independent research organizations, and individual entrepreneurs.

GameChanger is managed by a central department of full-time technology and business specialists, operating a process outside the constraints and priorities of Shell's day-to-day business operations. It also has teams in each of Shell's operating businesses. In 2005 GameChanger had funds of around \$20 million to allocate.

The process involves a few simple steps and rules. Following the submission of an idea it is 'pre-screened' by a member of the GameChanger team who focuses on four key criteria: novelty, possible value, why it may be important for Shell, and whether it appears to have a credible development plan. If the idea looks interesting it is assigned to a GameChanger sponsor who seeks out Shell staff to 'champion' the idea. If a suitable champion is secured, the idea is put to a 'screening panel,' which quickly makes a decision on whether formal proposal should be developed. If it proceeds, the idea is developed further by its originator and the Shell champion and a more detailed proposal is put to an 'extended panel' which undertakes to make a decision in between twenty-four and forty-eight hours. Success at this stage often leads to investment in the proposal and if it is of a technical nature it may be developed in Shell Technology Ventures: <http://www.shelltechnologyventures.com>. The tools therefore assist in both 'Search' and 'Select' innovation support activities.

The GameChanger team is responsible for monitoring emerging technologies and social and regulatory trends that might fundamentally impact on the business. One example has been work on the potential of ionic liquids to provide a new class of solvents with low volatility, which, because they do not evaporate, offer considerable environmental advantages.

## SELECTING

Innovative capabilities include the way firms select technologies that will provide the future basis of market competitiveness. The selection of new technologies entails choosing which technologies are core to the firm, where it needs a proprietary position, and which are related and complementary. Choices need to be made on which technologies to concentrate on developing internally, and which to access externally, through purchase or collaboration. Decisions also need to be made on which technologies owned are exploited internally and which are licensed or spun-off.

A number of analytical frameworks and concepts are useful in guiding the development of capabilities for selecting technologies and markets, including: first-mover/fast-follower advantage (discussed earlier), platform technologies (discussed in Chapter 7), core competencies/technologies, and the product life cycle.

### Core competencies/technologies

Core competence is a term used in the strategic management literature for those central elements that define the firm's ability to compete (Prahalad and Hamel 1994). Competencies are argued to have strategic potential when they are:

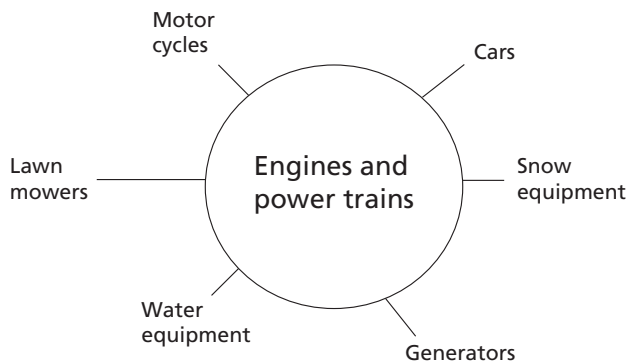
- Valuable—exploit opportunities and/or neutralize threats in a firm's environment.
- Rare—the number of firms that possess them is less than that needed to generate perfect competition in an industry.
- Imperfectly imitable—because of their complexity, or the uniqueness of the conditions under which they were acquired.
- Have no strategically equivalent substitutes—no alternative ways of achieving the same results (Ciborra and Andreu 1998; Barney 1991, 2001).

Competencies can have a technological basis. Differential competencies potentially allow a firm to gain benefits over its competitors.

For firms selecting future technological investments around core technologies it is worth referring to studies that demonstrate:

- The importance of cumulative know-how, and the value of building on existing competencies (Prahalad and Hamel 1994; Pavitt 1990).
- The riskiness and difficulty associated with complete technological diversification. Incremental diversification is the least difficult and risky and more likely to be successful (Roberts 1991).
- The danger of core competencies becoming core rigidities, creating engrained practices that cannot evolve to deal with new circumstances (Leonard-Barton 1995).

Honda provides an example of the way firms can think about core competencies. It produces a variety of products, but its core expertise lies in the design and manufacture of engines and power trains, and it has developed its product range around these competencies (Fig. 4.4). Once core competencies have been determined, it is possible to consider their technological basis (Fig. 4.5). Using this form of analysis, it can be seen that Honda's innovation strategy involves the supplementation and improvement of these technologies that contribute to its core competencies.



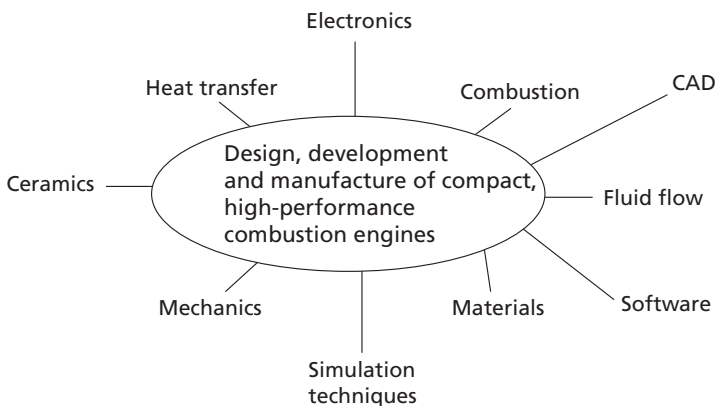
**Figure 4.4.** Honda's core competencies

### Box 4.7 McLaren Motorsport

McLaren, the Formula 1 (F1) motor sport company, has a strategy driven by one simple performance indicator—winning races. The business model needed to fund this endeavour focuses the company on a strategy of managing its brand and the advertising revenue it generates. It has two main business streams: design, development, production, and racing F1 cars; and production of a limited range of prestige sports cars, codeveloped with Mercedes (known as the McLaren SLR, selling for around \$500,000 each in 2007). The F1 business generates sponsorship from companies advertising their own products and services. In 2007, McLaren's main sponsors were Vodafone and Mercedes. To win F1 races, the company knows that it needs to pay attention to every detail of the innovation process, starting with lessons from feedback from drivers and electronic monitoring systems of the existing range of cars (McLaren's and its competitors'). Races are simulated, and the performance of every component of the machine is analysed using virtual prototyping technologies. Results from these exercises inform choices about which materials to use, and how they should be designed, engineered, and produced. Everything McLaren does is aimed at reinforcing the strategy built on its brand of being first on the racetrack and therefore a world-class engineering company. The McLaren Technology Centre, based in Woking, UK, employs around a thousand engineers. It is at this centre that cars in both business streams are designed and manufactured. The centre itself was designed by Lord Norman Foster and embodies the McLaren ethos and strategy of developing and using the most advanced technologies (<http://www.mclaren.com/technologycentre/>). McLaren's approach to innovation strategy is dominated by its understanding of its core technological competencies and the value this ultimately confers on its sponsors. These competences (see Fig. 4.6), determine the technologies needed to build and deliver racing cars and high-end sports cars (see Chapter 8). In recent years, McLaren's strategy has evolved to expand the services it offers in related markets based on its technological and engineering strengths for delivering very accurate and perfectly engineered machines capable of winning races and breaking records. This has led to the launch of new business lines: McLaren Applied Technologies, and McLaren Electronic Systems.

Sumitomo Electric Industries provides an example of successful related diversification over an extended period. According to Kenney and Florida (1994: 319):

[T]he company's original core business in the late nineteenth century was copper mining and smelting. During the early part of the twentieth century Sumitomo Electric used its skills in smelting to move its business focus progressively into copper wire manufacture. In the immediate



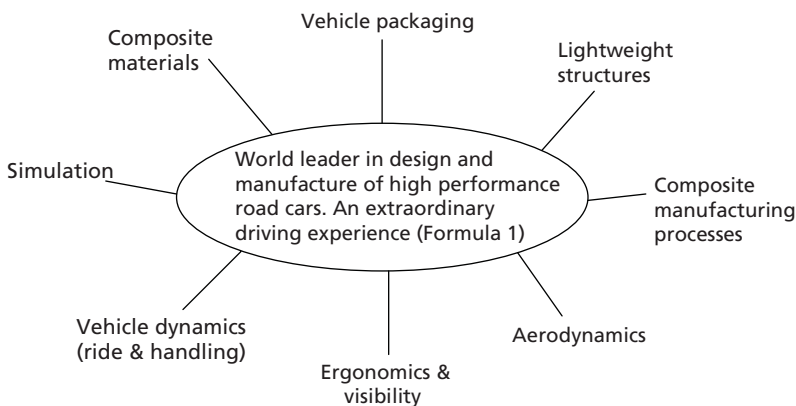
**Figure 4.5.** Honda's core technological competencies

postwar era the company drew upon its technological base in metals and wire to move into special steel wires, in wire coatings to move into rubber and plastic products, and in electronics to move into electronic materials and antenna systems. By the 1960s, the company moved into progressively more complex systems technologies such as integrated electronics systems and disc brakes. In the 1970s and 1980s, Sumitomo used its built-up technological competencies to move into high-technology electronic systems (e.g., workstations) and automotive electrical systems. At each stage in its development, Sumitomo leveraged internal technological capabilities developed through R & D to underpin diversification and growth by entering new fields.

3M is another firm that historically developed around core technologies. Its original core technologies, developed in the 1920s and 1930s, of abrasives, adhesives, and coating-bonding have been continually developed and added to by four new core technologies: software, instrumentation, imaging, and ‘non-woven’ products (e.g., fabric and film). As Quinn (1992) argued, these core technologies (some of which were acquired rather than developed internally) have historically enabled the company to develop a range of products, which led to continued commercial success. In contrast, when the company attempted to diversify away from them, the results were less successful.

GE selects 10–12 of what it calls ‘enabling technologies’, including ceramics, organic chemistry, solid-state physics, and combinatorial chemistry. It promotes the use of technological knowledge across its business divisions: so, for example, its expertise in ceramics is used in medical scanners, lighting, and turbine blades for both power systems and aircraft engines. Its expertise in computational fluid dynamics is used in simulations of x-ray tubes and airflow through jet engines.

P&G’s business has historically evolved from connections in technology such as between candles and soap, from the animal fat in soap to the first all-vegetable shortening. This led to discoveries in emulsifiers and surfactants, used today in products such as shampoos and liquid detergents.



**Figure 4.6.** McLaren Racing’s core technological competencies (see Box 4.7)

#### Box 4.8 Innovation in prams—finding new combinations

Developing safe vehicles for transporting children is a demanding task. Parents require security, flexibility, and ease-of-use in prams. Children do not like to sit still and rarely listen to instructions. The history of prams and strollers shows the way technologies are recombined to create innovation.

The first baby carriage was developed in 1733 by William Kent, an English landscape and furniture designer, for the Duke of Devonshire's children. The baby carriage or perambulator (pram) was designed to be drawn by a small animal as the child rested in a shell-shaped seat. This early pram was a toy and it was not until 1848 that Charles Burton, an American inventor, created the first functional, human-controlled pram to transport his children. In the late 1800s there were significant improvements in pram design, increasing consumer demand. Queen Victoria was a notable early user. The growth of the pram market led to a surge in patents and innovations. The most significant innovation was William Richardson's introduction in 1889 of a 360-degree movable seat, which allowed parents or nurses to see their child while they were pushing the pram. From the early 1920s, prams became more widely diffused and became a popular consumer item. Silver Cross, based in Leeds, UK, was considered at this time to manufacture the 'Rolls Royce of prams'. During the Second World War, however, the Silver Cross factory was requisitioned for the production of parts for the Royal Air Force. The experience of working with newer, lightweight materials, such as aluminium, in the war stimulated the introduction of these materials into Silver Cross prams. In the 1950s and 1960s, Silver Cross and others were able to lower the weight of prams significantly by using aluminium.

In 1965, Owen MacLaren, a former aeronautical engineer and test pilot for the *Supermarine Spitfire*, transformed the children's transportation market by introducing the world's first folding stroller. Whilst working in the aerospace sector, MacLaren had developed antiskid brakes and landing gear for aircraft in severe weather conditions. In 1944, he established his own firm making aircraft parts. In 1961 he developed his first consumer product, a portable aluminium-frame picnic chair. MacLaren got the idea for the stroller from his family. His daughter was married to an executive at Pan Am, a leading airline, and travelled widely. It was difficult for her to travel with her child and traditional pram. MacLaren used his insights and experiences from aerospace to develop an alternative solution. His stroller was lightweight and easy to use. It could be folded up and carried like an umbrella. The product was an immediate success, leading to sales of over 600,000 by 1976, half of which were exported.

Since the 1980s, there have been many new innovations in child transport, including the three-wheel 'jogging' stroller, 'three-in-one' travel systems, and exchangeable car seats. One of the most successful of the new generations of strollers has been the Bugaboo, which emerged from a student project at the Design Academy in Eindhoven, the Netherlands, in 1999. The Bugaboo has become a design icon of the 2000s, appearing in 'Sex in the City'.

Source: Gapper 2006.

Canon is an example of a firm that strategically adopts, adapts, and refines generic technologies and recombines them in unique ways. Each new product in Canon involves a combination of existing technologies and technology new to the firm. Its photocopier cartridge technology, for example, involved combining its expertise in camera and office equipment technology with newly acquired knowledge in electrophotographic processes and photosensitive materials. Canon's strategy has led to the development of specialized, proprietary photographic photocopier, and printer products that are not easily imitated (Sandoz 1997).

Innovation is evolutionary, and an important means of understanding that evolution is captured in Box 4.8. This broad theory can assist in the searching for, and selection of, innovation opportunities.

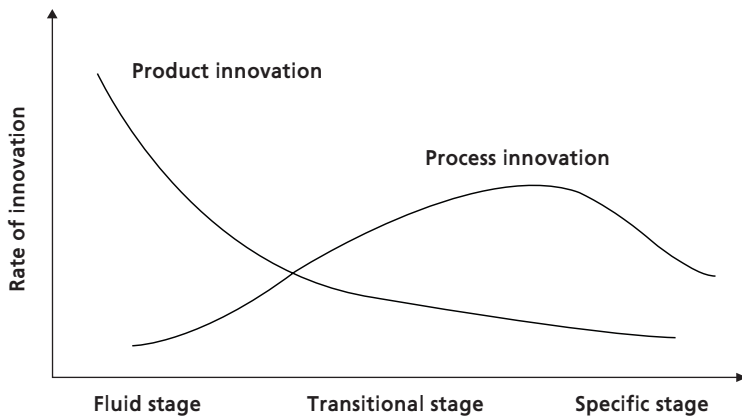


## Product Life Cycle

The Product Life Cycle (PLC) is one of the most important theories for understanding innovation. It is a theory that brings together many different areas of innovation management, including strategy, industrial dynamics, and technological evolution. It is a useful tool in helping firms assess the evolution of their industry and select when and how to invest. The concept was used in the study of international trade through the work of Raymond Vernon in the 1960s. Vernon suggested that early in the life of an industry, production would be concentrated close to customers and sources of innovation. As the industry matured, however, production would become more standardized and proximity to the sources of innovation would become less important. This meant that production could be codified, standardized, and transferred to lower cost locations (Vernon 1966). PLC was introduced in marketing thinking in the 1960s as a way of understanding the evolving nature of product markets.

The most important extension of this approach in the MTI field was the work of William Abernathy and Jim Utterback in the mid-1970s. Abernathy and Utterback (1975, 1978) developed a dynamic model of product and process innovation through the life cycle of an industry. The model divided the PLC into three stages: fluid, transitional, and specific. It considers the different focus of attention firms place on product and process innovation over the life cycle. It is represented in Fig. 4.7, which is perhaps the most famous and frequently reproduced figure in the field of innovation studies.

As Fig. 4.7 describes, in the *fluid stage*, firms explore a range of different potential types of products. The market is in flux and customers are still learning about the products; what it can do and needs it might meet. There is great uncertainty about which product will win favour in the market. There are often competing designs with different functional attributes. There are frequent new product innovations as firms



**Figure 4.7.** The product life cycle

Source: Abernathy and Utterback 1975.

address the specific needs of small groups of customers. Products are commonly made in small batches with small-scale plant and equipment. The costs of changing the product's configuration are low and production processes can be rapidly adapted to meet requirements of the new product. The focus of competition lies in the functional performance of the product, and whether it meets the needs of the customer. There are likely to be many entrants to the industry, in what Schumpeter describes as 'swarms' of imitators. There are few specialized suppliers of components for the product, and firms often need to rely on in-house component development. Knowledge underpinning the innovation often resides in a small number of locations, often universities. There are few codified lessons about how to make the product and little information about the nature of the market. Once FMA is exploited, many new entrants are able to make breakthroughs, bringing new products to market and capturing market share from incumbents. The organizations developing these products in this stage tend to be highly informal and led by entrepreneurial managers.

In the *transitional stage*, demand for the product begins to expand and this forces major process changes in the nature of production. The industry stabilizes around a single product design, allowing firms to manufacture in increasing volumes. This product design slowly becomes dominant. The dominant designs may not be the best, but are the most widely accepted (see Box 3.12). Firms focus on improving specific features of the product, including its functional performance. It is produced by general-purpose tools, and increasingly with purpose-designed specialized equipment. It is still possible for firms to incorporate new design features, but it may become increasingly expensive to do so. The market becomes focused on variation in the features of the product design. Efficient producers emerge that are able to produce in volume at high quality. There are increased numbers of specialized suppliers producing components that can be integrated into the product. Knowledge about the product resides in many actors, including consultants, customers, and suppliers. Information on the nature of the market becomes more codified and available, but it is still uncertain and firms respond to this information in divergent ways. Producers are increasingly organized into project teams and groups with specialized roles. At this stage, the number of new firms entering the industry is similar to the number of firms leaving.

In the *specific stage*, firms focus on process innovation—in operations and production—seeking to lower costs and increase scale of production. Most products in the market are similar in their functionality and customers decide which to buy based on cost. These products are based on an entrenched dominant design. Production uses highly specialized equipment, suited to the production of a single product. It is difficult to radically change product designs. The organizations making the product use formal structures, with strong and inflexible operating routines. There is a well-established supply chain for components, and knowledge about the product is highly codified. The industry is concentrated among a few firms, who are specialist manufacturers.

Although the Abernathy and Utterback model is the dominant view of the PLC, Klepper extended the approach by developing formal economic models of the PLC (Klepper 1996, 1997, 2002). Klepper is critical of the Abernathy and Utterback model because its definition of the dominant design appears to be an ad hoc justification for what emerges from a process of selection in the market. For Klepper, the dominant design approach lacks a causal explanation of why industries shift from one stage of the industry to another, other than as a result of historical events. Klepper's model sees the stages of the life cycle as being shaped by the marginal advantages of product and process R & D. Early in the life cycle of an industry, the returns to product R & D outweigh the benefits of process R & D. This is largely because the industry is so unsettled that there is little point in firms investing in process development. As the market expands, however, the benefits of investments in process R & D increase, eventually overtaking those from additional investments in product R & D. Firms increasingly shift their focus to process development and gaining advantages from scale. At this stage, there is a shake-out in the industry, and many exits. Eventually only a few firms are left and they become heavy investors in process R & D.

Regardless of the model used to explain the life cycle, there is evidence that the PLC is a predictor of the evolution of a number of industries, such as the US automotive sector. Table 4.3 shows the number of US automotive firms from 1894 to 1962. The introduction of the Ford Model T led to the rapid exit of many firms in the industry. The Model T changed the economics of production, leading to rapid productivity gains through the introduction of the assembly line. The introduction of large-scale assembly lines increased throughput, brought about greater consistency, facilitated higher quality of final products, and created new systems of managerial measurement and control. It allowed Ford to reshape the market for automobiles by dramatically lowering both the time to build and the cost of an automobile. In its first year of production in 1908, Ford produced a Model T every 93 minutes, a reduction from the 728 minutes required previously. By the time the last Model T was built in 1927, the company was producing an automobile every 24 seconds (albeit on multiple assembly lines). In part because of these efficiencies, the Model T's price dropped from its original 1908 cost of nearly \$1,000 to under \$300 in 1927. This was possible despite the fact that, beginning in 1914, Ford paid assembly-line workers \$5.00 per day at a time when prevailing wages averaged

**Table 4.3.** Number of firms in the US automobile industry

Period	New entrants	Firm exits
1894–1918	60	0
1919–1929	22	43
1930–1941	6	29
1946–1962	4	8

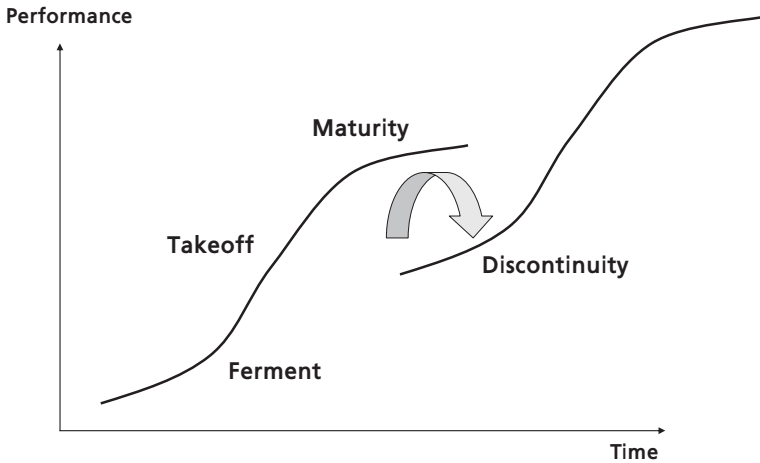
Source: Fabris (1966)—cited in Utterback (1994).

about \$2.35. In total, between 1908 and 1927 Ford produced fifteen million automobiles with the Model T engine. Mass production was based on a standardized product. After 1913, all Model Ts were painted black—hence Henry Ford’s often quoted comment ‘you can have any colour you want as long as it is black’. Prior to this, from 1908 to 1913, Model Ts came in green, red, blue, and grey, but not black. The large-scale assembly line and highly standardized products shifted market shares in the automotive sector and became an impressive engine for growth in the sector. It had significant effects in far removed industries and reshaped industrial relations between workers and management, and management and owners (Sabel 1982). It had profound impact on society, helping transform patterns of consumption and the design of cities, and providing previously unattainable mobility for all members of society.

The PLC pattern is seen in a number of other industries, such as semiconductors, disk drives, televisions, and even fake Christmas trees. The applicability of the PLC to service industries, however, remains questionable. Barras (1986) argued that there is a reverse PLC within services. Process innovation in services leads to major product innovations, and industry shake-outs occur when the benefits of product innovations become greater than those of process innovations. This approach has been questioned, with a number of authors suggesting that the service industries are more likely to follow the traditional PLC.

The PLC approach has several limitations. First, it can be an accurate description of the development of individual product markets, but is less useful for explaining the life cycle of industries. Defining the boundaries of an industry remains very difficult in the early stages of the PLC as products may emerge from a diverse range of sectors. It is not clear when the ‘industry’ has been created and when its life cycle starts. Second, some industries do not follow the patterns of evolution specified in the PLC and some appear not to follow a PLC at all. Aero-engine manufacturing, for example, has remained highly concentrated and product-innovation oriented since 1945 (Prencipe 1997). Third, it is not clear where the PLC begins and ends and how long it lasts. PLC analysis is performed on industries over extremely long periods of thirty to fifty years; movement through the stages of the evolution of industries is prolonged in some industries but rapid in others. Fourth, it is wrong to assume that product innovation is no longer important at later stages of the PLC. Firms in highly concentrated industries—such as autos—often continuously invest substantial resources in product innovation. Although the importance of product innovation might decline over time, it does not disappear. Fifth, as we saw earlier, the evolving pattern of service industries remains disputed and as services account for a large share of the economic system it is unwise to generalize a theory of innovation based on manufacturing industries alone.

Attention to the PLC, however, can be useful in helping to shape innovation strategies. Managers need to be aware of the stage of their industry, and formulate innovation strategy accordingly. A process-based innovation strategy may be ineffective early in the life of an industry, whereas a product-based strategy may be ineffective late in the



**Figure 4.8.** Discontinuity in life cycles

cycle, unless it is facing a discontinuity (see Fig. 4.8). Managers can analyse the state of the industry by looking at levels of market concentration. They can also examine the importance of cost or functionality in consumption. Managers need to be aware of the potential emergence of dominant designs, and be ready to shift their efforts towards these designs as soon as they appear. Although the character of a dominant design before it emerges is largely unknowable, firms that create options by investing in a range of different possible futures, and who can quickly adapt to new trends in products, are more likely to make a successful transition across the stages of the PLC. Managers must beware of overcommitting to a single design or product before the dominant design has emerged.

A further guide to managerial decision-making is provided by consideration of the notion of discontinuities between life cycles. When a discontinuity occurs, for example in the progression from LPs to CDs, and then to MP3 players (see Fig. 4.8), the challenge is to decide when to make exploratory research investments during the takeoff and maturity stages.

Selection does of course require assessment of a firm's current position: you need to know where you are before you decided where you need to get to. A variety of technology and innovation audits tools exist to help firms. Technology audit tools include benchmarking and assessing technological strengths quantitatively and qualitatively. These can be used to analyse factors such as the comparative quality and productivity of researchers in similar fields (Bibliometrics, see Box 3.10), the range and depth of patent ownership, and operations productivity. Innovation audit tools assess a firm's resources for innovation, innovative capabilities, and innovation processes. There are numerous examples of these tools (Chiesa 2001). For an example of a commercial tool developed by the authors, see [thinkplaydo.com](http://thinkplaydo.com).

## CONFIGURING AND DEPLOYING

Configuring innovation entails acquiring new technological resources, coordinating and integrating all the various activities involved in the innovation process, and aligning the firm's strategies. This innovative capability will be examined in subsequent chapters. Innovative capabilities include the effective deployment and implementation of technology. Implementation is much easier when there is broad agreement about the importance of particular technologies and their relevance for the company's future. Reaching such agreement is assisted by the new paradigm of management, and its approach to strategy, outlined in Chapter 2. This approach focuses on gaining consensus and commitment to decisions. Whilst this process may be lengthier than simple top-management fiat, implementation of decisions is faster as there is usually less opposition to decisions that are fully understood.

## LEARNING

The ways firms learn, and use that learning, have long been understood to be key elements of corporate strategies (see Chapter 2). 'Technological learning' is an important element of firms' development and survival. Learning can be described as the ways firms build, supplement, and organize knowledge around their capabilities and processes and within their cultures, and adapt and develop organizational efficiency through improving their use. The need to learn is commonly explained by a requirement for adaptation and improved efficiency in times of change. In turbulent environments learning can be seen as a purposive quest of firms to retain and improve competitiveness, productivity, and innovativeness. The greater the uncertainties facing firms, the greater will be the need for learning. Learning can be seen to have occurred when organizations perform in changed and better ways, and when strategies are better defined, more appropriate, and effectively implemented. The goals of learning are useful outcomes, which include, at best, improved competitive performance, at worst, survival.

Firms need to learn for a number of reasons. They need to learn to develop better value propositions to respond to changes in the external environment, for example, to the rapid and comprehensive changes occurring in technology, described in Chapter 2. They also need to learn so as to overcome strategic and organizational tendencies towards introspection and parochialism (Morgan 1986), which can be particularly disadvantageous in turbulent and rapidly changing circumstances.

Nevertheless, firms do learn, survive, and improve comparative performance. This learning happens beyond the 'everyday' adaptation and improvement organizations can achieve in their existing competencies through learning by 'doing' (Arrow 1962) and 'using' (Rosenberg 1982), and encompasses 'higher' level learning (Fiol and Lyles 1985) which questions the validity of current competencies and facilitates the construction of new ones. This is described in the management literature as 'generative' as opposed

to ‘adaptive’ learning (Senge 1990), and by Argyris and Schön (1978) as ‘double-loop’ learning (error–detection–correction–modification) as compared to ‘single-loop’ learning (error–detection–correction). It is a key element of a firm’s innovative capabilities.

In conditions of rapid and disruptive market and technological change, firms can be argued to need ‘higher level’ learning because existing ‘lower level’ learning focuses on current systems, products, and technologies and not on new competencies and opportunities. However, such learning is constrained. Much of the management, innovation, and business economics literature points to the conservatism of the strategies firms adopt, reflecting what companies are currently best at, rather than what changing markets require. The emphasis of much of this literature is that ‘history matters’, and that what a firm can in effect do in the future is strongly influenced by its past and its collective learning.

Firms purposefully adopt strategies and structures that encourage learning (Senge 1990; Malerba 1992; Dodgson 1991a). They learn through the activities of key individuals or ‘boundary spanners’ (Michael 1973—see Chapter 6), by executive succession (Tushman, Virany, and Romanelli 1986) and through recruitment and training programmes. Important in this process is the way they develop shared cultures that facilitate learning because of common languages and repositories (Schein 1985). Furthermore, the management strategy literature has long pointed to the ways firms not only react to external change, but also proactively seek to shape the environment in which they operate and learn (Ansoff 1968; Chandler 1962).

A major mechanism by which firms learn about technology is through their internal R & D efforts (see Chapter 6). Firms also learn from a wide range of other activities, particularly from marketing and operations and from the iterative interactions between corporate functions and operations.

Companies are increasingly creating a new managerial role to assist them develop and implement innovation strategies—the Innovation Director (see Box 4.9).

## Returns from innovation strategy

The benefits of an innovation strategy are improved performance in the ways firms create and deliver value and enhance their competitive advantage, which can be assessed in a variety of ways. The extent to which an innovation strategy is driven by profit maximizing or broader objectives depends upon the specific circumstances of the firm and its corporate strategy. Maximizing profits or shareholder returns might ensure continuing investment in the firm, and offer protection from unwelcome takeover bids, but may place pressures on quarterly business performance, which can be inimical to longer-term innovation efforts and spending. In a different context, founders of small technology-based firms may deliberately target an exit strategy of selling their technical



### Box 4.9 Role of the Innovation Director

A new and exciting role is emerging in many businesses—that of Innovation Director. The work is stimulating and involves understanding and awareness of many aspects of the business. They need a deep understanding of their business' existing resources and capabilities and the technologies that underpin current activities. They need to look outside to understand what their competitors, suppliers, key customers, and research partners are doing. They need to 'read the tea leaves' using techniques such as Foresight, to advise other senior decision-makers on which areas to invest new technologies. Innovation Directors need to go beyond the identification of potential new opportunities and threats to establishing the mechanisms to support innovation. This means creating the new technological order whilst simultaneously understanding and supporting the existing norms and practices that create the value that produces the resources to invest in innovation.

Firms whose businesses rely heavily on technology or scientific activities have generally placed strategic importance on the role of R & D, appointing research and technology directors to senior positions with responsibility for investment in and delivery of innovation. One indication of the growing strategic importance of technological innovation is that a wider range of firms are appointing Chief Technology Officers (CTO), or Chief Innovation Officers (CIO) to senior executive roles within their businesses.

The changing nature of innovation described in Chapter 3 has widened the roles of those that traditionally would have been responsible for R & D. Decisions about partnerships with suppliers, choices over which clients to prioritize in development work, what to do about intellectual property, the role of regulations and standards, and how to improve performance from investments in future products and services, are being widely discussed at main board level in many types of firms. The role of the CTO first emerged in the USA in the 1980s as an extension of the R & D function, in recognition of the wider sets of issues that confront innovative firms. In small enterprises and start-up companies the CTO title is increasingly used to signify a wide-ranging role covering all technical and scientific issues. By the mid-2000s, firms could be seen to be increasing the visibility and strategic content of their innovation activities by creating new roles in innovation management. Companies from Shell and Schlumberger in the oil and gas business to Cadbury Schweppes in confectionary, Citibank in financial services and Laing O'Rourke in construction and civil engineering have appointed CIOs to direct these activities. These posts report to the main executive board and in some cases have a seat on the board, rather than having discrete, functional reporting lines within R & D.

What does the role of the Innovation Director actually involve? There are no hard and fast definitions of the role, but it typically encompasses strategy, implementation, internal communications, and external relations. Key skills involve the ability to span boundaries—disciplines and functional lines of activity—and to broker the exchange of ideas and development between different teams and business units.

### Strategy skills

The key strategy skills focusing on the corporate level include the following:

- *Formulating* strategy to the extent that firms have an articulated strategy for innovation (see earlier discussion); this falls within the remit of the Innovation Director.
- *Leading and championing* new product and service development—being an advocate of innovation across the organization. This entails continuous and dynamic interactions with other senior decision-makers—in R & D and marketing, for example—and especially with the CEO.
- *Policy compliance and engagement* ensuring that technological innovation is considered within the context of current and possible future regulatory frameworks, standards, environmental conditions, and corporate governance and social responsibility.
- *Searching* for new ideas and ensuring that the business is networked to other institutions where there are likely to be opportunities to learn and spot new ideas. Assessing innovation opportunities, drivers, and constraints. Commissioning competitor analysis, providing future forecasts and technology road maps to enable other senior decision-makers to understand how technology is developed and deployed in the business.
- *Selecting* projects using a variety of techniques such as portfolio analysis and MCA.



- *Configuring* innovation investments. Brokering new value-creation opportunities between business units and with external partners. Organizing resources for experimentation and development work and developing programmes for delivery, including the management of portfolios of projects. Integrating activities between projects, business units, and the corporate functions of the firm.
- *Deploying* innovation to deliver value. Protecting and exploiting IP and commercializing developments ensuring that clear paths to market are in place with relevant marketing and sales functions in the business.
- *Learning* to improve innovation performance. This also includes promoting an environment which is conducive to innovation, nurturing, and mentoring innovators, providing room for failure, and encouraging reviews and learning processes.

### Operational skills

The key implementation skills focusing on the business or project level include:

- *Resourcing*; overseeing research, technical, and design staff, including recruiting, training, and mentoring. Financial planning and resource allocation. Technology support, including linking with IT, knowledge management, and virtual laboratories.
- *Coordinating* research, development, design, engineering, and prototyping activities across the organization.
- *Networking*, internally with technical support, design, operations, marketing and sales, legal, and financial departments; externally—fostering relationships and partnerships with lead users, key suppliers, science and technology providers, standards bodies, regulators, press, public relations, and lobby groups.
- *Delivering* new products and services to the required specification and within budget, overseeing project management and review processes.
- *Auditing* performance, setting benchmarks, milestones, targets, and key indicators to provide feedback.

The success of an Innovation Director is usually measured by the success of the firm's innovative performance. These measures may include the success rates of new commercialized products, productivity improvements in existing processes, the number of new product launches, and external awards. The Innovation Director may also be judged by the effectiveness of internal management processes, such as the ways in which technical resources are mobilized and developed within and among projects, business units, and central support services. The appointment of an Innovation Director should not diminish the responsibility of Boards of Directors, CEOs, or line managers for innovation.

capabilities to a larger acquisitive firm after a few years. Meanwhile, privately owned medium to large firms may be prepared to make longer-term innovation investments that are generally discouraged by stock markets keen on quarterly returns in the case of publicly traded companies. As we shall see in Chapters 7, 8, and 9, innovation investments deliver value in a number of ways, bringing a range of benefits to the firm, such as enhanced customer loyalty and the possession of business options. Other beneficial outcomes might be derived from improving the overall performance of the networks, communities, and supply chains to which the firm belongs. Given the high degree of mobility of skilled and creative workers, improving employee satisfaction within the company can also prove a welcome outcome. This diversity of benefit is one of the reasons why, as we showed in Chapter 3, there are profound problems involved in measuring the returns to innovation. These difficulties are seen in the application of one of the best-known approaches to assessing returns described in Box 4.10.

### Box 4.10 Balanced scorecard

The balanced scorecard was developed by Robert Kaplan and David Norton in the early 1990s to create a set of business performance indicators that link to corporate strategy (Kaplan and Norton 1992). Their aim was to provide a measurement system that associates four indicators tracking key elements of business performance. The balanced scorecard was developed to broaden business performance metrics from what were perceived as narrow financial measures, to encompass operational performance indicators, including customer perspectives, internal business process perspectives, and innovation and learning activities. It places emphasis on strategy and vision, rather than on purely business controls for reporting and directing performance.

The balanced scorecard can be used to help align specific innovation goals and their measurement with other key firm performance measures. These are integrated and linked to the overall strategic direction of the firm. Innovation activities are measured and valued as one of the core strategic drivers of business performance. The balanced scorecard is used in strategy development and alignment on a periodic basis. It provides visibility of goals and measures in core business processes linking these to customer perspectives and financial performance to enable decisions about future investments in product or process innovation. It is also useful in providing additional metrics to the normal financial measures in annual reports.

Management chooses a number of goals for each of four segments of the scorecard—finance, business process, customer perspectives, learning and growth. Measures are assigned to each goal and benchmark data are collected on a regular basis to provide evidence within each segment. The segments can be weighted to enable assessment of the likely relative impact of performance in one segment on the others. This provides a mechanism to assist in decision-making that links potential positive and negative impacts across different areas of activity, thus enabling a more holistic perspective to be taken in strategic decision-making.

Early users of the balanced scorecard include Mobil Oil and Brown and Root in the 1990s. Mobil used the technique to assess why it was underperforming industry norms on profitability in its Refining Division. Brown and Root used the technique to assist in aligning vision and strategy of two companies that were merged to install oil platforms in the North Sea in 1992. Other users include Hilton Hotels and Wells Fargo Bank.

The balanced scorecard can provide benefits to decision-makers because it makes explicit measurements that focus on operational and organizational issues aligning them to financial indicators and strategies designed to drive performance improvement. The scorecard identifies operational strengths and weaknesses across corporate programmes such as quality management, operations and logistics, customer service, and R & D.

The use of the balanced scorecard approach, however, has a number of limitations. If it is to prove successful, it must be embedded in the decision-making machinery of the firm and this requires sustained senior management support and attention, particularly if it is to be integrated with corporate strategy. It may take several years before goals and measures and their linkages in each segment are properly understood, by which time some metrics will have changed. Moreover, the ability to develop a robust tool will depend upon the quality of data that can be consistently collected on each measure. Keeping a balanced scorecard up to date can therefore be a complex activity.

Quantifiable evidence may not be available or appropriate to collect in some areas of activity such as innovation and learning. This problem was recognized in the original design of the balanced scorecard, which attempts to link tangible and intangible assets; but mixing subjective, qualitative evidence on some attributes with quantitative evidence such as financial data remains challenging for most firms. Ideally a balanced scorecard will be designed to relate data about past performance with how the organization is positioned to meet future targets. This is very difficult to achieve because in most organizations it is difficult to understand the frequency with which historical data must be captured and analysed if it is to provide a useful reflection on performance.

Whilst the overall vision of a holistic and balanced set of performance indicators is seductive for many business leaders, the cost and difficulty of setting up and maintaining such a system often detracts from its use.

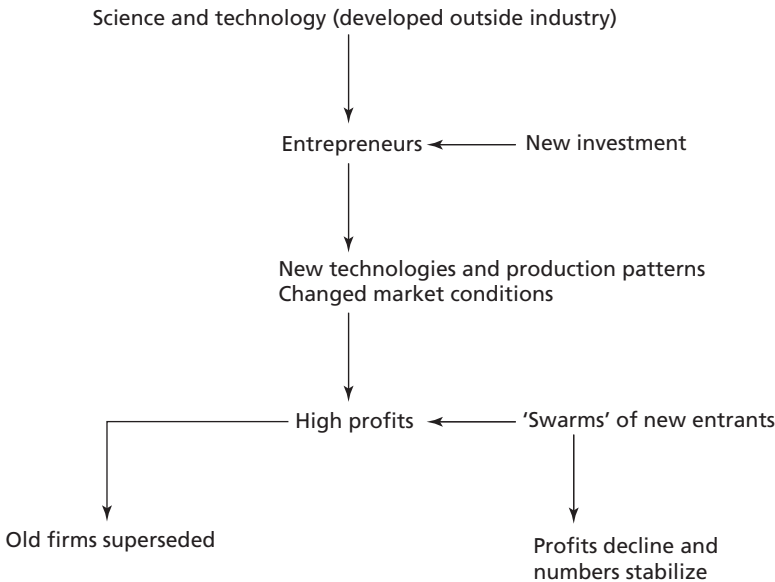
# Innovation strategy in SMEs

Around 99 per cent of all enterprises in Europe and the USA employ fewer than 500 people, and these enterprises account for 50 per cent of employment in the USA and over 70 per cent in Europe. SMEs produce over 50 per cent of total manufacturing value-added in Japan. Although over 40 years of research into the comparative advantages of large versus small firms in innovation is inconclusive, SMEs are acknowledged to be significant creators, partners in, and users of, technological innovations.

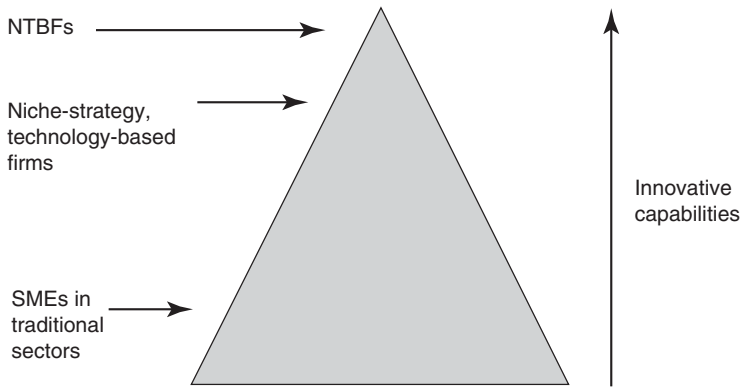
SMEs can play an important role in the development of new industries. According to Schumpeter's Mark 1 model of innovation, depicted in Fig. 4.9, it is entrepreneurs taking advantage of new science and technology that generates new industries. His Mark 2 model emphasized the innovation advantages of large firms (Freeman and Soete 1997).

There are many different types of SMEs, with various relationships with technological innovation (Fig. 4.10). New technology-based firms (NTBFs) are those SMEs whose business is based on new technologies in ICTs (including software, multimedia, and Internet firms), biotechnology, and new materials. Niche strategy, technology-based firms are those firms that use technology as the basis for their competitiveness. SMEs in traditional sectors, such as furniture and retailing, can be extensive users of technological innovations, but are rarely its source.

In NTBFs and the niche-strategy firms, technological mastery is the basis of competitiveness. In this regard, SMEs are disadvantaged compared to larger firms in their access



**Figure 4.9.** Schumpeter's Mark 1 model of innovation



**Figure 4.10.** Innovation in SMEs

to resources and complementary assets (see Chapter 9) and to some innovative capabilities (such as the amount they can afford to spend on research activities). However, they have strengths, particularly those related to their behavioural advantages (Rothwell and Dodgson 1994). So, for example, it may be easier for them to configure and deploy innovative capabilities as a result of their smaller size. They also have the capacity for fast learning (Dodgson 1991b). Amongst the key advantages of SMEs is the ability to access, generate, and develop technologies more quickly and more effectively than competitors.

There are five broad factors that influence innovation strategy in SMEs:

- *Accumulated technological competencies.* Firms with wide-ranging innovation expertise are better able to deal with the threats and opportunities that emerge from rapidly changing technologies. While many SMEs are started on the basis of technologies developed elsewhere, their strategic growth depends on the development of internal technological strengths. Without these internal capabilities they cannot advance the technologies they work with and successfully access novel technologies from external sources.
- *External orientation.* Small firms rarely have the technological base, or financial and staff resources, to develop and commercialize technologies themselves. They have to be highly receptive to open innovation models, working with other firms, research organizations, and universities, and also be very effective in the management of such partnerships to be competitive in the long term.
- *Organizational specialisms.* Smaller firms adopt organic styles of management more easily than larger firms (see Chapter 7). Their staff are generally better able to communicate across functional and departmental boundaries (which may not exist at all in very small firms) than staff of large firms. The flexibility and adaptability of SMEs are a key advantage, as is their ability for fast learning. Large firms commonly try to replicate some of these organizational advantages by creating small profit centres,

using small development groups (see the example of Lockheed's Skunk Works in Chapter 7), and creating 'ambidextrous' structures with different groupings for routine and developmental activities.

- *Internal strategic cohesion.* Although small firms often have difficulties in developing and implementing strategies, in successful high-technology, high-growth companies the scale of the firm's activities and the limited number of people determining strategic direction enable rapid and effective integration of corporate decision-making across business and technology areas.
- *Management skills.* These include the range of skills found in larger firms, including technological assessment, building and maintaining benefits from collaboration, communicating strategic objectives, and integrating innovation strategy with corporate objectives. SMEs can have advantages over larger firms in that they can offer great flexibility and incentives in their employment systems. They can offer greater task range and responsibilities to employees, as well as substantial stock options.

Technology-based SMEs do, however, face difficulties when trying to apply common approaches to corporate strategy.<sup>1</sup> For example, in the case of the 'industry positioning' approach of Porter (1985), their industry might not exist, so it is difficult to assess changes affecting industry structure. When the industry does exist, innovation in the nature of products and services profoundly disrupts industry boundaries limiting this approach to strategy-making. Their future markets and technologies may be unpredictable, so it is difficult to plan in the way suggested by Ansoff (1968). And it may be impossible to determine which of their resources and capabilities are valuable and should be protected according to the approach of resource-based theorists such as Barney (1991). These shortcomings apply to technological entrepreneurship more widely.

Research into innovation strategies in SMEs points to the particular challenges confronting their growing rapidly on the basis of their technological competencies. For innovative SMEs to grow successfully they need to overcome certain 'thresholds' in their activities and behaviours that can constrain their development.

The first threshold confronting an SME is its *start-up phase*. It is at this stage that it is determined whether the firm has the requisite resources and expertise to develop a business. Other thresholds emerge after the company has established itself and is entering into growth phases. A second threshold is *market and product expansion*. Many SMEs need to make the transformation from single to multiple products, and from customized to batch production. They often need to move from a focus on small market niches to higher-volume, more standardized markets. As domestic markets are often too small to allow for sufficient growth, they have to export.

<sup>1</sup> We are grateful to Erko Autio and John Steen for their insights into the shortcomings of conventional strategic management approaches in uncertain environments.

A third threshold facing SMEs is *technological diversification*. If an SME's technology is derived from a scientific base—for example, if it emerged as a spin-off from a university or research organization—there is a need to master the production and engineering skills required to produce commercially. The firm needs to integrate its R & D and operations activities. If, on the other hand, the technology is derived from an engineering function—for example, if it emerged as a spin-off from an engineering firm that was not interested in developing a particular new product—there is a need to understand its basic underlying principles so as to assist the development of new generations of product. It needs to undertake formal R & D.

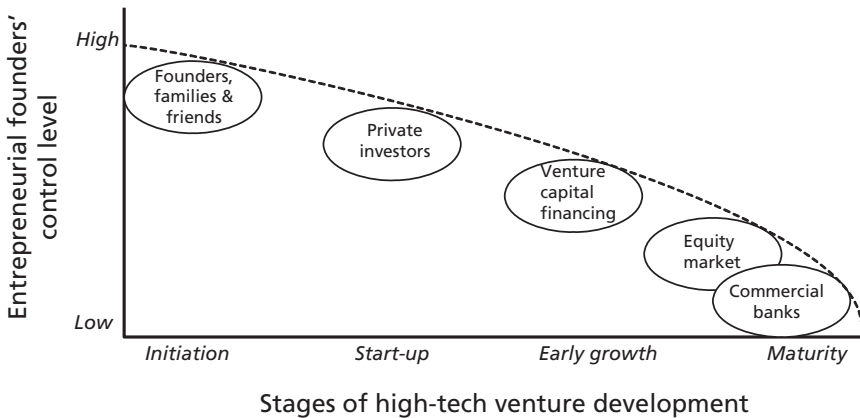
Another threshold facing SMEs concerns *management transformation*. Growing firms need to make the transformation from being entrepreneurially managed to being professionally managed. An entrepreneur is rarely the most appropriate person to run a larger company. Stelios Haji-Ioannou founded Easyjet in 1995 at the age of 28 and remained an executive member of the management team until after the business was floated in 2000. He stood down from his executive role after pressure from the board and because his natural entrepreneurial inclination lay with starting new businesses, not running existing ones. Haji-Ioannou is a serial entrepreneur. He remains a major shareholder in Easyjet through his role and ownership of the EasyGroup from which he establishes new business ventures based on the Easy brand: more than seventeen of which have been launched to date. The sorts of skills required of an entrepreneur are not readily applied to establishing organizational structures, delegations, financial reporting systems, and personnel policies required when a company expands.

The perennial problem of small firms is finance and cash flow. Box 4.11 analyses how technology-based SMEs finance growth.

Critical in overcoming the growth thresholds is the role of private investors ('business angels') and seed funds in the USA, including those created by government policy. The 'quality' of these funds is as important as their 'quantity' in assisting firms to address the thresholds. Business angels not only bring funds into the firm, but also bring their expertise and experience of managing technology-based growth. Experienced businesspeople can give valuable advice to growing firms about the need to confront the thresholds,

#### **Box 4.11 Financing growth in technology-based SMEs**

Large firms usually have a greater range of financing options for their innovation, including retained earnings, share issues, bonds, and loans. SMEs rarely have access to this range of funding, and the absence of these resources is often a major factor constricting their growth. What sorts of finance enable SMEs to overcome the thresholds described above? The sources of start-up finance include, progressively, personal savings, family and friends, private investors including wealthy families' funds, venture capital funds, equity markets, and commercial banks. At each stage the control levels of the founders of SMEs diminishes (see Fig. 4.11). Venture capital funds, and funds from a variety of financial institutions, can assist the early growth period of the firm.



**Figure 4.11.** Sources of finance, control levels, and stages of growth

Source: Adapted from Mayer 2002.

and how to do so. They can be instrumental in encouraging the start-up to change its funding basis from debt to equity, and thereby increase the amount of available capital to assist with the transitions required. More generally, business angels:

- Have a business background.
- Are willing to make equity investments that are too small for a venture-capital company.
- Are often willing to make their experience available to the businesses in which they invest through a seat on the board of directors, a consulting role, or even part-time employment in the business.
- Expect a significant capital gain from their investment.
- Are willing to assess investment proposals much more quickly than equity funds and institutional investors (Chadwick 1996).

The US government operates a very successful venture capital type fund through the Small Business Innovation Research (SBIR) programme. This programme plays an important role in stimulating innovation and small-firm development by offering substantial contracts for those firms that can make new products. SBIR supports businesses with fewer than 500 employees, and provides 100 per cent funded contracts to deliver particular contractual obligations to US Federal Agencies. Agencies advertise technical problems needing solutions, and there follows an open competition between proposals prior to a contract being awarded. In 2006, for example, the Department of Defense offered up to \$80,000 to any small firm that could develop a compact, high-power DC–DC converter for Navy non-explosive acoustic sources. Further funding of

up to \$800,000 was available for the development of a prototype (DoD 2006). SBIR mandates 2.5 per cent of Federal Agency total R & D spending to be used in this way, contributing \$2 billion annually, through 4,000 awards (Connell 2006). SBIR has the advantage of ensuring that the prize awarded is focused on developing a new product; a product that could have a large market outside the original government contract. Some highly successful companies have been supported by this program, including Amgen, Qualcomm, and Genzyme. As Professor Alan Hughes at Cambridge University, UK points out:

These sums are roughly equal to the total angel finance and two to three times the early stage venture capital funding, because the private venture capital in the US is pretty much like it is in the rest of the world—it's not particularly risk loving. It's only a small proportion of funding which goes into early stage finance. So actually what the SBIR does is produce a situation in which a lot of the very early stage investments have this huge public sector mandated activity already providing certification and proof of performance capacity in small firms that win these contracts. ([www.mindsharing.com.au](http://www.mindsharing.com.au))

## Summary and conclusions

This chapter discussed the nature and importance of innovation strategy. Innovation strategy is notoriously difficult both to practise and analyse. Few companies have consistently managed to develop technological innovation in a strategic manner (Christensen 1997). Without downplaying the complications involved in the development of innovation strategy, this chapter has presented a relatively simple analysis. Innovation strategy involves decisions about which technologies and markets provide the best opportunities for delivering value and building competitive advantage. These decisions are taken within the context of, and fit within, the firm's corporate strategy and its available resources, and guide the selection of the innovation processes used and its various activities, such as R & D and operations. Innovative capabilities are those bundles of skills that contribute to innovation strategy by guiding the resources used for innovation and enabling their reconfiguration. Innovation strategy also encompasses choices about innovation processes and how they are most suited to particular competitive circumstances.

The chapter has presented some basic tools that companies can use to assess innovation opportunities. It has highlighted the need to ensure that the right tools are used and their results are interpreted cautiously. There are dangers in radical, disruptive, and emergent business environments in using many frameworks from the strategic



management literature, and many established tools and techniques are simply not applicable in highly uncertain innovation environments.

SMEs face specific issues in strategic MTI. These often relate to issues of managing growth and navigating the various thresholds that can constrain their development. As with large firms, the success of SMEs' innovation strategies depends to a large extent on their capacity to learn and to this extent they have comparative advantages in their capacity for fast learning, partly because of their flexibility, which explains why many large firms attempt to emulate their organizational advantages.

# 5 Networks and Communities

## Introduction

This chapter defines innovation-supporting networks and communities and examines how they can be used to help a firm improve its innovative efforts. We distinguish between networks and communities that broadly support innovation and formal technological collaborations between limited numbers of partners with specific objectives. The chapter pays particular attention to the importance of social capital, organizational learning, and trust in networks and to the role of lead users in innovation. In Chapter 2 we discussed national, regional, sectoral, and technological systems of innovation and the way they influence the broad context in which firms innovate. Here the focus is less on the structure and components of these systems and more on the way firms operate within the networks and communities to which they belong and the management challenges involved in using them to best effect.

## What are networks and why are they important?

What is a network? Definitions vary, but they are usually seen as patterns of organizing involving multiple connections. These involve collections of nodes, which could be individuals, teams, or organizations, linked by a relationship. Where such relationships abound amongst groups of firms and public-sector institutions, they are sometimes described as ‘innovation networks’ (Freeman 1991). Our focus is on networks that support and encourage innovation, exploring the impact of networks on innovation at the individual, team, and firm level.

The role networks play in innovation is not new. During the industrialization of Britain in the late 1700s there were strong linkages between the individuals developing the first generation of steam engines. James Watt and his contemporaries often met at the Royal Society and other professional communities to share ideas about technology and markets (Nuvolari 2004).

Networks are important because they are ubiquitous. Everyone is part of networks of friends, family, and colleagues. Every firm is embedded in a variety of networks with

their customers, suppliers, and possibly universities and competitors. A generation of research on the innovation process has shown that innovators rarely innovate alone. They are embedded in dense networks and external relationships that propel, generate, and sometimes limit opportunities for innovation. As we saw in Chapter 3, the innovation process has become increasingly open and distributed over time. MTI decisions are shaped by these kinds of relationships within networks.

A major reason for firms belonging to networks and communities is that as technology becomes more complicated and complex, it is necessary to combine and integrate knowledge, components, and systems from many different domains (Hargadon and Sutton 1997; Fleming and Sorenson 2001; Amin and Cohendet 2004). A modern car is not simply an extraordinary feat of mechanical engineering; it contains software, communication systems, and new materials and its construction requires knowledge about these and many other fields. Firms derive competitive advantage from being expert at combining and integrating the knowledge and technologies of others in novel and valuable ways. This requires firms to work with external actors, develop the capacity to capture and absorb ideas and technologies developed by others, and learn especially from the ideas and insights of their customers and users (Cohen and Levinthal 1990). This issue will be examined further later in the chapter.

By understanding networks, it is possible to gain insights into the interactions and relationships that support and constrain innovation. Networks enable individuals and firms to gain access to resources they do not possess, without necessarily having to buy them in a market transaction. They provide clues about where ideas may be located or where assets may be found to help realize the commercial potential of a new idea. Understanding networks is therefore central to MTI. Networks offer a rich web of channels, many of them informal, and have the advantage of high source credibility: experiences and ideas arising from within are much more likely to be believed and acted upon than those emerging from outside (Kogut 2000; Powell, Koput, and Smith-Doerr 1996).

A strength of networks (especially for smaller firms) is that they offer a way of bridging gaps between what firms do and what is possible (best practice). Networks can enable the sharing of resources: for example, specialist equipment or collaborative R & D projects where the costs and risks of investment to any individual firm would be prohibitive. In addition, networks create the possibility for extensive self-help through experience sharing and learning. Cooperative networks in Europe have enabled small-scale industry to compete successfully in global markets through involvement in collaboration (Best 1990). The Italian furniture industry, for instance, is the world export leader, yet the average firm size is less than ten.

Freeman (1991: 512) argues that networks should not primarily be explained by reference to costs, but rather in terms of strategic behaviour, appropriation of knowledge, technological complementarity, and sociological factors such as trust, ethics, and confidence in the cooperativeness of others. The important issues of trust and

organizational learning in networks, communities, and technological collaborations are discussed later. In addition to the positive benefits, networks can also have negative consequences. The network model of innovation may limit participating firms' access to 'complementary assets' (Hobday 1994 and see Chapter 9) and hence their ability to achieve full commercial returns on innovative activity. Networks may trap firms in low-value parts of the value chain. They might also have some features of cartels and conceivably exclude possible new entrants, with negative consequences for competition. The negative consequences of networks are further discussed later.

The challenge for managers is how best to configure external relationships alongside the internal capabilities within firms to create value. This raises important questions for MTI such as: How to manage the integration of ideas and technology developed by others into products and services? How best to harness users' knowledge in developing new and better products and services? How to take advantage of the benefits and avoid the dangers of collaboration? These questions are the subject of this chapter.

## Scientific networks

The science system provides the best example of the role of networks in supporting innovation. The development of science has always relied upon open exchanges between individuals. Its universalistic approach means that ideas are shared between individuals who are separated by national boundaries, languages, and cultural barriers. Scientific discoveries are shared through publication. Publications establish the individual(s) responsible for the advance of and their 'priority' in the knowledge production system. They are an important source of knowledge exchange, but there is considerable informal knowledge-sharing between scientists meeting at conferences, in seminars and laboratories. Arthur Koestler once described scientists as 'call girls' because they are willing to fly anywhere in the world to tell anyone what they know for the price of an economy ticket. The transformation of physics in the early twentieth century benefited greatly from a constant series of conferences across Europe and USA between scientists sharing information about new developments in the field. The open nature of these communities raised serious concerns when the revolution in physics was transformed into practical applications, such as nuclear bombs and power. The conversation between the two Nobel Prize winners and former colleagues Niels Bohr and Werner Heisenberg in Denmark in 1941 is a key moment in world history, dramatically documented in Michael Frayn's play, *Copenhagen*. At the time, the nature of this conversation was a subject of utmost concern to the Allies, leading to Bohr's rescue from Denmark and his later meeting with Churchill and Roosevelt as the Allies sought to determine the nature and extent of Nazi efforts to build a nuclear bomb (Rhodes 1996).

The interactions within science allow scientists to build upon existing knowledge. The status of a scientist is determined by the usefulness of his/her ideas to others, often

measured by citations to work in subsequent scientific efforts. The scientific system is regulated informally by peer review, managed by journals or by research-granting authorities. As such, it remains subject to relatively little outside scrutiny, but it is highly competitive with great rewards and considerable glory for those who succeed—see the discussion in Chapter 6 on incentives for researchers. Although not without flaws, this system remains incredibly powerful in generating new knowledge, creating opportunities for scientists around the world to quickly share knowledge and work collectively and individually to advance knowledge in their area. Indeed, one of the greatest inventions of the twentieth century, the ‘World Wide Web’ was developed by scientist Tim Berners Lee because he wanted to share information more effectively with his colleagues working in the same research laboratory, CERN (Hafner and Lyon 1996; Gillies and Caillau 2000).

Major discoveries often arise out of the links and exchanges between different areas of knowledge. Many of the major advances in science in the twentieth century occurred because of interactions among scientists in different areas working on a common challenge. For example, James Watson and Francis Crick, the joint discoverers of the structure of DNA, were trained as biologist and physicist respectively and met as young scholars at Cambridge. Their discovery in turn relied heavily on the efforts of Maurice Wilks, a physicist, Rosalind Franklin, a physical chemist and expert in crystallography, and the support of numerous colleagues.

## Social capital

A central concept in the study of networks and communities is that of *social capital*, the goodwill that is engendered by social relations that can be mobilized to facilitate action (Adler and Kwon 2002; Burt 2005). An example of the influence of social capital can be seen in Italy, a country with pronounced differences in wealth between north and south. The unemployment rate in Lombardy in 2005 was less than 4 per cent; in Sicily it was more than 25 per cent. In seeking to explain these differences, Puttnam (1993) argued that the success of some Italian regions could be traced back to the dense number of associational activities, such as the number of football and church clubs in the north compared to the south. His study found that northern Italian communities had greater social capital enabling the development of effective economic and social institutions, including basic ones such as firms and courts, which operated with difficulty in the south.

The idea of social capital suggests that individuals and organizations gain commercial advantage from investments in building networks. Like other forms of capital, investments in building relationships can yield future gains (Adler and Kwon 2002). The ways in which firms work with and relate to the associated social capital around them can create opportunities for innovation within and between organizations, strengthening

regional economies—such as Baden-Württemberg in Germany and Emilia-Romagna in Italy. It can also produce regions in which firms learn together to improve a collective innovation process, for example in the Basque Country in France–Spain, in Wales, or around Barcelona (Cooke and Morgan 1998 and see Chapter 2). Social capital is not a substitute for other resources, however; rather it complements other activities, enabling actors to more effectively utilize what they have and what they know. Social capital is also costly to build and maintain. Once developed its value does not easily depreciate. In fact, it may increase and strengthen over time (Adler and Kwon 2002). The advantages of social capital do not merely accrue to single individuals. In the examples of innovative regions mentioned, there are strong spillovers from the social capital of one individual to another and from one organization to others.

The advantages of social capital from networks depend upon the structure of the network and/or content of exchange. Structural advantages could be a product of the fact that you know the right people, whereas the content advantages could be that you know people with the right information (Adler and Kwon 2002).

The importance of the structure and/or content of networks has led researchers to examine the influence of different types of network on performance and innovation (Borgatti and Foster 2003; Brass et al. 2004). This research examines a range of networks, and how an individual may be central in one network, but on the periphery of another. The position of individuals or organizations in different types of networks may give them both structural and content advantages over their colleagues or competitors, allowing them to be more effective innovators than others (see Box 5.1). Of central importance here is the role of the technological gatekeeper discussed in Chapter 7.

There is a continuing debate about the advantages of tight interactions within a group and loose relations between groups. This is often referred to as the advantages of strong or weak ties. In a seminal sociological study of the job market in Boston, Granovetter (1973) found that workers were likely to learn about jobs from people they barely knew. These weak ties were associated with low reciprocity, weak emotional commitment, and infrequent contact, but the diversity of these links provided invaluable sources of knowledge. Burt's (1992) work on structural holes in networks also supports the advantages of weak ties. This research focuses on the gaps that develop between different groups of people inside an organization and seeks to analyse the extent to which individuals are able to bridge them. Individuals who are able to span these gaps are called brokers. By creating links between previously disparate groups, brokers are able to import ideas from one place and apply them in another. This enables brokers to gain insights and find new combinations that other individuals cannot (Burt 2005). They can see opportunities to make connections and pass information between groups. Brokers are likely to be promoted more quickly, generate more innovations, and earn more than non-brokers (Burt 2005; Obstfeld 2005; Rodan and Galunic 2004). In other words, brokers can have more fun.

**Box 5.1 Social Network Analysis—The ties that bind**

Over the past eighty years, sociologists have developed increasingly sophisticated techniques for understanding the social interactions between individuals. One of the key tools in this approach is Social Network Analysis (SNA). SNA provides a mechanism for exploring connections between individuals, allowing researchers and firms to map and examine relationships between members of different groups and organizations (de Nooy, Mrvar, and Batagelj 2005; Wasserman and Faust 1994). SNA programs include UCINET, SEINA, and Pajek. Analysis can be carried out at individual, team, business unit, or firm level. SNA data can be collected using communication traffic, public records, and by electronic or paper-based surveys. SNA can be performed wherever it is possible to obtain information on interactions between individuals or organizations.

SNA has also become a popular tool for making social connections. The social networking sites, 'Myspace' and 'Facebook', are amongst the most visited on the Internet, with millions of individuals offering information about themselves to others and creating worldwide networks. In April 2007, there were some 500 million registered members of social network sites. These included 800,000 members of 'VampireFreaks', a community of 'Goths', and 'Facebox' with 8 million young people under the age of 18 in the UK.

SNA is used by firms to better understand who talks to whom and where the most important connections are in the firm (Cross and Parker 2004). This information is important because it provides insights for managers into where and from whom people get ideas and which individuals provide bridging ties between different parts of the organization. Social networks rarely overlap with formal organization structures and therefore provide a way of seeing how things really get done. Such analysis often brings to the fore individuals whose contribution goes unrecognized by the formal hierarchy, yet who play a critical role in making things happen (see Fig. 5.1).

There are many different types of networks operating inside organizations. SNA research has explored differences between 'advice', 'communication', and 'friendship' networks and how individuals may be central in one network, but peripheral in others (Cross and Sproull 2004).

SNA is used in new product and service development to explore potential connections between different groups or individuals. It is useful in helping form teams by exposing the networks of members and assessing how well connected they are inside and outside the organization (Hansen 1999). It helps organizations reconfigure existing teams by bringing in new members with different social networks.

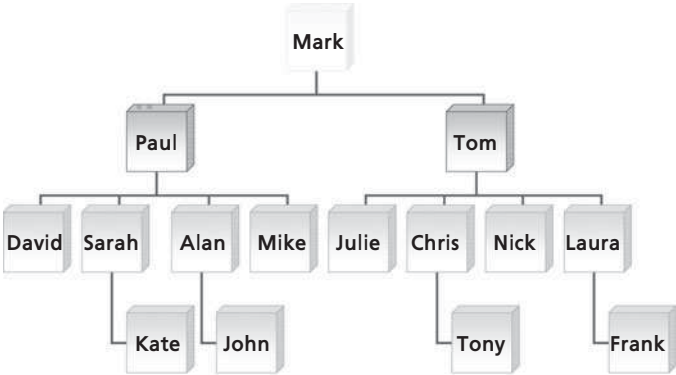
As SNA has diffused, it has become one of the central tools in understanding why some individuals or organizations are innovative and others are not. It opens a window on the structure of personal relationships that support innovation.

To learn more about SNA and management, see Cross and Parker (2004).

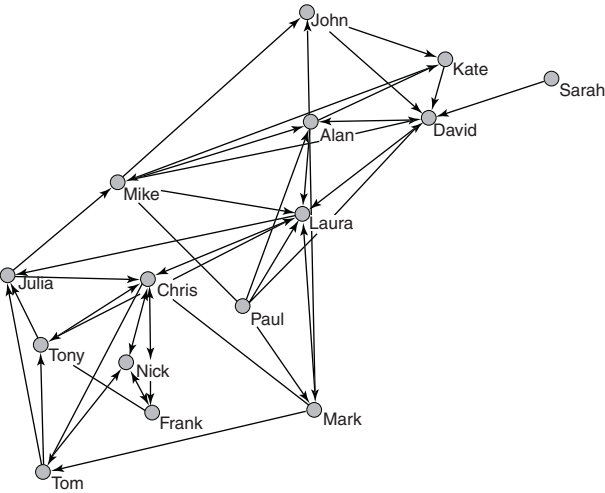
In contrast, Coleman (1988) argues that tight links within a group can help build strong norms and understanding that allow teams to function more effectively. He calls this closure. Burt argues that the successful use of social capital requires a combination of closure and brokering: a tight, intimate set of ties within a group as well as ties with diverse sets of outside actors. This view is consistent with Reagans and McEvily (2003), who find that cohesion and range are important to enable knowledge transfer and innovation. It is this combination between tight relations and diverse inputs that provides the greatest benefits for innovation. It is possible to try and attempt to manage and create these productive social relationships, in part at least—see Chapter 4 on the Role of the Innovation Director.

The benefits of social capital have been well documented. Individuals with strong social capital have been found to live longer, be happier, and earn more money than those without (Adler and Kwon 2002; Borgatti and Foster 2003). Managers with high social capital reap rewards from their networks (Burt 2005). The advantages of social

### Formal corporate structure



### Informal corporate structure



**Figure 5.1.** Formal and informal organization structures

capital are present for firms as well. Baum, Calabrese, and Silverman (2000) found that biotechnology start-ups able to forge networks with other actors including universities were more likely to survive than others without them. Shan, Walker, and Kogut (1994) find an association between cooperation and innovative output in biotechnology start-ups. In a study of networks in the Chilean wine industry, Giuliani and Bell (2005) found that knowledge exchange and learning amongst firms is often led by a few central actors, who operate as technological gatekeepers for the entire network. Powell, Koput, and Smith-Doerr (1996) investigate inter-organizational collaboration in biotechnology and assess the contribution of collaboration to learning and performance, showing that firms



beneficially embedded in networks are likely to have better innovative performance. All these studies point to the central importance of social capital in shaping the ability of individuals and organizations to innovate.

Social capital can also have a negative effect on innovation and performance, which add to the challenge of managing it. Ahuja (2000), for example, finds that indirect and direct ties influence the ability of a firm to innovate, but the number of the firm's direct ties moderates the effectiveness of indirect ties. Social capital can be very expensive and time consuming to build and returns may be less than the cost of the investment. Building external relationships may direct managerial attention and resources away from the internal activities necessary to make a new product work (Laursen and Salter 2006; Ocassio 1997). External networks are no substitute for novel and functioning products, services, and technologies. On the other hand, too much inward-looking social capital may lead some firms to become short sighted, blinding them to danger. Grahber (1993) describes how the steelmakers of the Ruhr region in Germany became too tightly linked and therefore missed opportunities to change. Overly narrow social capital can lead to the 'Not Invented Here' (NIH) syndrome, or 'the tendency of a project group of stable composition to believe that it possesses a monopoly of knowledge in its field, which leads it to reject new ideas from outsiders to the detriment of its performance' (Katz and Allen 1982: 7). The case of P&G's movement towards C & D described in Chapter 6 is, in part, an attempt to overcome this problem in a large R & D organization.

### Box 5.2 Clusters

Clusters are a form of network. Some clusters focus on the 'horizontal' nature of relationships between SMEs that both compete and collaborate. Others would see the relationships between large firms and their core suppliers as leading to clustering in many cases. These are essentially hierarchical relationships, which happen to involve inter-firm rather than intra-firm relationships. The equality of relationships between firms found in such clusters derives from the technological interdependence of a group of large and often international firms.

Some observers, most notably Porter (1990), have assigned great importance to the presence of demanding customers as stimulants to innovation in different clusters. As we shall see later there is considerable evidence that, in some industries, customers are the critical elements in the development of new products.

There is some debate as to whether the firms involved in clusters are in the same or related industries. In the wool textile cluster in Prato, Italy, for example, there are both textile companies and the engineering firms that make textile equipment. Similarly, in the Finnish forest cluster, machinery manufacturers are an essential aspect of the cluster's success. The cluster includes both paper manufacturers and the emerging firms that clean up environmentally after the paper processes. In that cluster the 'forest' is the key link between the economic activities. In other work, clusters are more strictly defined as parts of an industry (all making leather goods or ceramic tiles, for example), but linked through their inputs to different activities in the production chain.

For some local and regional governments, the creation and encouragement of clusters has become the primary focus of economic development policies (Wolfe and Gertler 2004). These policies are commonly overly simplistic in their prescriptions, with little appreciation of the specific industrial, technological, and cultural contexts that so influence comparative advantages and mitigate against 'off-the-shelf' policies.

Social capital may also lead to myopia as groups become closed off to sources of disputation. As Bob Woodward describes in his book *State of Denial* on the Bush Administration's management of the war in Iraq, entrenched self-reliance may lead to a lack of critical reflection and debate inside an organization, in turn setting off a series of poorly thought through and incompletely executed initiatives.

These different perspectives on social capital emphasize how important it is for managers to find an appropriate balance between creating strong ties within a team and diverse ties outside and across teams. Networks can help complement and support internal activities; but cannot act as a substitute for them. In the next section, we explore how firms can best capture the advantages of networks for innovation.

## Harnessing users for innovation

Many studies have shown that innovation often arises from users (see Table 5.1). In some sectors, such as medical instruments, users are responsible for the majority of all innovations (von Hippel 1976). Lead users are those knowledgeable individuals or organizations that are prepared to be early users of innovations—innovators or early adopters in Rogers' terms (see Chapter 3)—and are capable of working with the developers of innovations and providing positive and critical feedback (von Hippel 1988). They are especially important for innovation because they are usually ahead of the market, facing the problems first. They are also in a position to benefit greatly from innovation. Working with lead users can provide firms with opportunities to gain insights into how their products are used in practice and how they may be used in new ways, different from that planned by the innovator. It also allows these firms to extend and incorporate user innovations into their products (Riggs and von Hippel 1994; Urban and von Hippel

**Table 5.1.** Share of industrial & consumer product innovations developed by users

Product area	Source of Innovation			Number of innovations
	User	Manufacturer	Other	
Petroleum processing (Enos 1962)	43%	14%	43%	7
Computer innovations 1944–62 (Knight 1963)	26%	74%		161
Chemical processes and process equipment (Freeman 1968)	70%	30%		810
Scientific instruments (von Hippel 1976)	76%	24%		111
Semiconductor and electronic subassembly manufacturing equipment (von Hippel 1977)	67%	21%	12%	49
Wire-stripping and connector-attachment equipment (Van der Werf 1984)	11%	33%	56%	20
Windsurfing, skateboarding, and snowboarding equipment (Shah 2003)	60%	25%	15%	48

Source: Shah 2003.

1988; von Hippel 1998). In some sectors lead users comprise numerous individuals that collectively create whole communities. Many computer games developers, for example, allow user communities to develop modifications in the way that 'id Software' (see Box 7.5) does with its popular titles, 'Doom' and 'Quake'. This encourages user participation in the game, helping to extend its life and features beyond initial designs (Jeppesen 2005). Other communities in open source software (OSS) and in companies such as Wikipedia are discussed later. Another example of user innovation can be seen in STATA, a popular statistical program used by economists (von Hippel 2005). STATA Corp. encourages users to develop new econometric programs and then incorporates them in subsequent editions of its best-selling software. If an econometrician develops a new test for endogeneity in cross-sectional datasets, she can have it programmed in STATA for others to use. The econometrician developing the new technique wants it to be used by other scholars, as its use will enhance her reputation and status in the academic community. In turn, users want to access the latest analytical techniques to ensure their data analysis is based on the best available and most appropriate method. The environment creates considerable advantages for STATA, allowing it to stay ahead of other software programs.

In many products and services, users have information and insights that can only be gained through considerable efforts on the part of the innovator. This information is 'sticky', based on the experiences and knowledge of users, and often hard to find and transfer. Firms are often unaware of the novel uses of their products and services (von Hippel 1994). At times, innovations are made without the consent or support of the original developer and it may be useful for the innovator to discover who is developing novel uses. In some cases, these users are well removed from the traditional market or customers of the firm (see Box 5.3).

It is common for software developers to involve lead users in their development processes by inviting them to join as advisors or testers of the software prior to its release. There is a long tradition of beta testing with users in software development enabling the developer to quickly fix problems before the final product is released to the wider range of less technically gifted users. In the case of P&G, users are part of the screening and selection process for new designs. P&G uses distributed focus groups to test out ideas before it commits to a new product launch. In the development of a new bottle for the cologne Hugo Boss, P&G used a focus group of more than 200 women between the ages of 25 and 45. Women are the largest purchasers of male cologne and purchasing decisions are heavily influenced by the shape of the bottle as well as its scent and brand name. Manufacturing glass bottles in large volumes can be extremely expensive, as bottle-making systems remain relatively inflexible. It is therefore advantageous to assess the likely popularity of the final design before committing resources to large-scale manufacture. P&G experimented with a number of designs and sent virtual models of them to its focus groups around the world. Members of the

### Box 5.3 Dancing robot dogs

In many areas of software development, new products and services arise first through the efforts of illegal users or hackers. Flowers (2006), calls this phenomenon 'outlaw innovation'. An example is seen in software for the Sony Aibo, a robotic dog. In 1999, the year of its release, a product hacker named AiboPet began to hack Aibo software to improve performance of the original Sony product. This software called 'Disco Aibo' enabled the robot dog to dance to music. Sony was unhappy with this development and notified AiboPet that it had infringed its IPR. Sony was attempting to protect its product for controlling robot dogs, Aibo Master Studio. This product retailed for \$500 in 2000. In contrast, AiboPet was free. AiboPet argued that its software was a further development of Sony's software and that its use resulted in the sale of more Aibos. This argument had little effect and by 2001, under significant pressure from Sony, AiboPet ceased to operate. News stories about the case and irate letters from Aibo owners led Sony to rethink its IP strategy. As part of a new approach, it decided to use and capture innovations from hackers rather than trying to compete with them. As a result, Sony published software specifications for Aibo in an open architecture, enabling others to develop software for the robot dog. In 2004, Sony released Aibo Software Development Environment for the latest version of its robot dog. This new software incorporated many of the features of AiboPet, enabling users to create new dance routines for their robot dogs. The new software was free and included many of the improvements originally developed by hackers. There continues to be a strong community of hackers developing software for robot pets: see [www.aibohack.com](http://www.aibohack.com).

Source: Flowers 2006.

focus groups then voted on which design they preferred and eventually a winner was selected for mass production. This product eventually became a best-seller in the cologne market.

Products can be designed to allow users to actively contribute to their development. A modular product structure can enable users to make changes in one part of the system without requiring redesign of the system itself (Henderson and Clark 1990). This is commonly seen in software, but there are examples in other sectors, such as Japanese housing (Barlow and Ozaki 2003; Barlow et al. 2003) (see Box 7.13).

Von Hippel (2002) argues firms need to develop 'user tool kits' to successfully enlist users into the innovation process. These tool kits allow users to experiment with different designs through trial and error. They also create a 'solutions space' where users can play with and manipulate designs. This requires firms to make available libraries of modules that the user can recombine in different ways. The new user-designed product can then be transferred into production without reference back to the original company. 'Nike iD' is an example of an early and, as yet, incomplete user tool kit. For an extra \$10, users can choose the colour and personalize the design of their own running shoe from a library of on-line choices. Nike offers limited choices, but over the next few years the ability of users to make their own shoes is expected to greatly expand, leading to the introduction of a full user tool kit for designing running shoes.

The ability to enlist users into innovation processes can be especially important for small and resource constrained firms (see Box 5.4). By winning over users to a product, it may be possible to create a community of them. Early users may be attracted to products and services not simply because they perform a particular function, but because they are

### Box 5.4 User communities in musical software

Propellerhead Software is a Swedish company specializing in musical software products. It was founded in 1994 and by 2007 it employed over fifty full-time staff. It develops products that enable musicians to compose music with a virtual tool kit, with features such as sound-producing modules, sound effects, and sound-organizing elements. Its products complement and sometimes even substitute for physical sound-recording studios. It is popular with musicians such as Liam Howlett of Prodigy and Mocean Worker. Propellerhead's software costs between \$100 and \$500. It can be downloaded from the Web and it is compatible with other audiovisual production technologies. One of the key elements in Propellerhead's software development process is the engagement of users to collaborate and exchange information. An example of how Propellerhead does this can be seen in the product testing of *ReCycle*. It decided to make a prototype of this software freely available on the Web to generate interest in it and to learn from users. On the first day of its release it received 30 hits, the next day 3,000, and thereafter more than 30,000 hits per day.

As the chief executive officer and cofounder of Propellerhead explains,

[I]n 1996–1997 when Propellerhead started, there was 'only' a good idea. The lack of financial resources initially blocked the firm's access to traditional and costly distribution channels through, for example, music instrument stores. Therefore, Propellerhead decided to focus on distributing its products entirely via the Internet. ... Following the 1999 release of Propellerhead's product *ReBirth*, a number of users joined in an Internet-based chat hub where they managed to 'hack' the *ReBirth* software. (Jeppesen and Frederiksen 2006: 48)

These hackers managed to integrate their own sound samples and graphic designs into the software. One of them stated: 'It was a form of friendly competition among us.' After this hacked version appeared, Propellerhead started to communicate directly with the hacker community. At first, Propellerhead was 'surprised' by the fact that hackers would give so much of their time to work on its software.

The CEO and cofounder of Propellerhead explains further,

We were really excited about this. ... This approach to hacking opened up Propellerhead's eyes to the benefits of having access to a community of innovative users. Keeping a welcoming attitude toward users' product modifications, the firm decided to support users' innovative efforts by opening up parts of the product code to users who wanted to make so-called mods (modifications of the original product) to their products ... Propellerhead decided to set up their own 'official' online user community on the firm's website. Over time, Propellerhead turned their community into the main hub for their products. (Jeppesen and Frederiksen 2006: 48)

Propellerhead Software supports the development of this user community and by 2006 it included more than 3,800 members, generating hundreds of exchanges each day in discussion groups. The most typical user innovations are minor modifications to existing software made by utilizing tools supplied by Propellerhead. These modifications often include new sound samples. Some modifications are more advanced and their development is not a trivial effort. Some, for example, would have taken a Propellerhead product developer between 100 and 150 hours to create a similar feature in the program. The main motivation for the individuals who make these modifications is a desire to support the community and help solve problems. Indeed, many of the people who make modifications are not themselves musicians.

The case of Propellerhead shows how a small firm can utilize users to increase its innovative potential. Propellerhead was successful because it had a novel product that met a need among musicians. It was also open to user adaptations to its product and has sought to support and build a community of developers by sponsoring exchanges among users and hackers. This approach relies on users' desire to solve problems and work together to develop collective and shared resources. In doing so, Propellerhead has been able to enhance the quality and functionality and lower the cost of its software for its users.

Source: Jeppesen and Frederiksen (2006). To learn more about Propellerhead and its user communities, please see [www.propellerheads.se](http://www.propellerheads.se).

part of a community movement. Early users of ‘craigslist’ of classified advertisements, for example, were attracted to the service because it broke with conventional advertising Open Source Software (OSS) models. There may be increasing returns, as more people register on ‘MySpace’ or ‘YouTube’, for example, these sites become more valuable both to the individuals who contribute to them and the companies that own and operate them. Google’s purchase of ‘YouTube’ in 2006 for \$1.6 billion reflected the popularity of the site rather than the value of the software and small team that developed it.

Many users are for various reasons willing to offer their time and effort free to these communities. Many contributors are driven by the desire to gain status and the urge to solve problems. A prime example of the motivations of users can be seen in OSS (Lakhani and von Hippel 2003; von Hippel and von Krogh 2003). Here a community approach is used towards new product development (see Box 5.5). A group of programmers or hackers work together in separate but related areas to help build software that can be freely shared. Individuals who make contributions may hope to gain future employment with firms that monitor these networks. Individuals may be sponsored by firms themselves wishing to enhance their reputation. More often, however, contributions are linked to intrinsic motivations—the desire to support a community, to help others, and to make something happen.

### Box 5.5 The GNOME project

OSS is a new model of product development that relies on free contributions from a large number of individuals to achieve a common goal. It has led to the development of a range of successful software products and offers an alternative to in-house software development. The movement has been heavily supported by leading computer and software companies, such as IBM, Red Hat, Sun Microsystems, Hewlett-Packard, and others. OSS is written in a programming language that incorporates commands to enable it to work. Programmers can add explanations to help other developers work on the code. Other programmers can see, interpret, and evaluate code. Open-source (OS) projects are coordinated by central hubs, allowing a number of projects to be developed at the same time.

The GNOME project was a major OS project launched in 1996 by Miguel de Icaza to develop a graphical user interface desktop environment for the Linux operating system. de Icaza and others decided to pursue the project because of frustration with existing Linux desktop environments, which no longer followed the codes and traditions of the OSS movement. Their idea soon won popular support in the OS community and thousands of developers started contributing code. The project also won the support of Red Hat, a leading OSS developer. Several versions of the code have been released and it has become a popular tool for Linux users.

The project is run as a community with a formal structure. It has a Foundation to coordinate software releases and determine which projects are considered part of the community. Individuals who make significant contributions to GNOME can apply for membership of the Foundation. These members elect the Board of Directors, responsible for overall governance of the code. Although the community is largely made up of hobbyist programmers, GNOME has benefited significantly from the contributions of individuals sponsored by firms. These individuals play a key role in developing the core code and coordinating activities across different projects. For GNOME participants, however, the project is not simply about software; it is about building a ‘worldwide community of volunteers who hack, translate, design, quality assure, and generally have fun together’.

*Source:* Dahlander and Wallin (2006). For more information about GNOME project, please see [www.gnome.org](http://www.gnome.org).

This approach to innovation can change the role of the firm from being one of originator or creator of new products and services to enabler for users to develop new products and services for themselves. The experience of Wikipedia is instructive. The company that runs Wikipedia had only five employees in 2006, including its founder Jimmy Wales. It is a non-profit organization and most of its funding comes from small donations. Wales states that Wikipedia's mission is to 'distribute a free encyclopedia to every single person on the planet in their own language' (Schiff 2006). There are over 250 languages in use by Wikipedia and hundreds of thousands of people have contributed to the site from around the world. The site includes the facility for multiple contributors to contribute to a post and each entry includes the record of all edits by previous users. Wikipedia went live on 15 January 2001. After a month it had 600 articles and after a year there were 20,000. In 2007, there were approximately 6 million articles. Schiff's (2006) article on the company, in the *New Yorker*, says there are 200,000 contributors to the English language site, with only 3,200 of these responsible for the majority of posts. The two rules of Wikipedia are that all entries must be neutral and verifiable. Contributors to Wikipedia are called 'Wikipedians' and they are largely male. As use of the site has increased, it has had to develop more extensive forms of governance, including monitoring of rogue posts and exclusion of users who abuse the system. The site has increasingly become the location of political arguments about information, undermining the authority of its posts. Wikipedia is less accurate than the *Encyclopaedia Britannica*, but not massively so (Schiff 2006). One study found that there were four errors in Wikipedia for every three in *Encyclopaedia Britannica*. Wikipedia represents a new form of user involvement in innovation showing the power of users in creating collective resources.

Examples such as Wikipedia show how firms can play new roles in the innovation process. In this model, instead of the firm trying to anticipate the needs of users, it will simply facilitate product and services developed with users via a tool kit. It is uncertain how widespread this model will become, but it is unlikely that this innovative form of behaviour will disappear. Instead, the role of the firm—as an integrator of knowledge and resources—will adapt to a situation where it becomes part of a system of organizations and individuals, who collectively and individually work to develop, commercialize, adapt, and re-use innovations. Firms able to harness these collective efforts will gain competitive advantage.

This new approach to the organization of the firm requires willingness to open up development processes and products to external contributions. It also requires them to develop mechanisms to not only allow users to contribute, but also to feel a sense of ownership and collective endeavour with fellow users. This sense of community helps firms develop collective solutions to problems that previously would have been handled individually, if at all. Such mechanisms may enable the innovation process itself to change to be more democratic and open, creating greater equality between the producers and users of innovations (von Hippel 2005; Coombs, Harvey, and Tether 2004).



## Technological collaborations

Some forms of network have a specific focus on technological development, have a limited number of partners, and tend to be more formalized and structured in a business sense than the networks and communities described before. We call these technological collaborations. They take the form of technology-based joint ventures, strategic alliances, and multi-partner R & D projects, and are an increasingly important feature in the generation of technology and therefore are a key MTI activity. Technological collaboration essentially involves shared commitment of resources and risk by a number of partners to agreed complementary aims. Vertical collaboration occurs throughout the chain of production for particular products, from the provision of raw materials, through the production and assembly of parts, components, and systems, to their distribution and servicing. Horizontal collaborations occur between partners at the same level in the production process. As we have seen in Chapter 3, vertical, user–supplier links play an important role in the innovation process. Horizontal partnerships also assist the innovation process, although firms may be comparatively more reticent to form such collaborations, as these may lead to disputes over ownership of their outcomes, such as IPR, or direct competition between collaborating firms.

Technological collaboration between firms can take a variety of forms. It may be a joint venture, formed by two or more partners as a separate company with shared equity investments. It could be a partnership linking firms on the basis of continuing commitment to shared technological objectives without equity-sharing, often known as ‘strategic alliances’. It may take the form of R & D contracts or technology-exchange agreements, whereby firms’ shared objectives involve the interchange of research findings or technological know-how. Increasingly, universities and public research laboratories are partners in such R & D contracts.

## Why do firms collaborate to develop technology?

There is a wide range of explanations as to why firms collaborate to develop technology. They include those discussed in Chapter 2, where we examined changing industrial structures and systems of production, and more particularly the role of technology and innovation in this change. There are also economic explanations (cost reduction) and the competitive relationships between firms (competitor exclusion or locking-in key players), while other explanations are less instrumental and focus on qualitative issues such as organizational learning, which is discussed later. Generally, however, from the perspective of the firm, technological collaboration is seen as a means of improving technological knowledge and skills.



Although technological collaboration occurs in many different forms, and may reflect different motives, a number of generalizable assumptions underpin it. The first is the belief that it can lead to positive sum gains in internal activities—that is, partners together can obtain mutual benefits that they could not achieve independently. Such benefits may include:

- *Increased scale and scope of activities.* The outcomes of technological collaboration may be applicable to all partners' markets, and thus may expand individual firms' customer bases (increased scale). Synergies between firms' different technological competencies may produce better, more widely applicable products (increased scope). Increasing the scale of resources to technology development can also raise entry barriers to other firms.
- *Shared costs and risk.* Technological collaboration can share the often very high costs, and therefore high risks, of technological development (although it also, of course, means future income streams are shared).
- *Improved ability to deal with complexity.* As we have already seen, closer technological integration between firms is a means of dealing with the complexity of multiple sources and forms of technology. It allows, for example, for the better transfer of tacit knowledge by providing a mechanism whereby close linkages among different organizations enable the development of sympathetic systems, procedures, and vocabulary. It may also allow partners to 'unbundle' discrete technological assets for transfer (Mowery 1988).

A second assumption regarding collaboration concerns the way it assists with environmental uncertainty (see Chapter 2). Increasingly sophisticated and demanding customers, growing competition in and globalization of markets, and rapidly changing and disruptive technologies place pressures on firms to exist with, and attempt to control, these uncertainties. This is believed to be achieved more easily in collaboration than in isolation. BAA's collaboration with Laing O'Rourke to develop Terminal 5 at Heathrow airport (discussed in Chapters 2 and 8), would have resulted in unacceptable levels of uncertainty had the client and main contractor not engaged in a novel, collaborative agreement. A number of analyses of collaboration link it with uncertainties in the generation and early diffusion of new technologies (Freeman 1991). The PLC model of Abernathy and Utterback (1978), discussed in Chapter 4, for example, implies a cyclical role for collaboration based on uncertainty. Thus, in early stages of development there are periods of high interaction between organizations, with many new entrant companies possessing technological advantages over incumbent firms, and extensive collaboration between firms until a 'dominant design' emerges in a technology. As the technology matures, uncertainty declines and collaborative activity recedes. The high level of collaborative activity seen in the creation of technical standards is a means

of reducing uncertainties by introducing interchangeable products and interfaces (discussed in Chapter 9).

A third set of assumptions underlying collaboration concerns its flexibility and efficiencies compared to the alternatives. For example, collaboration may be an alternative to FDI, mergers, and acquisitions, which are difficult to change once entered into. As a governance structure, collaboration has advantages over the alternatives of arm's-length market transactions and vertical integration. It can allow firms to keep a watching brief on external technological developments without having to invest heavily. Large-firm–small-firm interaction can be facilitated such that the resource advantages of the former are linked to the behavioural or creative advantages of the latter, while each maintains its independence. A large drug company, for example, may choose to collaborate with our biotechnology firm (Chapter 1) as a means of developing its options, so that it can invest more heavily once the technology is better proven and better understood. The large firm will have gained the opportunity to learn about the technology during the collaboration.

Potentially, there are numerous advantages from technological collaboration if these assumptions hold. That is not to deny the potentially adverse aspects of collaboration. Technological collaboration can be anticompetitive, by excluding certain firms, or raising entry barriers, or operating in the form of cartels that antitrust legislation prevented in the past. As discussed in relation to social capital, there may be strategic dangers from firms that become overly reliant on externally sourced rather than internally generated technology. Without internal technological competencies there can be no 'receptors' for external technology, nor capacity for building technological knowledge, which, apart from its other benefits, provides the basis for attracting future partners.

Examining whether the potentials of collaboration are in practice being realized is difficult, as data on its extent and outcomes are often piecemeal and frequently contradictory. The bulk of evidence suggests an increasing role for technological collaboration in industry, but the majority of studies of its outcomes point to the considerable difficulties in achieving mutually satisfactory outcomes amongst the partners.

## The extent of technological collaboration

Measuring the extent to which technological collaboration occurs is notoriously difficult. There are, however, numerous examples from around the world of increased collaborative activity. The encouragement of technological collaboration is a key policy focus of the European Commission, as seen in policies such as ESPRIT (a collaborative programme with an IT focus) and various Framework programmes (funded collaborative research in a range of industries)—in 2007 the European Commission was managing funding of Framework Programme 7. In the USA, SEMATECH provides

an example of government-sponsored technological collaboration, and, in Canada, the Industrial Research Assistance Program (IRAP) encourages collaboration between firms and universities. In the UK, the DTI provided funding of just under \$200 million for collaborative research between industry and research organizations in 2007. A wide range of technological collaborations also occurs in Japan, ranging from large-scale, high-technology schemes such as the FGCS Project to local support schemes in over 150 Regional Technology Centres. Taiwan's ITRI has played a central role in encouraging technological development and diffusion through collaborative projects. Large Korean firms are increasingly forming technological alliances with US, Japanese, and European firms (Sakakibara and Dodgson 2003; Dodgson, Mathews, and Kastle 2006).

Several databases on technological collaboration measure the numbers of new international alliances announced in the technical press. These tend to under-represent collaborations based outside non-English-speaking countries. The best of these databases, the MERIT-CATI database, showed an increase in the number of new collaborations, from 189 in 1981 to 339 in 1991, and 602 in 2001 (NSB 2004). The majority of these new collaborations occurred in new technologies, particularly in IT and biotechnology, and were based in the USA, Japan, and Europe.

The extent to which firms source technology externally, both vertically and horizontally, is affected by industrial structures. A commonly cited reason for the high levels of external integration in the Japanese industry, for example, is the structure of industry itself. The large business groups—the Keiretsu—control a wide range of diversified interests and can facilitate close trading relationships and cooperation and strong technological linkages between contractors and subcontractors.

The incidence of formal collaboration recorded in innovation surveys remains low, with only around 10 per cent of UK firms indicating they have formal collaborations for innovation. This partly results from many firms lacking the resources and absorptive capacity to work interactively with others (Tether 2002). Firms may also operate in sectors where issues of appropriability are so great that they mitigate the advantages of collaboration (Cassiman and Veugelers 2002). For those firms able to form formal collaborations, however, there can be significant performance benefits (Belderbos, Carree, and Lokshin 2004).

## **The challenges of managing technological collaboration**

It is difficult to consider what constitutes success in managing technological collaboration, since the range of firms' circumstances, their expectations, and their experiences

of collaboration are so varied. Some firms are content with satisfactory technological outcomes, others require bottom-line financial improvements as a result of their collaborative activity. In all cases, managing successful technological collaboration is a difficult task. This is because of changes over time during the course of collaborations and because of what can be called the ‘technology collaboration paradox’. Although the management challenges discussed here relate to formal technological collaborations, they can also apply in some circumstances to managing networks and communities more generally.

The changes that can occur during the course of a technological collaboration are similar to those that can affect all joint ventures and include:

- Changing aims of collaboration.
- Changing bargaining power of partners.
- Obsolescence of the original reasons for forming the collaboration.
- Initial focus on the wrong sets of issues.

The technological collaboration paradox derives from the way in which one of the greatest attractions of collaboration is the possibility of learning from partners. As discussed later, organizations learn more from dissimilar organizations, where technologies, cultures, management practices, and strategies are different and where the opportunities for learning are therefore greater. A small firm may be attracted to working with a large firm because of its high levels of resources and well-established operational procedures. Alternatively, the large firm may be attracted to working with the small firm because of its flexibility and entrepreneurialism. Private-sector firms may be attracted to working with universities or research laboratories because of their relatively unfettered, curiosity-driven research, while these laboratories may work with large firms because of their greater resources and commercial expertise. In all cases it is an attraction based on varied competencies, which are the result of very divergent organizations with different ways of working. Herein lies the paradox: the more attractive the partner in this sense, the greater the opportunities for miscommunication and misunderstanding because of the differences between the partners.

## PARTNER SELECTION

As a result of these potential problems, partner selection is the most critical decision affecting the success of technological collaboration. There are advantages in selecting partners for long-term relationships. As many of the motives for technological collaboration reflect attempts to deal with complexity and uncertainty in novel

and rapidly changing technologies, it is perhaps unsurprising that there are advantages in partnerships with long time horizons. In long-term relationships the problems inherent in the technological collaboration paradox may be overcome. There is greater opportunity for firms to exchange knowledge equitably. Managers and technologists in different companies can develop better working relationships, and knowledge is more easily and comprehensively transferred. If these advantages are to be obtained, selection of the partner should be made on the basis of the long-term attractiveness of the collaboration, as well as the intrinsic interest of the proposed project.

Partner selection should, therefore, be a strategic decision. In many successful collaborations, negotiations over partner selection are undertaken by top management, but this is not always the case. Success also seems more likely when partners provide complementary technologies. Complementarity in expertise is frequently cited as a reason for the technological success of the collaborations that enabled partners to learn novel skills (Dodgson 1993a).

Technological collaborations facilitate the transfer of knowledge. Once this knowledge has been transferred, the need for the partnership may be assumed to be finished. As technologies and markets are continually developing, however, the transferred knowledge may no longer be the most appropriate for changed market conditions. Individual firms continue in their efforts to develop their specialist skills through R & D. For this reason there are advantages in firms collaborating not only on the basis of existing technology, but also on the understanding that partners may continue to improve their technological competencies. These improvements are related to the comparative advantages of individual firms.

Technologies may be completely complementary, but firms may have totally incompatible business aims. Collaborators will generally not want to compete in the same markets using the product of their partnership. Potential markets need to be demarcated, either on a product basis or geographically. Innovation and corporate strategies need to be sympathetic and mutually supporting.

Managers and technologists may find it difficult to work with people in similar positions in other firms with lower levels of competency. Specialist vocabulary may not be common, understanding of latest research techniques or findings may not be shared. Unequal competencies result in delays and diversion of efforts as the weaker partner is brought up to speed. Unless there is an element of respect for the partner's technological abilities, transfer is unlikely to be wholehearted. International collaboration accentuates the need for greater respect for partner competencies. Furthermore, awareness of the commensurate abilities of partners may provide a stimulus to creativity. It may, for example, provide an element of competitiveness between research teams, that assists innovation—see Chapter 6.

## FLEXIBLE AND ADAPTABLE STRUCTURES

The process of technological collaboration is often described as tension ridden. In part these tensions derive from the way technologies and markets constantly change. Unless collaborations are dynamic, they may be aiming at a target that has moved. Throughout the course of a collaboration, opportunities may arise that were initially unforeseen, and outcomes from collaboration often may not be the ones originally envisaged (see Box 5.6). For these reasons, collaborations need to be adaptable in structure and purpose.

This case study of BT&D supports the view that collaboration should build longer-term capabilities as well as focus on particular products, given that the latter may fail in the market or have limited life cycles. As the focus of collaboration may change over time—for example, as the project progresses nearer to the market—the skills mix of managers, scientists, and engineers needs to adapt accordingly.

### Box 5.6 Collaborative tension between BT and DuPont

When DuPont created a new technology venture with BT, called BT&D, the synergies appeared obvious. DuPont wanted to diversify out of chemicals into electronics, and BT had some excellent electronics technology in its research laboratory that it wanted to commercialize. However, within a short period tensions arose.

- *Changing strategies of the partners.* Increased prices for chemicals helped DuPont refocus priorities back into its traditional industry. BT shifted its strategy away from being a technology supplier towards becoming a service company.
- *Inexperience of one partner.* DuPont had lengthy experience of joint venturing and working with small spin-offs. BT had very little and its expectations were too high as a result.
- *Reporting arrangements.* The spin-off company reported to a technical function in BT and a marketing function in DuPont, and this caused some confusion.
- *Top management structure.* It took some time to appoint an independent managing director for the joint venture, and until that time the representative of one partner company was viewed with suspicion by the other.
- *Cultural mismatch.* One partner was essentially a research laboratory, with little market awareness; the other was a marketing organization, with little appreciation of the demands of R & D.
- *Harmonization of human resources.* Staff on secondment to the joint venture from the partners had the salaries and conditions of the parent company. These differed and caused some tensions when it was discovered that people were being differentially rewarded for doing similar jobs.
- *Adjustment of the target market.* The original business aim of the joint venture was not realized. DuPont pragmatically accepted this and allowed the joint venture to develop a new business. BT had problems with this.
- *Changing expectations.* The joint venture became a very different company from that initially envisaged. DuPont accepted this, as it was commercially attractive. BT found the joint venture did not achieve what it wanted—that is, the commercialization of some of its technology. Originally the joint venture was owned 50–50. After a number of years DuPont bought a majority ownership. Eventually both founding partners sold their joint venture to Hewlett-Packard (HP) and it has now been merged into HP's massive spin-off, Agilent Technology.

## COMMUNICATIONS AND HUMAN-RESOURCE FACTORS

Good communications within and between partners are critical to the success of technological collaboration. Building into partnerships effective communications paths is often problematic, particularly for small firms linking with multinationals. Having established the appropriate reporting linkages, the next problem is using them effectively. Reporting unnecessary or poor-quality information may reduce the credibility of the whole system (and the collaboration). Without giving away all the knowledge and skill that made one partner attractive to the other, it is important to transfer information that is necessary to make the collaboration work. Sometimes one partner may feel that it is contributing more than the other. In such circumstances, a *quid pro quo* is needed. This may be achieved at later stages in the project, or in future projects. It may be achieved formally, through, for example, proportional allocation of IPR or equity. Or it may be done informally through the trading or exchange of information at the discretion of project managers (using the so-called favour bank).

Operating in periods when the flow of information is primarily one way requires a high level of trust in partners that the flow will in future be reversed. High-trust relationships within collaborations are often based on the assumption of continuity and reciprocity between partners. In-depth studies of technological collaboration place great emphasis on the personal factors that enable trust to develop and collaboration to succeed. Communications depend on individuals, and are enhanced by the ability of individuals to be trusted. Managers, scientists, and engineers are trusted by their equivalents in other firms to deliver what is expected of them, and on time. Counterparts are trusted to be honest, and not to impart false or misleading information. Trust is particularly important when there is imbalance in contributions to the collaboration. Partners may be trusted to rectify the imbalance in the future. As interpersonal trust between individuals in different organizations is likely to be affected by labour mobility or individual disagreements, successful technological collaboration often depends upon the extension of interpersonal trust to inter-organizational trust. This issue and broader considerations of trust are examined in greater detail later.

The management of human resources provides the critical factor determining the success of partners within technological collaborations. Human-resource management is an important aspect of collaboration in a number of respects. First, collaboration requires very good project managers. Such personnel need to be attracted into the partnerships, without, for example, jeopardizing career and pay prospects by working in what might be seen as a subsidiary activity. Second, given the importance of interpersonal communications in collaboration, the retention of key individuals—managers, scientists, and engineers—is crucial. Third, attention to human-resource issues can reduce the tensions



**Box 5.7 Making sure partners are well suited**

A story famously circulates in the IT circles about an initial meeting between a team from IBM and Apple. A collaborative project was decided upon at high level in these firms and the participating teams were asked to attend a get-to-know-you meeting at a hotel. The IBM team met beforehand and talked about the forthcoming meeting. They were sensitive to the cultural differences between the two companies: IBM staff at the time, for example, were notorious for wearing formal blue suits whilst Apple staff dressed very casually. The IBM team decided to make a concession and wear weekend clothes to the meeting. They arrived in sweatshirts, jeans, and sneakers; only to find the Apple team waiting for them in newly purchased blue suits.

This cultural mismatch occurred between firms in the same nation and industry. The opportunities for cultural misunderstandings in collaborative projects are much greater in cross-industry or multinational endeavours.

that sometimes occur in collaborations because of the lack of harmonization between the salaries and conditions of partners. As Box 5.7 shows, miscommunication can easily occur in collaborations.

## Organizational learning in networks and communities

There is a literature that places learning centrally in its analysis of networks, communities, and technological collaborations. For Kogut (1988), for example, joint ventures are ‘vehicles by which knowledge is transferred and by which firms learn from one another’. These approaches suggest that learning provides motive for and desired outcomes from networks. Learning is necessary to comprehend and respond to the changing industrial and technological systems described in Chapter 2. It is a key innovative capability described in Chapter 4. Networks also help with firms’ internal constraints to learning. An external orientation assists firms to overcome the organizational introspection described in the management and organization theory literature. Psychologists refer to the way people learn vicariously, by watching before they perform and profiting from the successes and failure of others (Bandura 1977). Firms similarly can use networks to learn in this way. External relationships can bring new knowledge into the firm of a specific, project-based nature. They can also enable firms to reconsider their existing ways of doing things—be it in R & D organization or the implementation of new technology. Networks provide an opportunity to observe novelty through the approaches of partners and can stimulate reconsideration of current practices. Learning vicariously can also help prevent the repetition of mistakes, and networks can provide opportunities for ‘higher-level’ learning (see the discussion in Chapter 4).

The primary ascribed motive for learning through inter-firm links is to deal with technological and market uncertainty. The outcomes of networks are reduced uncertainties



through improved predictability of technological development. Consideration of organizational learning also helps understanding of the dynamics of networks. Such considerations are important for a number of reasons. First, networks adapt and change as their rationales shift over time due to technological obsolescence or when members have nothing left to contribute. Second, actors learn at different speeds with marked consequences. Advantages accrue to those that can learn quickly. Thirdly, learning focuses on the process by which externally derived knowledge is diffused throughout the organization (e.g., from central to divisional R & D, from R & D to operations, and from individuals to groups), and hence provides benefits and returns to that learning.

An insight into the need for diversity in learning sources is provided by Di Maggio and Powell (1983), who refer to 'organizational fields' of organizations, which in aggregate constitute a recognized area of institutional life (suppliers, consumers, regulators, and so on that produce similar services or products). They argue that, 'once disparate organizations in the same line of business are structured into an actual field ... [by competition, the state, or the professions], powerful forces emerge that lead them to become more similar to one another' (Di Maggio and Powell 1983: 148).

This tendency towards 'isomorphism' has profound implications for learning. If firms in a network extensively share knowledge over a long period, they will increasingly come to resemble one another, with detrimental consequences for novelty and innovation. Similarity reduces opportunities to learn—variety increases opportunities to learn. Returning to the discussion on strong and weak ties, it would appear to be beneficial if firms were to seek heterogeneous sources of external learning, with perhaps long-term, intimate links to assist incremental improvements, and some short-term links with companies to assist radical, higher-level learning.

Learning is exchanged not only between the actors in a particular network, but also potentially between the broader networks of participating firms. One of the key requirements of successful collaboration is for participants to understand the nature, process, and likely outcomes of partnerships and to adjust the ways in which they behave to enable the team to deliver more than would have been possible had they worked on their own. Behaviours associated with team working and developing an appropriate set of values and cultures is an important prerequisite for success in collaboration. While learning from experience is likely to be the major form of instilling such knowledge, it is noteworthy that the approach taken by the Japanese government's Plaza Program eases firms into collaboration by a lengthy 'getting-to-know-you' procedure, before joint projects are established. The cautious approach to forming partnerships and the recognition of the need for a high level of trust between technological collaborators is a feature of the Japanese public-policy approach to forming technological linkages.

## Trust in networks and communities

The quality of relationship between actors has obvious implications for the outcomes of networking. A wide number of studies have shown how effective inter-firm links and learning between actors depend on high levels of trust (McEvily, Perrone, and Zaheer 2003). Lundvall (1988: 52), for example, argues that to overcome the inevitable uncertainties in jointly developed product innovations, ‘mutual trust and mutually respected codes of behaviour will normally be necessary’. Indeed, one of his criticisms of the developing Chinese national innovation system is the lack of trust between various parties (Lundvall 2006). Saxenian (1991: 430) contends that:

[A] network of long-term, trust-based alliances with innovative suppliers represents a source of advantage for a systems producer which is very difficult for a competitor to replicate. Such a network provides both flexibility and a framework for joint learning and technological exchange.

The firms in this network are argued to exchange sensitive information concerning business plans, sales forecasts, and costs, and have a mutual commitment to long-term relationships. This involves ‘relationships with suppliers as involving personal and moral commitments, which transcend the expectations of simple business relationships’ (Saxenian 1991: 428).

Trust in regional innovation systems has already been discussed. Freeman (1991: 503) argues that:

Personal relationships of trust and confidence (and sometimes of fear and obligation) are important both at the formal and informal level. . . . For this reason cultural factors such as language, educational background, regional loyalties, shared ideologies, and experiences and even common leisure interests continue to play an important role in networking.

There are a number of reasons why high trust facilitates effective networks. The first relates to the sort of knowledge being transferred within them. It may be tacit, uncodified, firm specific, and commercially sensitive. It is, therefore, not readily transferable, requiring dense, reliable, and continuing communication paths. Furthermore, it is often proprietary. What is being exchanged is the kind of knowledge and competence that is not easily replicated or purchased by competitors and thus can provide important elements of a firm’s competitiveness. Not only are partners expected to share trust in each other’s ability to provide valid and helpful responses to uncertainty, they are expected not to use this knowledge in ways that might prove disadvantageous to their partners.

A second reason relates to the timescale of successful networks. Trust facilitates continuing relationships between firms (Arrow 1975). Continuity is valuable because, as we have seen, the objective of inter-firm links may change over time. It is only within a long-term horizon that reciprocity in collaboration can occur. At any one time, one partner

in a collaboration will be a net gainer. The disincentive to cut and run is based on the view of future gains, which can only be achieved through continuity of collaboration. Trust mitigates opportunistic behaviour—as does fear of mistrust on the part of future new partners should a firm behave in such a manner.

Many networks are long lived. This enables effective communication paths to develop, and facilitate social and other links to be established. Macaulay's classic (1963) article arguing that contract law is often ignored in business transactions is revealing in this regard. He argues that trading partners' primary motives are to remain in business and that they will avoid doing anything that might interfere with this. This includes avoiding the legal system, but also being sensitive to the reactions of business partners and concerned about their business reputation. A priority for business, he argues, is the need for flexibility over the long term. He points to the way detailed negotiated contracts can get in the way of good exchange relationships.

Some businessmen object that in...carefully worked out relationship(s) one gets performance only to the letter of the contract. Such planning indicates a lack of trust and blunts the demands of friendship, turning a cooperative venture into an antagonistic horse trade. (Macaulay 1963: 64)

The advantages of cooperativeness and fairness in continuing reciprocal relationships are demonstrated by Axelrod (1984). In his analysis of the large variety of approaches to the 'prisoner's dilemma' game, he castigates the unsuccessful contestants ('expert strategists') from political science, sociology, economics, psychology, and mathematics for their 'systematic errors of being too competitive for their own good, not being forgiving enough, and being too pessimistic about the responsiveness of the other side' (Axelrod 1984: 40). Axelrod argues that his approach, based on the assumption of continuing interactions, has implications for the conduct of business relationships.

A third reason for the advantages of high trust in networks reflects the high management cost of such linkages (see the discussion earlier on technological collaboration). Selecting a suitable partner and building the dense communications paths through which tacit knowledge can be transferred has considerable management costs, both real and opportunity. These costs are increased when consideration of interpersonal trust is extended to inter-organizational trust. Trust between partner firms is commonly analysed by means of relationships between individuals. Given the problems of labour turnover and the possibilities of communications breakdowns on the part of particular managers, scientists, and technologists, to survive, trust relationships between firms have to be general as well as specific to individuals. They have to be ingrained in organizational routines, norms, and values. Inter-organizational trust is characterized by communities of interest, organizational cultures receptive to external inputs, and widespread and continually supplemented knowledge among employees of the status and purpose of the relationships (Dodgson 1993*b*). Such features are not costless, and,

once the effort has been made to build such strong relationships, jeopardizing them through a lack of trust is not a sensible option.

## Summary and conclusions

Firms belong to various kinds of networks and communities. Relationships with external parties can sometimes take the form of formal technological collaborations with limited numbers of partners. These external linkages have many benefits for innovation, helping firms deal with problems of complexity and uncertainty and providing an alternative form of governance structure to market transactions and vertical integration. They pose numerous challenges for MTI, including building social capital and establishing the right balance between strong and weak ties. Firms face the continual challenge of balancing and merging internal and external sources of knowledge. It is especially important to manage relationships with lead users of innovation. The ‘democratization’ of innovation described by von Hippel (2005) includes the means by which firms engage users in developing their own innovations.

Firms can experience great difficulty in managing their external linkages. Technological collaboration can have other negative connotations, including its potentially anticompetitive aspects. Furthermore, over-reliance on networks and their use as a substitute for in-house R & D and new products and service development is a flawed strategy. Such an approach reduces the capacity of a firm to receive knowledge from outside sources and to adapt externally derived technology to its particular needs, and restricts the development of innovative capabilities.

The greatest management challenge presented by communities and networks is selecting the appropriate ones to belong to and choosing particular partners. There are many advantages in choosing networks and partners with long-term orientations, which ensure complementary technological contributions. Because the process of collaboration is so difficult and prone to unexpected developments (both positive and negative), it is advantageous to use flexible and adaptable structures for management. Key elements of successful management include high levels of interpersonal and inter-organizational trust, and efforts to maximize the organizational learning that can occur.

# 6 The Management of Research and Development

## Introduction

R & D is a major source of rejuvenation and growth for companies, providing an important contribution to innovation and competitive advantage. Business invests heavily in R & D because expectations from it are so high. In 2004 the business sector spent over \$350 billion on R & D in the OECD nations, accounting for over 69 per cent of their total R & D expenditures (NSB 2006). Real levels of US R & D corporate expenditures increased by 67 per cent in the decade up to 2004. Companies in industries such as pharmaceuticals and IT commonly spend over 10 per cent of their annual sales on R & D, which may constitute a significant proportion of a company's activities. Almost 40 per cent of Nokia's and one-third of Samsung Electronics' employees, for example, work in R & D. The high levels of investment in R & D and anticipation of and pressure for its results are the major reasons why R & D is a significant issue for MTI.

This chapter examines the main issues in the management of R & D, including patterns of expenditure, organizational structures, management of R & D teams, balancing of R & D portfolios, its international management, and the evaluation and assessment of research.

## Why do firms do R & D?

Firms undertake R & D for a variety of reasons, including:

- Supporting existing business activities.
- Establishing new business developments.
- Facilitating related business diversification.
- Selling R & D services to other companies.
- Providing the skills to help 'reverse engineer' competitors' products and services (to see how they work and how they were made).
- Helping predict future technological trends.

- Complying with regulations and social and political expectations.
- Participating in research networks.
- Portraying a positive corporate image.
- Creating future options through new knowledge and technology.

As the Microsoft's research director explained when discussing why the company had created a central research laboratory, 'it never hurts to have smart people around' (Cusumano and Selby 1995).

The research productivity of private-sector R & D is clearly seen in the case of AT&T's 'Bell Labs'. Most of Bell Labs has been transferred to Alcatel-Lucent Technologies, and focuses on short-term research. At its peak, however, Bell Labs had 25,000 R & D employees. It was the birthplace of the transistor, laser, solarcell, light-emitting diode, digital switching, communications satellite, electrical digital computer, cellular mobile radio, long-distance TV transmission, sound motion pictures, and stereo recording. It received more than 26,000 patents, averaging one per day since its founding in 1925, and won six Nobel Prizes.

Firms commit resources to R & D in the expectation of future gains, but there are no hard and fast external benchmarks for managers to decide the level of R & D funding. There is no 'optimal' level. Expenditures by individual firms are often determined by the expenditures of their competitors. It is common for firms to seek to match or exceed the average level of R & D by sales in their sector. In recessions, however, R & D funds may be severely curtailed. In the early 1990s, for example, many European construction firms closed their R & D departments.

The nature of R & D is changing in many companies as shown in Box 6.1.

#### **Box 6.1 'Connect and Develop' at P&G**

Procter and Gamble (P&G) is one of the world's largest and most successful consumer businesses. It operates in almost every country in the world, with net sales of over \$40 billion and some 100,000 employees. Products include world-leading brands such as Pampers, Pringles, Ariel, and Tide.

P&G has a substantial R & D organization, with over 6,500 scientists. It has over 29,000 existing patents with several thousand added every year, making P&G one of the largest holders of US and global patents. Comparable companies in ownership of patents include Microsoft and Intel. On average, P&G spends around \$5 million on R & D and registers eight patents a day.

P&G possesses strong brands and is always looking for brand growth. However, it operates in an extremely competitive, mature, global market, hence the company is continually searching for new, innovative ideas. Throughout the late 1990s it experienced lower than expected sales growth and attributed this to shortcomings in its ability to produce new products to satisfy consumers' changing needs. No new major product on the scale of 'Tide' or 'Pampers' had been developed for over two decades. P&G recognized that to meet sales growth targets its innovation rate would need to increase significantly. P&G's management also realized that the cost of investments in R & D, technology and innovation were increasing faster than sales growth, and that this was unsustainable. But innovation remains the key to P&G's strategy. Chairman of the Board and President and Chief Executive A. G. Lafley stated that: 'Innovation is our lifeblood—new ideas and new products that make consumers' lives better, build customers' sales and profits, and build P&G's market share, sales, profits, and Total Shareholder Return.'

Among the problems identified within the company were that P&G did not always benefit from its existing knowledge and did not listen to, or learn enough from, the outside world: it operated within a closed innovation system.

In June 1999, P&G launched a new strategy to increase growth through innovation called *Organisation 2005*. One of the main aims of *Organisation 2005* was to stimulate innovation by making P&G's internally focused and fragmented communications more outwardly focused and cohesive (Schilling 2005). Gordon Brunner, Chief Technology Officer, and Head of Worldwide R & D at the time, said he wanted to create a culture that connected people and technologies in a more effective way. To emphasize this point Brunner said that R & D should become C & D—'Connect and Develop'.

The concept of C & D was fundamental to the new strategy (Sakkab 2002). P&G was founded on making successful innovative connections. P&G's history was rich with innovative new products resulting from connecting to what was not obvious. As P&G's Dr Mike Addison put it at a 'Connect and Develop Symposium' in February 2003, 'Innovation is all about making new connections. Most breakthrough innovation is about combining known knowledge in new ways or bringing an idea from one domain to another.'

The recognition that the vast majority of solutions to P&G's problems lay outside of P&G was a critical first step in the development of C & D. Larry Huston—vice-president of Knowledge and Innovation—describes how prior to its inception he discovered that P&G operated in around 150 areas of science. At that time, P&G employed more than 7,500 R & D staff, yet it was estimated that there were approximately 1.5 million researchers around the world working in these areas of science and technology at levels equal to or better than P&G's internal expertise. The challenge was to access this external resource, and to change the culture within P&G to encourage and facilitate searching outside of the company for innovations.

As a result of its C & D strategy, P&G aims to drive new innovation through collaboration with external partners in at least 50 per cent of cases. Larry Huston says that the company's goal of leveraging external assets for 50 per cent of its innovations is very ambitious, given that historically this figure was probably only around 20 per cent. A number of organizational initiatives have been introduced to assist the process (Huston and Sakkab 2006), and significant cultural changes are accompanying the move towards an open innovation strategy. P&G is now prepared to bring in ideas from outside sources, including using the entrepreneurial advantages of small firms, and allows individual researchers a freer hand in the development of products, in contrast to its past autarchic approach and high-level supervision culture for new product development.

It is too soon to tell whether these dramatic changes in P&G's approach to innovation will achieve the objective of new blockbuster products. What is clear is that the company has had more success in accessing external sources of technology. Huston said that in 2004 perhaps 35 per cent of innovations were accessed externally. These changes were occurring rapidly; he estimates the number of products in the market place that were linked to external sources increased from four to fifty in one year, and that the pipeline of products with such sourcing 'looks impressive'.

Source: Dodgson, Gann, and Salter (2006).

## Patterns of R & D expenditure

Figure 6.1 shows some of the major aspects of R & D. It should be emphasized that there are often overlaps and iterations, and few projects follow a strict linear model of development between the different domains. As activities move closer to experimental development, the opportunities to change configurations and specifications are narrowed, and generally costs increase.





also make significant investments. In 2004, US firms spent \$8.8 billion on basic research; just above 4 per cent of total industrial expenditures on R & D. Non-profit organizations are also large funders of basic research, accounting for \$4.7 billion in the USA in 2004. Over the past thirty years in the USA, government-supported basic research funding has increased dramatically rising from \$9 billion in 1974 to \$33 billion in 2004 (in constant dollars). Industrial support for basic research in the USA, however, has stagnated since the early 1990s (NSB 2006).

Applied research expenditures similarly account for between 5 and 25 per cent of total R & D expenditures. In Japan, applied research accounted for 23.4 per cent in 2001; in France in 1999 applied research accounted for 27.5 per cent of total R & D expenditures (OECD 2005). In contrast to basic research, applied research funding is dominated by industrial R & D performers, which accounted for almost 62 per cent of the total of \$61.3 billion spent on applied R & D in the USA in 2004 (NSB 2006).

At some stage the practicality of the ideas from research have to be demonstrated. It may be possible to produce a new substance in a laboratory test tube, but can it be made in larger, potentially commercial quantities? Once R & D has proven the feasibility and potential of a new product or service, later stages consist of 'pilot' operations that establish whether the product or service could be economically justified—that is, capable of being produced and delivered in adequate quantities and yields at acceptable prices. The development stage of R & D is the largest component of R & D. It accounted for most 60 per cent of total R & D expenditures in the USA in 2004, with most of these funds coming directly from industry (NSB 2006). Experimental development is the largest component of R & D in Japan, France, Germany, Italy, Australia, China, and South Korea. In the USA, this area of R & D has seen rapid growth, almost doubling from the early 1990s to the early 2000s (OECD 2005).

Patterns of R & D performance and expenditure differ across countries. For example, government and industry respectively are responsible for the highest shares of R & D expenditure in Canada and Japan. These differences are also reflected in distribution between military and civil R & D activities, and the relative shares of R & D conducted in the higher education sector and in private laboratories.

Most corporate R & D is concentrated in large firms (although, as we show later, there are problems in measuring R & D expenditure in small firms). Some large companies are huge spenders on R & D: DaimlerChrysler and Pfizer, for example, each invested over \$7 billion in R & D in 2005. Fewer than ten countries around the world spend more. The top-fifteen corporate R & D spenders in the world spent a total of over \$86 billion in 2005 on R & D, and in the USA, firms with over a thousand employees accounted for 77 per cent of total R & D in 2004 (DTI 2006; NSB 2006). R & D is also

concentrated in several key sectors, including transportation equipment, pharmaceuticals, computer and electronic products, and professional and technical services. These sectors account for almost 50 per cent of total industrial R & D expenditures in the USA (NSB 2006).

## Organizing R & D

Although the size of the R & D budget can be important, just as significant is the way that R & D is organized in the firm. Ericsson, for example, developed the digital switch ahead of its competitor ITT, despite having one-third of the R & D budget. What matters are questions such as: Is the firm doing the right R & D?—a strategic question examined in Chapter 4. How effective is the firm at turning R & D into successful products & services?—the question examined in Chapter 7. And, is R & D organized effectively?—to which we now turn.

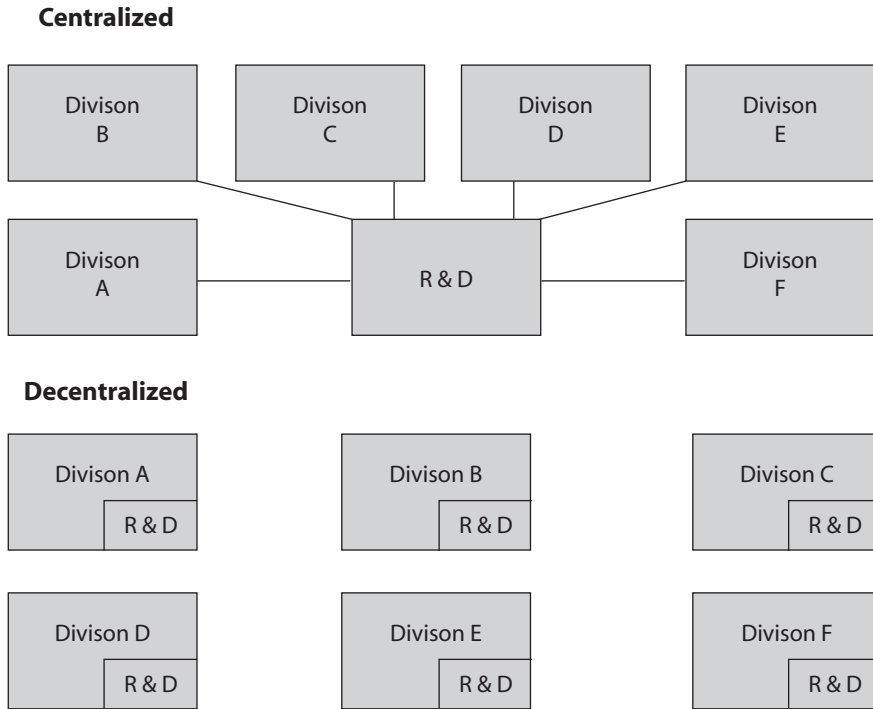
Whereas R & D structures in smaller firms are usually straightforward (one site where all R & D is undertaken), larger firms have choices. Firms can structure their research organizations in a number of ways.

## CENTRALIZED AND DECENTRALIZED R & D

Firms can have one or more central laboratories, or they can have one or more divisional laboratories reporting to business operations, or they can operate with both these forms of organization. One of the key structural questions for large, multidivisional companies in their research activities is the extent to which they are centralized or decentralized. Figure 6.2 shows the two extreme types of structure: completely centralized and completely decentralized. A number of issues affect companies' decisions about the extent to which R & D is centralized or decentralized.

### Type of activity undertaken

When the research is more basic and likely to have longer-term implications for the firm, there are advantages in having strong links with corporate headquarters, where longer-term strategic business decisions are made and where speculative research can be 'protected' from the immediate demands of business divisions. When the research is applied, or experimental development is being performed, there are advantages in decentralized links with divisions, which are closer to the customer and can respond better to their requirements. Once general principles are established, detailed development and design



**Figure 6.2.** Centralized and decentralized R & D organizational structures

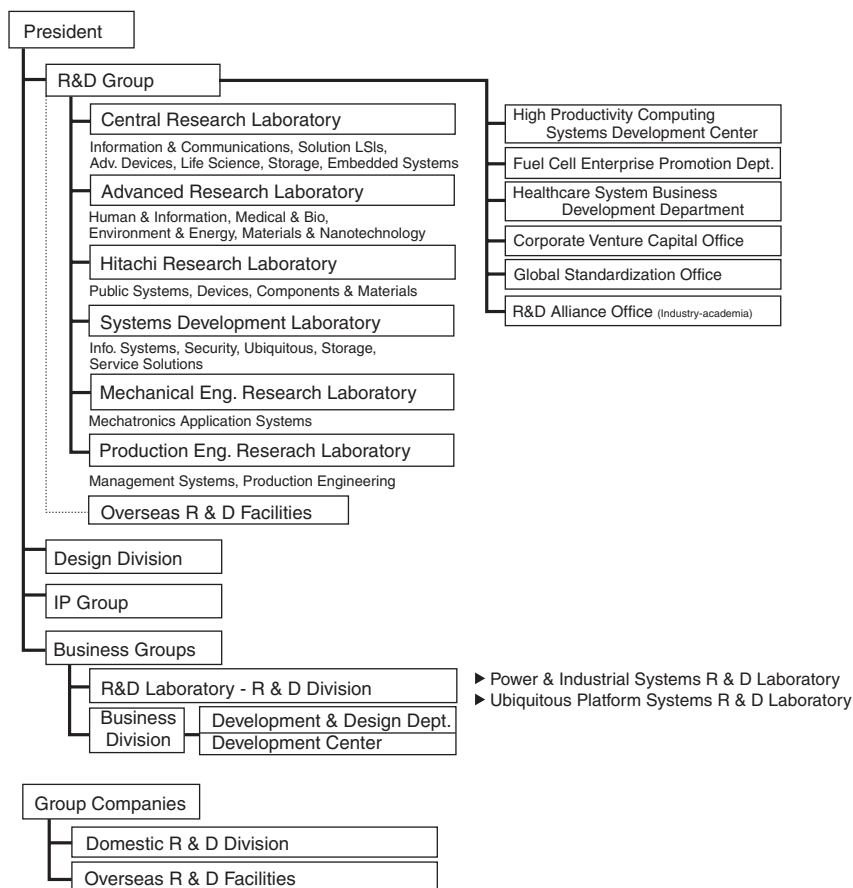
activities are often best linked to particular factories or delivery centres. The location of basic research in many countries tends to be determined by issues such as good living environments, transportation, and the general availability of scientists and engineers.

### Scale of research

Centralization of research is attractive when there is the need to achieve economies of scale—for example, when it is necessary to create a ‘critical mass’ of researchers for a particular project, or to utilize expensive research equipment. The cost of equipment in some areas of basic research is prohibitively high, such that only if nations club together can new facilities be developed. For example, the Large Hadron Collider, under construction at CERN, Geneva, is expected to come into operation in 2008. It is being built with the collaboration of 2,000 physicists and funded by a consortium of thirty-four countries. When communication between research groups is important, there are advantages in co-location in central R & D (see Box 6.4).

### Need for functional integration

When it is important to have strong links with other functions, particularly with operations and marketing, then decentralization of R & D has advantages.



**Figure 6.3.** Hitachi's R & D organization in 2007

## Recruitment, labour, and other cost considerations

Decisions about R & D structures can be influenced by locational and managerial efficiency questions. So, for example, certain regions may be famous for their researchers in a particular field, or be closely located to important customers, and this may affect companies' decisions about locating research (Silicon Valley would be a classic example; see Box 2.3). Specific considerations of the needs of key individuals, such as the ability to access the expertise of particular scientists, or effectively to utilize the limited availability of highly skilled research managers, may also affect R & D location decisions.

Figure 6.3 shows the R & D organizational structure of Hitachi, the world's third-largest electronics company, which has one of the most centralized R & D structures. In 2005–6 Hitachi spent around \$3.5 billion on R & D, accounting for 4.3 per cent of

sales. It had R & D laboratories located centrally and within the group's various business divisions. The central laboratories historically spend around a quarter of Hitachi's total research budget, of which 8 per cent goes on basic research and 16 per cent on applied research. It had 11,900 R & D staff in 2006, of which 9,000 were working on product development in various divisions and factories. The remaining 2,800 were working in the corporate research laboratories, including the Central Research Laboratory (which had over 1,000 employees mainly researching electronics) and the Advanced Research Laboratory (110 staff working on fundamental science). According to Sigurdson (1999), commissioned research in the corporate research laboratories—coming from business divisions, subsidiary companies, or contacts from other laboratories—constitute 70 per cent of the R & D activities. Commissioned research in the Central Research Laboratory is 55 per cent and nil in the Hitachi Advanced Research Laboratory where researchers only do fundamental science.

Sigurdson also argues that Hitachi may be following the pattern of other major companies, such as Siemens and General Electric (GE), by steadily decentralizing its R & D, and that this pattern may be occurring in other Japanese firms. Toshiba, for example, began the transfer of R & D to its business divisions some years ago. In part this reflects the financial problems faced by many Japanese firms in the late 1990s, but also the pressing need to transfer research as soon as possible to businesses—a problem discussed in the Japanese case study in Chapter 1.

Despite the trend towards decentralized R & D, centralized R & D can be very important. In the case of GE, its central R & D centre employs only about 10 per cent of GE scientists and engineers, but generates about 30 per cent of the company's patents and produces one-third of its technical publications.

A common difficulty facing R & D and Innovation Directors is justifying the funding for centralized R & D. Explaining some of the reasons for R & D described earlier, such as social and political expectations and future values and options, usually holds little persuasion for divisional business managers concerned about their next quarter's results. Possible types of funding arrangements include the use of a fixed rate: for example, all divisions contribute an agreed percentage of sales to central R & D. Another mechanism uses competitive systems, whereby headquarters identifies a number of research projects, and central and decentralized laboratories compete to win the projects. Other methods use a simple contract system, whereby the central laboratory undertakes research for the divisions or headquarters on a contract-by-contract or commission basis. Another approach is to levy divisions (if they are especially profitable one year, for example) to pay for particular projects. In practice, combinations of these funding mechanisms are used. Hitachi, for example, funds its central laboratories through direct grant and commissioned projects from the business divisions (an exception is its Advanced Research Laboratory, which as we have seen does no commissioned work). Siemens uses a 'market-based' model of funding with individual R & D units competing with each

other in an internal market. The R & D units offer R & D projects to the business units, which can decide whether or not to fund the projects. Business units may also propose R & D projects, setting a price and goals. Different R & D units then compete against one another to win the 'contract'.

GE links its Research Centre with its businesses in a number of ways. Half the Centre's budget is contracted by the GE businesses on a customer–contractor principle. The Research Centre has technology transfer specialists who work with each GE Division to ensure that research is being effectively transferred. The other half of the budget is devoted to research related to GE's business activities, but with no specific goals. GE Business CEOs visit the Research Centre every quarter to be appraised of the opportunities arising from its research.

Both centralized and decentralized R & D have advantages and disadvantages, and the funding of both is often unaffordable for all but the wealthiest corporations, such as Hitachi. R & D organizational structures may vary over time. In his study of the structure of R & D in industry, Rubinstein (1989) found that companies historically tended to undergo phases of centralization, then decentralization, then centralization, in their research, and exhibited a high degree of dissatisfaction with their organization of R & D whichever form it took.

Some companies, such as Alcatel-Lucent and 3M, co-locate their divisional and central laboratories to gain the benefits of both forms. Ultimately, the R & D organization has to reflect the strategy pursued by the company.

## DISTRIBUTED NETWORKS FOR R & D

Often the critical issue for R & D organization is how well it is integrated—internally and with external sources of R & D. Intel, for example, is a major R & D player. It spends over \$4 billion annually on R & D, but it has never had a stand-alone R & D laboratory. Two factors help underpin Intel's success. The first lies in the ways it co-locates R & D and production. In the semiconductor business R & D and new process development are simultaneous and are undertaken in actual manufacturing conditions. The second lies in the way it accesses a massive virtual laboratory of researchers in universities and the Silicon Valley technology community through long-term relationships and commitments (Best 2001).

The shift towards the use of an 'integrated network' of R & D units is seen particularly clearly in the case of large pharmaceutical firms, using a 'meta-national' notion of the multinational (Bartlett and Ghoshal 2002). The idea is that each unit contributes to the creation of new technological assets that build on knowledge from particular scientific fields and are located in places with unique competencies. The experiences of GSK in the early 2000s are illustrative of this new approach to R & D management (see Box 6.2).

**Box 6.2 Integrated R & D in GSK**

GSK is one of the world's largest pharmaceutical firms and it spent around \$6 billion on R & D in 2005. It employs over 15,000 in R & D around the world. The firm was formed by the merger of Glaxo Wellcome and Smith Kline Beecham in 2001. Drug discovery is a global activity in GSK, centred on ten Centres of Excellence of Drug Discovery (CEDD) in the UK, USA, Italy, and Croatia. GSK conducts R & D in over twenty-two different locations around the world. The CEDDs include:

- Cardiovascular and Urogenital (e.g., diseases of the heart, circulation, and urinary system).
- Metabolic (e.g., diabetes, obesity, diseases of aging).
- Oncology (cancer).
- Neurology and Gastrointestinal (e.g., epilepsy, migraine, stroke, irritable bowel syndrome).
- Psychiatric (e.g., depression, schizophrenia, anxiety).
- Respiratory (e.g., asthma, chronic obstructive pulmonary disease, allergic rhinitis),
- Infectious Diseases (e.g., HIV, tuberculosis).
- Immune Inflammation (e.g., rheumatoid arthritis, psoriasis, type 1 diabetes).
- Biopharmaceuticals (specializing in the exploitation of biopharmaceutical technologies to discover new medicines).
- Macrolides (application of expertise in macrolide chemistry for infectious disease and other indications).

The stages of product development in pharmaceutical research are highly linear, but involve considerable expense and risk: a very complicated process in the terminology of Chapter 3. At GSK, an initial stage in the process involves *Molecular Discovery Research*—finding early-stage lead compounds to serve as the starting point for further development into medicines. Molecular Discovery Research synthesises those with the greatest potential and validates results through numerous assays and tests. As a lead series matures, it moves into the next stage for further development and testing. The second stage is *Drug Discovery*, which is managed by the CEDDs. The CEDDs focus on studying mechanisms of disease targeted for treatment, elucidating functional effects of the most promising compounds, and developing leads into drug candidates. CEDDs play a key role in integrated knowledge across the stage of drug development in GSK. The CEDDs are in continuous contact with the research teams which initially identify promising compounds and as well as the downstream development teams which conduct clinical trials (Criscuolo and Narula 2007).

In 2006, GSK developed a new Centre of Excellence for External Drug Discovery. This group works in alliances with external partners who may possess their own promising compounds. It is charged with delivering clinical proof of concept molecules into the GSK late-stage development organization at a rate consistent with the internal drug discovery centres but from a portfolio derived from and managed by external companies, in essence 'virtualizing' a portion of the drug discovery pipeline. Moreover, it is responsible for accessing innovative approaches to Drug Discovery. This approach allows GSK to combine its internal skills with promising drugs from external sources, bringing technology from outside the firm into its internal product development processes.

As advanced lead compounds are developed, they are sent to preclinical trials (tests in animals). After this stage, the compound is handed over to pharmaceutical development, which is then responsible for the design of the pharmaceutical dosage form, such as an injectable, inhalation, or oral formulation, and the safety, efficacy, and ease of use of the medicine. It also manufactures, packages, and supplies products to clinical trials (tests in humans). It determines and plans the manufacturing processes needed to ensure that GSK could supply the medicine to patients once regulatory approval is granted. Products are then passed on worldwide and commercial development units, which assess markets and prepare the product for delivery to customers.

The GSK integrated-network model of R & D has several benefits. It encourages CEDDs to compete against one another for resources, assessing their performance. Each CEDD acts as a largely independent unit, creating its own alliances. This encourages decentralized decision-making and local flexibility. The movement toward the decentralized model, however, raises several problems for cross-firm exchanges. There can be relatively little exchange across CEDDs. As one manager explained:

The CEDDs are almost like separate companies, they have their own budget, their own ways of working. One of the dangers of the CEDDs is that they might end up not sharing best practices. The CEDDs have various levels of communication, but it is pretty poor, because they have been set up almost like small companies. They are almost in competition, they are evaluated based on the value that the particular CEDD delivers to the business. In addition people do not move between CEDDs because they have expertises in a specific therapeutic area. (Criscuolo and Narula 2007: 16)

To overcome these barriers to exchange across different CEDDs, GSK uses a variety of approaches to promote collaboration and integration. These include:

- Cross-disciplinary project proposal review boards.
- Joint CEDD task forces focused around the development of tools and knowledge that can be used across many GSK research projects.
- Temporary and long-term assignments of staff within different CEDDs (Criscuolo and Narula 2007).

There are enormous challenges in coordinating R & D between the different levels in a firm (especially when it is conducted internationally, as will be shown later). Many companies, such as Dow Chemicals, create high-level R & D Councils to coordinate R & D and look for synergies across the company. Dow employs 5,600 in, and spends over \$1 billion annually on, R & D. Its business-level R & D is aligned with one of Dow's global businesses: Performance Plastics, Performance Chemicals, Agricultural Sciences, Basic Plastics, Basic Chemicals, and Hydrocarbons and Energy. Around three-quarters of Dow's R & D staff work at the business level. Its corporate-level R & D, which accounts for the remaining quarter of R & D staff, focuses on broad technical capabilities developed on behalf of the whole firm. Across the company about two-thirds of the R & D is directed towards exploring the unknown, seeking new value opportunities, and one-third to improving the known, preserving value. The R & D Council's innovation strategy aims to identify new emerging activities and priorities and geographic and technological drivers to assist in the delivery of growth for the company. Its role is broad and includes: seeking synergies between R & D investments at business and corporate levels; developing plans for R & D in emerging economies (Dow is making large R & D investments in China and India); developing a collaboration strategy for external R & D partnerships and alliances; and identifying Dow's next technology platform following biotechnology. The Council is responsible for R & D resources and activities common across Dow: people, technologies and applications, work processes, and services.

## Managing research teams

Research management has to be sensitive to the aims and needs of different kinds of R & D activities. Firms have different control structures for various kinds of research.



The classic study of innovation management in the 1960s showed how firms were organized in 'organic' or 'mechanistic' forms according to their aims (Burns and Stalker 1961). *Organic forms* are associated with the encouragement of flexibility and initiative and the avoidance of prescriptive communications channels and authority. They have a community structure of control and devolved technical authority. *Mechanistic forms* are associated with hierarchical control, authority, and communications, demand for obedience, and very precise definitions of methods. These are two ideal types of organization, but subsequent research has shown the advantages for innovation of organic forms where there is a high degree of technological complexity. Organization also reflects the need, when projects are more easily predictable, specified, and controllable, to move from 'loose' to 'tight' management control. The management of R & D is a prime case of the need for organic organization, although it is conceivable that more mechanistic approaches can be used closer to the engineering and design activities within the experimental development domain, in the unlikely event of the firm seeing little value in encouraging creativity in these areas.

There is a substantial literature on the management of research teams and projects. The research on teams is often large scale, involving many hundreds, if not thousands, of respondents. It provides fascinating insights into a number of areas. For example, the productivity of research teams declines after about five years, as team members begin to restrict their external networks, and research productivity declines for researchers in their early to mid-30s and then intriguingly increases again in their 60s (Katz and Allen 1982; Farris, DiTomaso, and Cordero 1995). Other research shows that there are research 'stars' whose research output increases with age (Goldberg and Shenhav 1984; and see the discussion later on research stars).

Within research teams, individuals have different approaches towards communicating technological information. Scientists in the team usually rely on primary literature (journals), are outward looking, unconstrained by the firm, and relate to other scientists as peers. Technologists and engineers, on the other hand, tend to rely on secondary literature (trade and professional magazines), are inward looking, are concerned only with problems within the firm, and relate to colleagues within the firm as their peers (Allen 1977; Vanaelst et al. 2006). Effective research-team management enables both types of researchers to operate to the advantage of the firm.

There is a wide range of 'stage-gate' project management systems used to filter and evaluate research activities in a rational and impartial manner (see Chapter 7). The use of these techniques, importantly, is also seen to be fair by those affected by the decisions that these systems help management reach. Table 6.1 shows a management system based on the roles of key individuals during the course of a project's development. As projects develop, evaluation techniques are used at the various stages before allowing progression to the next level.

**Table 6.1.** Project management system based on the roles of key individuals

Stage	Person responsible for each stage
Idea	(Self Appointed) idea champion*
Candidate	Candidate champion*
Research project	Research project manager
Development project	Development project manager
Product	Product manager

\* Part-time responsibilities

Developments in groupware during the 1990s, such as that mandated for large-scale project management in the US Department of Defense, can help open up the research process by making inputs into problem-solving exercises anonymously so that ideas are evaluated according to their usefulness rather than their source (which can be helpful in hierarchical organizations).

Companies use a variety of tools and techniques to assist their research management. Box 6.3 describes one such technique.

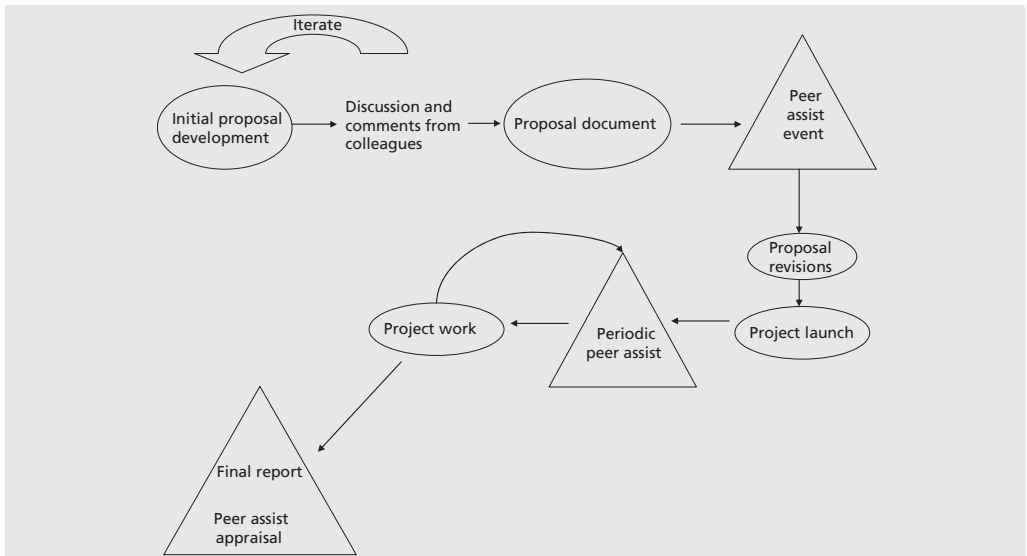
### Box 6.3 Peer Assist

Peer Assist was developed by British Petroleum (BP) in the 1980s to help define and review new research and exploration projects and to monitor progress once they had been launched. It was designed to provide constructive, critical advice on the development, direction, focus, and outcomes of a project. The method differs from the widely used 'peer review' process in academic and research communities, which provides yes/no results and little direct feedback on project proposals. In the traditional approach, the ideas developed in review processes are discussed in written documentation rather than dialogue. The richness of reviewers' ideas is often only partially communicated to project proposal teams and opportunities for learning are lost as reviewers have little opportunity to engage directly. By contrast, the 'Peer Assist' technique encourages and engenders dialogue between a team of expert peers and the project team members. BP describes one use of peer assist as facilitating 'learning before doing', allowing ideas to be clarified and honed before a project is given the 'go ahead' (Collison and Parcell 2001).

Peer Assist can be used in defining and developing ideas for R & D projects. It can help ensure there is balance within an overall portfolio of projects and alignment with the organization's strategy. The technique is used before, during, and after a project. In the initial stage of project definition, Peer Assist can provide ideas on the direction, orientation, size, shape, resourcing, and likely outcomes of a project.

The timing of the first Peer Assist workshop is important. It is inadvisable to hold the workshop too early when the project idea is ill-formed and the Peer Assist team does not have enough structured information to debate. If the process is held too long after the project has started, however, it may be too late to absorb useful suggestions from the Peer Assist process. A Peer Assist workshop can be called if a project experiences an unexpected problem and the team requires decisions about which way to move forward.

Peer Assist entails a number of steps (see Fig. 6.4). In the first instance a project leader or team member suggests a proposal for a Peer Assist workshop. This involves *clarifying purpose* to define the specific problem or question to be addressed and *developing a project plan* with aims, objectives, intended resource requirements, and planned outcomes. Proposal teams explore existing knowledge and identify other teams that may be tackling similar problems and issues, demonstrating where their approaches differ.



**Figure 6.4.** Peer assist process

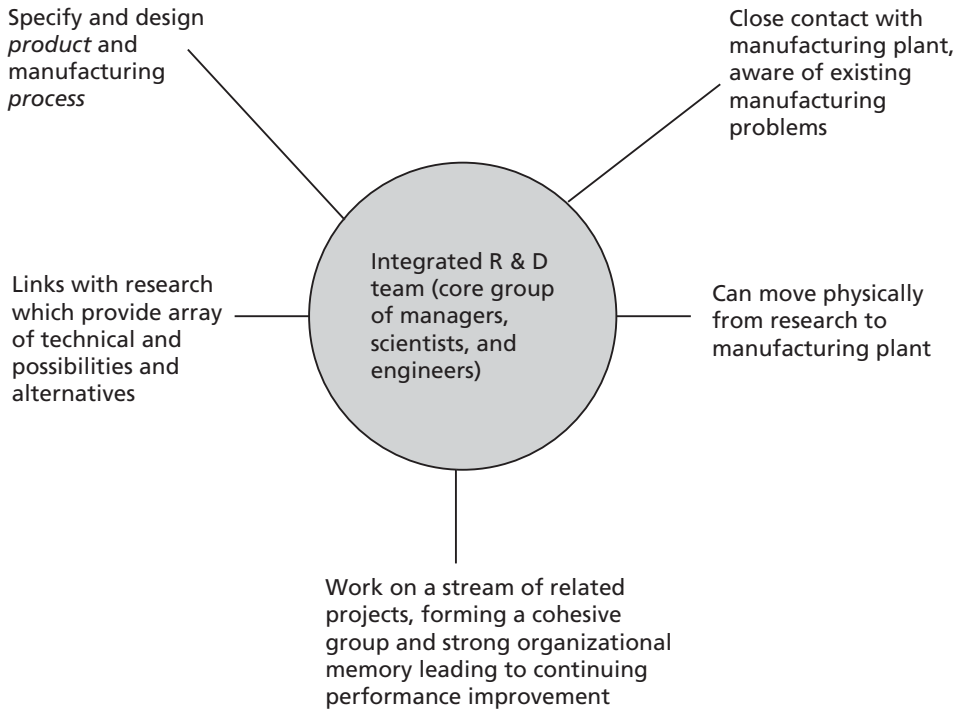
It is important to select an appropriate team of experts for the Peer Assist team. Normally between six and eight people are chosen from a cross-section of disciplines of relevance to the project. Members should be selected for their willingness to engage in developing ideas in an open manner and the team should be non-hierarchical in its approach. If the project has direct applications orientation it can be important to include members from the user community. Peer Assist processes vary in length depending upon the complexity of the problem, with most workshops occupying from four or five hours to two days.

A facilitator from outside the project team is used to guide the workshop, setting the ground rules, and focusing participants on achieving a set of desired outcomes; clarity of what is expected from the process is important. Participants should be provided, in advance of the workshop, with briefing materials on the project's context, method, and resources. Project members should be prepared to provide further evidence and to listen to questions and comments during the process.

The main purpose of Peer Assist is to encourage and facilitate learning to generate and hone ideas. Templates for capturing feedback during the process are devised by the project team or the facilitator. Outcomes are usually logged as written reports. In some situations this log can be used as part of an auditable process to show how decisions are taken for programme management purposes.

Peer Assist works well when the project team has developed a clear proposal, which enables them to be assisted by respected peers in an environment that supports the development of ideas and learning. Lessons can be applied immediately. The type of benefits from this process include: lessons about how others might approach a problem or research question, ideas and possible solutions developed through a collective process, and insights from a wider pool of knowledgeable experts. The process can also help to support a strong team ethos and knowledge-sharing in which junior members can be encouraged to present their ideas in a supportive, yet critical environment. Sometimes projects are halted after a mid-term Peer Assist review, because the team decides that there is little benefit in continuation.

Integrated, interdisciplinary, or cross-functional teams involving representatives of a wide range of functions within the firm, bring benefits for innovation. A study of a group of mainframe computer companies (AT&T, Bull, Fujitsu, Hitachi, IBM, ICL, Mitsubishi Electric, NEC, Toshiba, and Unisys) in the early 1990s, showed the value of creating



**Figure 6.5.** Integrated R & D teams

Source: Iansiti 1993.

integrated R & D teams with a 'systems focus' (Iansiti 1993). It was found that systems-focused companies achieve the best product in the shortest time and at the lowest cost. The integrated R & D team included a core group of managers representing both the research function and existing manufacturing capabilities. Figure 6.5 shows some of the characteristics of integrated R & D teams.

A similar approach proved effective for US car manufacturer Chrysler in the 1990s. According to Lester (1998: 75), Chrysler created five autonomous 'platform teams', each devoted to a different product line (small cars, large cars, minivans, Jeeps, and trucks).

Each team consisted of all the people needed to design and produce a new car, including manufacturing, purchasing, finance, and marketing professionals, hourly manufacturing workers, and even representatives of key outside suppliers, as well as engineering and design staff.

Hardly any bureaucracy was allowed to remain above the platform teams. Each team was presided over by a top executive, giving it a voice at the highest levels of the corporation. The teams received precise instructions from the top regarding key vehicle specifications—engine power, weight, fuel economy, and so on—as well as total budgets for the projects. Once these specifications were met, however, the teams were free to

work out how to meet them, with little or no interference from senior management. In return for this increased responsibility and authority, the platform teams were also held accountable for their performance. And since the members of the team were judged by the overall success of the vehicle, rather than their particular bit of it, they were inclined to find ways to cooperate with each other.

The use of platform teams was one of the major reasons, according to Lester, for the regeneration of Chrysler in the 1990s, before the merger with Daimler-Benz to form DaimlerChrysler in 1998, and Chrysler's subsequent difficulties.

In Gann and Salter's (1998) study of project-based organizations around the development of CoPS, it was found that 'integrative competences' were becoming increasingly important. Rapid team-building skills were described by project-based firms as core capabilities for personnel at all levels.

People need to be able to form teams quickly to tackle new projects or respond to events in existing projects. Professionals, managers, and shop-floor operatives need to be able to respond to unforeseen events and deploy a high level of problem-solving expertise. (Gann and Salter 1998: 443)

#### **Box 6.4 Media richness and the transfer of knowledge**

Transferring experience and ideas from one person or team to another is one of the most difficult tasks in organizations. Knowledge is often 'sticky' to individuals and teams, locked in jargon, informal codes, and personal or collective experiences and relationships (Teece 1977; Szulanski 1996; Brown and Duguid 2000). It is hard for someone to codify or express all they know; their knowledge may be based on highly personal experience and understanding of a situation. It may also require recipients to make a considerable effort to learn before the information provided by one individual can be absorbed by another (Cohen and Levinthal 1990; von Hippel 1994).

Considerable attention in management studies has been devoted to trying to understand how organizations can promote knowledge-sharing between individuals and teams and much of this attention has focused on the use of different media. In a classic study in the early 1970s, Allen (1977) showed that communication between scientists and engineers was strongly influenced by geography. This study found that 25-metres distance between two people within an office was enough to ensure that they did not speak to one another. In response, BMW designed its new corporate R & D laboratory to ensure that engineers working on related topics were located within 25 metres of each other. Other research shows that people tend to share knowledge with people who are physically close or whom they know intimately (Cross et al. 2002; Argote, McEvily, and Reagans 2003). One reason for this pattern is that we are all social creatures, responding to personal aspects of face-to-face communication. Our choices about whom to communicate with and how are products of our experience, attitude, and nature of the information we wish to exchange. Since the 1980s, considerable attention in communication research has focused on why people choose to use different media and how these choices shape the effectiveness of their exchanges (Daft and Lengel 1986; Fulk 1993; Monge and Contractor 2003). This work argued that different types of media were imbued with different degrees of richness. The richest media was face-to-face communication, followed by telephone conversations, and then written memos. Richer media offer the opportunity for the individual to make personal connections, use multiple cues, gain immediate feedback, and use variety and nuance in their expression. Rich media were seen to be especially well suited for exchanges where there was a degree of *equivocality*, that is, multiple understandings of a situation, and *uncertainty*, that is,

where critical or stable information was absent (Dennis and Kinney 1998). In contrast, media with little richness were largely an information repository, in which individuals have little emotional commitment. This theory posited that successful transmission of complex, uncertain information required face-to-face communication.

Of course, face-to-face communication can be expensive to organize, often requiring travel. Some firms, such as Sun Microsystems in the early 2000s, have sought to reduce the costs of business travel and instituted travel bans. Travel in Sun Microsystems had to be approved in writing by a vice-president of the company. The effect of the travel ban was considerable; staff had to find new ways of working with distant colleagues. It was common in Sun Microsystems during this period for staff working on a project to have never met their colleagues or even their boss in person. The policy encouraged staff to utilize the new ICTs, but it also limited the effectiveness of project teams, forcing them to conduct long telephone conference calls to keep track of developments.

With the new ICTs, such as video conferencing and electronic message boards, it is easier to communicate with people separated by distance. Evidence shows, however, that it is necessary for people to build up trust through face-to-face meetings before they can successfully use technology to work together (Orlikowski 2002; Monge and Contractor 2003; Sapsed and Salter 2004). Project teams often need to meet face-to-face early in the life of the project to get know each other. Face-to-face meetings are important for developing new ideas, gaining agreement, making commitments, and developing plans. Once a team has been able to gain understanding of work tasks, it is possible for them to work independently, communicating only through less rich forms of media, such as telephone and e-mail. It may also be necessary to have face-to-face communication late in the project as the team attempts to win support for the project outputs among different communities. This stage of a project often involves convincing potential customers or users of the benefits of using a new technology, service or product. Such efforts usually require the 'personal touch' (Sapsed and Salter 2004).

The media richness perspective on communication suggests that managers need to think about the nature of the exchange required in a project before committing themselves to a particular management approach. If a project is relatively routine, involving exchanges between staff who know each other well, there may be little reason to meet face-to-face or co-locate the project team. If a project involves development of a new product or service, however, where there is a degree of novelty, and groups of people with no prior experience of working together, face-to-face meetings may be essential in the initial stages. Investments in face-to-face meetings can help the team build understanding that they can draw on to enable them to ultimately work independently. Thus, managers need to think through the nature of a project and use a communication strategy that best fits the nature of the task and character of the team, perhaps involving a mix of ICTs and face-to-face meetings.

## Managing creativity in research

Researchers argue that everyone is capable of being creative. According to Margaret Boden (2003: 245) in *The Creative Mind* 'Creativity draws crucially on our ordinary abilities. Noticing, remembering, seeing, speaking, hearing, understanding language, and recognizing analogies: all these talents of Everyman are important.' And creativity can be 'based in ordinary abilities that we all share, and in practiced expertise to which we can all aspire' (2003: 256). It is the challenge of MTI to encourage and direct that creativity.

Managing research to encourage creativity involves resolving what has been called 'the dialectical process of synthesis between multiple dilemmas (e.g., freedom and control, flexibility and focus, differentiation and integration, incrementalism and discontinuity)' (Judge, Fryxell, and Dooley 1997). In their study of eight US biotechnology firms, Judge and colleagues found that highly innovative firms managed these dilemmas and created 'focused communities', whose innovativeness was encouraged by features such as family atmosphere, trust, caring, contemplation, and self-examination.

Some companies invest remarkable effort into encouraging creativity in research. During the late 1980s the small UK biotechnology company, Celltech, had a scientific advisory group of international eminence for assessing scientific performance and providing external 'peer review' at the highest level. The company held over fifty internal and external scientific seminars a year, the equivalent of many leading university departments.

In many creative firms, the researchers themselves have high levels of discretion over the selection and conduct of research projects. Dow Chemical's chemists, in their central R & D organization, have responsibility for planning, implementing, and evaluating their own work on projects. Celltech allowed researchers to spend 10 per cent of their time on personal research agendas (see Box 6.5). This mode of organizing creativity is not the preserve of smaller, high-technology companies. Nippon Steel, the largest steel manufacturer in the world, also allows its 1,200 R & D staff to spend 10 per cent of their time on projects of their own initiative. Celltech's buildings were designed to maximize the amount of communication between researchers, with number of large, open meeting rooms. The level of resources available to researchers and the freedom to undertake their own research help explain the movement of very talented US researchers in molecular biology from the public sector to such companies in the private sector. Fuji Xerox's Palo Alto, California, laboratory uses many of the most common methods of encouraging communications, such as round-tables on particular areas of interest, talks by eminent visitors, weekly 'work-here-in-progress' seminars by employees, weekly lunch meetings, and an internship programme.

Judge et al. (1997) determined that innovative firms had the following characteristics.

- Researchers possessed 'operational' autonomy, inasmuch as they acted entrepreneurially and had a sense of individual accomplishment. And top managers possessed 'strategic' autonomy, which aligned individual researcher interests with organizational aims. Too little control by top management was found to cause a disconnection between business goals and research enterprise. A balance



between operational and strategic autonomy promoted innovation by encouraging researchers to be creative in organizationally beneficial ways.

- Individual and group success was rewarded extensively through ‘intrinsic’ methods of personal acknowledgement and recognition by managers and peers, rather than by ‘extrinsic’ impersonal rewards in the form of salary increases, bonuses, or stock options.
- There was evidence of ‘group cohesiveness’, developed through particular attention being paid to recruiting people whose ‘faces fitted’ and who slotted into the social environment.
- Established goals were reasonable and deadlines were flexible.
- The firm possessed ‘organizational slack’, which allowed adaptation to the strategies pursued in the past and the present, and to be projected into the future.

Effective group and team management is essential for creativity and the success of R & D projects, but it is also important to manage key individuals. In their studies of the productivity of research laboratories in the USA and Japan, Narin and Beitzmann (1995) identified the importance of key employees. It is commonly one or two ‘stars’ that are responsible for a laboratory’s productivity. It is the job of research managers to identify these people, nurture their creativity, and ensure they remain with the company.

The challenge of encouraging creativity in R & D is clearly demonstrated by the Samsung Group. Samsung claims to have 30,000 employees devoted to R & D. It registered over 2,600 US patents in 2006, ranking in second place behind IBM. Samsung Electronics Corporation, part of the Samsung Group, spent 6.8 per cent of sales on R & D in 2005; that is, around \$6 billion. It is the largest manufacturer of DRAM (dynamic random access memory) and memory chips in the world. It has seventeen R & D centres. Samsung has been extraordinarily adept at catching up with world’s best science and technology. The challenge it faced in the late 1990s and early 2000s was to lead the development of science and technology, and this requires creativity—something Korean firms have not been noted for.

Researchers in Samsung have faced several problems in the past: poor project management (control and evaluation is undertaken by non-specialists); high levels of bureaucracy and rigid procedures (e.g., in requiring excessive documentation); slow information processing systems in areas such as patent searches; lack of involvement of personnel from the manufacturing function; too high a workload (working on too many projects); and lack of funding for longer-term research. Major changes are under way in Samsung to overcome these constraints on creativity, including a range of training courses in MTI. One significant stimulus for change in Samsung was learning from international experiences.



**Box 6.5 Forbidden fruit—Bootlegging in the R & D lab**

Bootlegging can be defined as ‘research in which motivated corporate entrepreneurs pursue innovative activity, which they themselves define and secretly organize’ (Augsdorfer 2005: 1). It is seen as a valuable means of producing good ideas, unconstrained by formal organizational and project requirements. It is often undertaken by individuals without the knowledge and approval of senior staff. Some organizations, however, allow their staff to devote a share of their time to informal projects. ‘3M’ allows its staff to spend 15 per cent of their time on their own projects. Given that this time is sanctioned by the firm, it might not be considered genuine ‘bootlegging’. Despite the acceptance of informal work in R & D laboratories in some firms, there are mixed views about bootlegging. It can be considered illicit or undermining of managerial control. Yet, given the difficulty of searching for and selecting R & D projects in large organizations, it can provide a useful source of new ideas. Indeed, bootlegging goes on whether or not management condones it. In a study of fifty-seven European companies, Augsdorfer (1996) found bootlegging accounted for 5–10 per cent of researchers’ time, and 5–10 per cent of researchers had active bootlegging projects at any one time. Bootleg projects were not necessarily more novel than formal projects. They tended rather to be used by staff to do ‘pre-research’, to help prepare ideas before entering the formal project selection process. They were also used to troubleshoot problems and help colleagues from other departments. This research suggests that bootlegging can be useful for an R & D laboratory by helping researchers explore new areas at low cost (Augsdorfer 2005).

Augsdorfer (2005) suggests that bootlegging can arise for a variety of reasons, including to satisfy curiosity, to attack technical problems that led to project termination, or to assess markets that the organization does not believe are viable or is not prepared to consider. Some argue that bootlegging is such an important activity for innovation that management should play a more formal role in its conduct (Pearson 1997). Pearson suggests that, whilst ICT enables more bootlegging outside work, by staff accessing company information remotely, budget constraints and greater formality in research management, such as total quality management (TQM) practices (see Chapter 8), may restrict this valuable activity.

An important role in a research team is that of ‘technological gatekeeper’ (Allen 1977; Macdonald and Williams 1994). This is an identifiable individual who is a good transceiver of information. He or she:

- Brings information into the firm/team.
- Disseminates information throughout the firm/team.
- Attends conferences, reads journals, and spends a lot of time in intense conversation with peers.
- Must be encouraged and rewarded.

His or her presence in an R & D project is correlated with finding superior technical solutions.

## Balancing research portfolios

Perhaps the greatest problem for research management is the tendency of companies towards short termism. Few industrialists have the foresight of Konosuke Matsushita,

who founded his company in 1932 with a 250-year plan (Barnet and Cavanagh 1994). Most 'long-term' industrial R & D has a time horizon of five years. Many large Japanese firms' R & D horizons, however, extend 10–15 years, and 3M's central research has a timescale of over ten years. Pharmaceutical firms, albeit with the confidence of potentially solid patent protection, can expect the production of a new drug to take up to fourteen years from initial screening to marketing. In 1998 IBM began to introduce its first chips coated with copper, rather than aluminium, following fifteen years of research.

Industrial firms are conscious of the high degree of 'failure' in research, knowing it to be a fundamentally uncertain and unpredictable process. Surveys of the introduction of new products show that less than one in ten new product ideas succeeds in the market (see Chapter 7). This tolerance, although not easily accepted (as most R & D and Innovation Directors will testify), holds many lessons for those trying to manage research. Success and failure are essentially unpredictable; serendipity and luck are important, and some failure is inevitable and cannot be prevented. There are simply too many unknowns (see Box 6.6).

#### **Box 6.6 Unknown unknowns of R & D project selection**

Choosing the right R & D project remains an uncertain decision. Tools, such as Multi-Criteria Assessment (MCA) (see Box 6.7), can help bring to the surface some of the underlying assumptions of different people, but they are of little use in the face of true uncertainty. One way to think of the issue is by drawing on the memorable words of previous US Secretary of Defense, Donald Rumsfeld, who in a 2002 news briefing described the problems of uncertainty thus:

As we know,  
There are known knowns.  
There are things we know we know.  
We also know  
There are known unknowns.  
That is to say  
We know there are some things  
We do not know.  
But there are also unknown unknowns,  
The ones we don't know  
We don't know.

—Donald Rumsfeld, Secretary of Defence, US Government, 12 February 2002,  
Department of Defense news briefing (Seely 2003).

At the time Rumsfeld was trying to deflect criticism of US policy in the lead up to the Iraq War, which started in March 2003. In the briefing, Secretary Rumsfeld was speaking about the state of knowledge of the US Government about Iraqi stocks of weapons of mass destruction.

He was using a view of uncertainty long understood in project management, known as 'no surprises' in which what Rumsfeld called 'unknown unknowns' are commonly referred to as 'unk unks'. This view has implications for understanding innovation management, and R & D project selection in particular. It is

possible to think of *known knowns* as activities that managers have a high degree of certainty about, such as the cost of producing another batch of an existing product, or the costs of employing an additional worker. *Known unknowns* are activities that can be described and thought through prior to the launch of a project, such as the dangers of falling behind schedule. These types of activities can be seen as risks, and managers can attempt to map, measure, and manage them. Although these assessments may be wrong, they are usually wrong in degrees, and not in orders of magnitude. *Unknown unknowns* are things that are truly uncertain (Knight 1921). They are things that managers do not and cannot know. They may involve the impossible estimation of the potential size of a market for a radical innovation that does not yet exist. They may be problems that were never anticipated. London's Millennium Bridge, for example, wobbled when large numbers of people walked across it at the same time (Dodgson, Gann, and Salter 2005). It is often the *unknown unknowns* that create the biggest problems for managers because they cannot be measured or mapped. Dealing with *unknown unknowns* requires the ability to adapt, change, and learn.

R & D directors and managers face a dilemma in organizing their budgets to meet both long- and short-term objectives. Whereas some research shows that R & D is likely to be more successful when it is related to firms' existing technology bases, these projects ignore new developments that can potentially provide future competitive advantages.

MCA is a technique that helps firms rank research priorities. The principles of MCA are described in Box 6.7, followed by an example of the use of the approach in BMW in Box 6.8.

#### Box 6.7 MCA technique

MCA is a systematic and transparent way of comparing options, assessing risks, and making decisions when there are difficult choices to be made. It is a decision-support technique, which emerged from operations research, and constructs a matrix of indicators that can be weighted, compared, and if required, converted into a single result. Results can be prioritized to assist future decision-making.

The technique takes explicit account of many variables and includes technical, quantitative analysis and qualitative judgements. Software-based tools are used by sophisticated MCA users to capture and process results quickly.

MCA is widely used across a broad range of areas from environmental analysis in sustainability projects, to evaluation and risk assessment in the use of nanotechnology or genetics, performance indicators—such as design quality indicators (see below)—to choices about developing new banking services to public policy issues related to planning, transportation, health care, or waste management.

MCA can be used to assist decisions about innovation. It is helpful for exploring alternative R & D directions, engaging with users, stakeholders, and policymakers, and prioritizing which innovations to pursue. It is particularly useful when there are complex, multi-causal issues to be considered such as adjudging technical, economic, social, and environmental impacts.

The technique can be used at the very early stages of an innovation process, such as when design problems are being defined and focused. It can also be used to help refine choices once a particular pathway is being pursued. For example, when a firm has decided to embark upon a specific product or service innovation and it is faced with a number of possible options about how to hone it for particular markets.

MCA is frequently used for evaluating research programmes, when experts from different domains are brought together to assess the extent to which it has succeeded in developing new ideas, solving problems, or meeting original goals.

The technique is used to elicit and prioritize among the choices made by groups of people, often with different disciplinary backgrounds, perspectives, and expertise. MCA is usually a facilitated process. The facilitator does not play a part in defining criteria, weightings, or voting on particular options. She or he assists individuals to articulate their ideas, encourages group brainstorming, and collates and presents results. The process involves the following steps:

1. A group with different organizational responsibilities is brought together. Customers, suppliers, regulators, and other stakeholders may also be involved.
2. Each individual in the group articulates, maps, and chooses options related to the innovation issue being addressed.
3. Each individual decides which criteria are important to them and if possible provides the reasons why (e.g., things they want to take into account).
4. The group assigns scores to the performance/outcomes of the various options.
5. Weightings are added, rating and ranking the importance of each criterion.
6. Results are computed: often the scores under each criterion are multiplied by their weightings to produce relative scores for each option.

Results can be displayed in a number of ways. They can compare how options perform relative to one another and explore why, or rank a set of priorities.

MCA is useful when there many alternatives and difficult decisions need to be made. It is pluralistic and multi-dimensional and assists in making judgements in complex situations. IBM has developed an evaluation system based on some complicated MCA tools, with more than sixty-seven criteria, that scientists and engineers use to rate each other's projects. These systems can help to provide a mechanism to support thoughtful decision-making in an area surrounded by uncertainty.

The limitations to MCA include misjudged weighting and voting on options, inappropriate interpretation of results, particularly when firms try to develop single aggregate scores, or when users are beguiled by what they consider to be robust quantitative results.

Box 6.8 describes how BMW chooses between R & D projects.

#### **Box 6.8 R & D project selection tools: The case of BMW**

BMW manufactures design-intensive, high-quality cars. The company's development activities are structured around a series of technical groups, each with its own R & D budget and portfolio of projects. Loch et al. (2001) describe how the transmission predevelopment group in BMW faced the problem of selecting between eighty different project ideas, each competing for resources. To deal with this challenge, the group revamped its previous informal system of decision-making into a more systematic selection procedure and decision-making process (see Box 6.7).

The traditional method of project selection in this group was based on intuition and the evaluation of individual projects in isolation from others. This method relied on engineers' 'gut feelings' about different options. In such a process, decisions were often based on personality and initiative rather than technical merit. It was felt within the group that its selection system relied too much on the experience of its manager, the success-rate of the group was low, and resources were being expended on projects for no clear reason. A new manager was appointed to lead the predevelopment group and a new system of selecting between R & D projects was developed. The group drew up a list of eight evaluation criteria for projects. The criteria were simply defined and included dynamics, economy, and driver interface. Each project was ranked against these criteria, but it was felt that results were not significant enough to enable effective decision-making.

The new manager decided to develop a more analytical approach in the form of a mixed-integer model. In this model, target criteria were placed above each project. The list of criteria was expanded from the original eight areas into a list of forty-one quantifiable variables. This list was sent to marketing and others within the firm for verification. Engineers developed a weighting system for the eight general

areas of performance, based on a comparison between target performance and the performance of BMW's competitors. The higher the score, the closer BMW was to its target performance.

Once this weighting system was created, it was possible to assess all eighty projects through the forty-one criteria. This produced a complex diagram, but since most projects addressed a limited number of criteria, it was relatively easy to see where the greatest contribution would be. Most projects were relatively specific and did not have major system-wide implications, so little attention was paid to interactions between projects.

Using this model, it was possible to estimate the main performance gaps. Analysis showed areas where projects were likely to have difficulties. This helped identify key problem areas and became a tool to focus decision-making. Engineers had difficulties understanding how the model actually worked and found it overly complicated. They were suspicious of the way small changes in a single criterion and weighting score could produce wildly different results. Susceptibility of the model to manipulation generated scepticism about its validity.

Nevertheless, parts of the model continued to be used. The key influence was the faith that managers had in the quality of the framework and main criteria; it became a standard tool for BMW's entire 'drivetrain development' organization. One BMW manager summarized the key lesson as: tools need to be quickly and easily understood, software needs to be logically transparent, and the tool should be able to describe, summarize, and graphically represent the issues. Complicated mathematical techniques should only be incorporated when they are needed.

It was concluded that careful management was required to ensure the participation of front-line engineers in the development of new techniques for assessing projects. Lead managers stressed to participating engineers that it was not numbers, but the criteria and the mechanisms for evaluating them that were the crucial issue. Everyone needed to buy into the criteria and evaluation mechanism, which could then be seen as a tool for sharpening thinking about projects. Although helpful for assessing individual projects, the model did not take into account interdependencies across projects. This was left for another stage in the model's development.

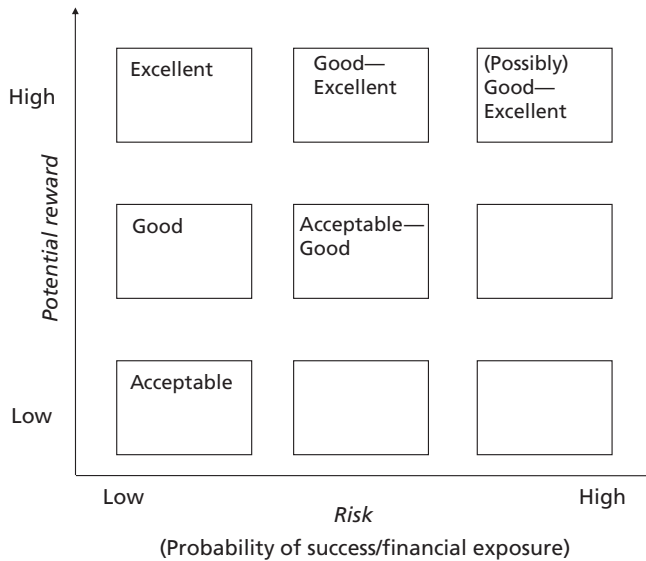
The case of BMW illustrates that the use of quantitative methods in decision-making has its greatest impact not on problem-solving, but in changing the way managers think about problems. It also highlights the importance of 'keeping it simple' when developing and implementing systems for project selection.

*Source:* Loch et al. (2001).

There are advantages to research managers operating their project research portfolios in the way that funds managers operate financial portfolios. There are benefits in balancing short-term, low-risk, low-reward investments with longer-term, high-risk, and high-reward investments. The dilemma was perfectly encapsulated by Jack Welch when he was CEO of GE, when he argued: 'Anyone can manage short. Anyone can manage long. Balancing those two things is what management is.' Decisions on the balance, focus, and sustainability of R & D portfolios should depend on the company's strategy.

Figure 6.6 characterizes a potential portfolio mix. Research managers need to balance risks with the potential rewards from R & D investments, in line with the innovation strategy of the firm and the level of available resources—finance, personnel, and equipment etc.

Research by Henderson (1994) on 120 pharmaceutical development programmes over thirty years shows that portfolio diversity is the key to success. Examining the mean number of patents per programme, she found the highest productivity occurred when there were between six and ten programmes. Productivity increased from one to six or



**Figure 6.6.** A portfolio of R & D investment projects

Source: Roussel, Saad, and Erickson 1991.

seven programmes, and gradually decreased after nine or ten. Henderson concludes that ‘the most productive companies are not only diverse enough to enable them to leverage their specialized scientific expertise but also related sufficiently to allow them to benefit from the cross-fertilization of ideas’.

#### Box 6.9 Is ‘blue skies’ research a good investment for governments and firms?

As we have seen, basic research is experimental or theoretical work conducted with no particular application or use in view. For scientists, basic research is the wellspring that delivers new ideas, giving them time and space away from immediate social and economic pressures to focus on tomorrow’s challenges. For some critics, however, basic research is a needless investment that generates largely impractical and mostly useless knowledge. Some suggest basic research should be treated like the funding of opera and left to private donations rather than the public purse (Kealey 1996). Indeed, it is common for politicians to mock obscure or seemingly weird basic research projects, such as ‘the flight habits of fruit bats’. Yet empirical research shows that basic research often produces economically and socially valuable outputs. Salter and Martin (2001) recognized six major economic outputs from basic research. These included: increasing the stock of useful knowledge; training skilled graduates; creating new scientific instrumentation and methodologies; forming networks and stimulating social interaction; increasing the capacity for scientific and technological problem-solving; and creating new firms. These outputs are not necessarily parts of the research itself, but they may accrue as a by-product of its conduct. There remains a long, tortuous, and unpredictable process that is required to translate findings in basic research into products and services. Investing in basic research also provides countries with the capacity to absorb the ideas of others, enabling them to become better at translating ideas into products.

These benefits also apply to firms. The ability to conduct and access basic research helps the competitive advantage of firms in knowledge-based industries. This was shown in relation to the case-study companies in Chapter 1. The US biotechnology firm emerged from the science base. The Japanese R & D company depends upon its links with universities around the world. The Taiwanese machine tool company needs access to basic research to get it to the next level of its technological development.

There is a close link between basic research and industrial application (Meyer-Krahmer 1997). Many firms are already significant performers of basic research, an area that has traditionally been seen as the preserve of universities and large government laboratories. IBM discovered superconductivity, for example, and Bell Labs discovered radio static (leading to the development of radio astronomy). The scale of corporate basic research is seen in the way companies are increasingly publishing in the scientific literature. Companies such as Philips, Hitachi, ICI, Siemens, Hoechst, and Toshiba publish as much as good mid-sized international universities, such as Sussex in England and Keio in Japan (Hicks 1995). In the biological and physical sciences and in electrical engineering, companies produce scientific papers cited as much or more than those from top US universities (the more papers are cited in other publications, the more they are considered to be influential). GM employs 360 Ph.D.s in its R & D Centre in Detroit, GE employs 835 Ph.D.s in its R & D Centre, and Bell Labs, at its peak, employed nearly 4,000 Ph.D.s.

Why do firms do so much basic research? As Rosenberg (1990) notes, firms do basic research for a variety of reasons, including sending signals to potential employees and collaborators that the firm is serious about and competent in its areas of science. Basic research in firms is as much about creating options (or option value—see Chapter 9) for future problem-solving and participation in research communities as it is about tangible scientific outcomes. Toshiba and Hitachi are good examples here; both are undertaking basic research into quantum physics with Cambridge University. They see this as providing the long-term potential for replacing existing integrated circuit manufacturing processes. Companies also undertake basic research to improve their corporate image and make recruiting easier.

Another reason for undertaking basic research is serendipity: the possibility of unexpectedly learning something useful when you are actually looking for something else. The outcomes of scientific enquiry can never be predicted accurately. One of the major scientific breakthroughs underpinning the development of optoelectronics, for example, derived from a theoretical physicist's work researching the nature of light on the eyes of bees.

Basic research in academia is also important for industrial firms in many industries. Mansfield's research shows how in two periods, 1975–85 and 1986–94, in a wide range of industries, over 10 per cent of the new products and processes introduced in these industries could not have been developed (without substantial delay) in the absence of recent academic research. He estimates that his sample of seventy-seven large firms produced sales of \$44 billion from products, and savings of \$17 billion due to new processes, first commercialized in the 1991–4 period and based on recent academic research (Mansfield 1998).

While basic research is important, and a good investment, it is highly unpredictable and its long-term horizons conflict with the short-term financial pressures firms usually face. Payoffs are long term, remain highly uncertain, and can only be realized by those that make the effort to learn and absorb its findings.

## Managing international R & D

### WHY INTERNATIONALIZE R & D?

Managing R & D in home countries is complex and demanding, but managing it internationally adds considerably to these difficulties. Many firms see R & D as such an important core asset that they are wary of losing control over it by conducting it in bases



overseas. Aware of the importance of good communications for the management of R & D, they are concerned that distance will raise barriers to the free flow of information and knowledge. Yet many firms internationalize their R & D, and do so for a number of reasons. The relative importance, and balance, of these objectives varies between countries and industrial sectors, and each has implications for MTI. Internationalization allows for the following:

- *Proximity to market and customers.* R & D can develop and design products and services appropriate to local conditions, demand, standards, and regulations.
- *Support for local operations.* Local R & D can quickly assist in overcoming manufacturing and delivery problems experienced locally.
- *Responses to political factors/government policies.* Some governments require overseas companies investing in businesses in their countries also to undertake R & D there. Some governments run 'offset' schemes, where access to government business depends on certain levels of local R & D activity.
- *Exploitation of foreign R & D resources.* The availability of R & D expertise may attract overseas firms. High-quality and low-cost software engineers in India, China, and Russia, for example, have attracted significant overseas corporate investment. Hitachi has research laboratories in Cambridge, UK, Dublin, Ireland, Milan, Italy, and Sophia Antipolis, France. It has a semiconductor research laboratory in California, an automotive products laboratory in Detroit, and an advanced TV and systems laboratory associated with Princeton University (which also has co-located laboratories from Siemens, NEC, Matsushita, and Toshiba). Hitachi has laboratories in Shanghai and Beijing in China, and one in Singapore. Taking advantage of the large talented labour market GE has recently invested \$80 million in the John F. Welch Technology Centre (JFWTC) in Bangalore, India. Over 2,200 JFWTC scientists, researchers, and engineers work in virtual teams with their counterparts worldwide. In recent years there has been a significant trend amongst many multinational companies towards investment in R & D laboratories in China and India (Reddy and Sigurdson 1997; von Zedwitz 2005). Initially these investments were driven by low labour cost considerations, but companies such as Ericsson, which invests heavily in R & D in China, are increasingly investing because of the quality of the scientific research conducted in these countries.
- *Parallel development.* Some companies use competing teams with different approaches to solving a particular project. When these teams are international, there is likely to be greater diversity in the possible solutions considered, and a higher level of competition.



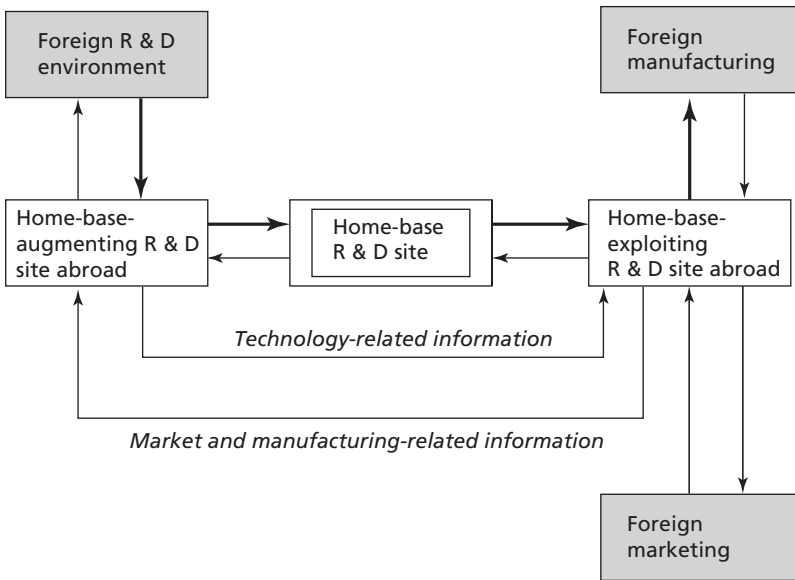
- *Specialization strategies of individual subsidiaries.* Multinational companies may decide to use particular countries as the global base for certain product or services families, and these will require R & D support.
- *Multiple learning inputs.* The knowledge and expertise accumulated in laboratories around the world may differ from and be greater in combination than that found within individual countries. GM in the USA, for example, works with designers and engineers from Opel, Vauxhall, Saab, and Holden to share resources and best practices to develop vehicles to suit different customer needs using fewer vehicle platforms.
- *Network forming.* International R & D allows firms to create the all-important personal networks with researchers in international universities and other companies. Nortel, for example, claims to work with 100 academic institutions, and Siemens claims to work with over 200 professors.

## THE EXTENT OF INTERNATIONALIZED R & D

Firms have utilized international R & D for some years. Cantwell (1998) found that large European and US firms carried out around 7 per cent of their R & D overseas in the 1930s. For the reasons listed earlier, it is argued that firms are increasingly undertaking international R & D. ABB, a quintessential globalized company, spends 90 per cent of its R & D budgets overseas, and major companies such as Philips, IBM, and Hoechst spend over 50 per cent of their R & D internationally. Nokia has R & D centres in eleven countries, Canon in ten, SAP in eight, and Motorola has laboratories in seven countries and development centres in twenty.

## MANAGING AND ORGANIZING INTERNATIONAL R & D

The Carnegie Bosch Institute (1995) distinguishes international R & D strategies that are 'regional' or 'global'. A global strategy has a product whose development draws upon expertise from around the world and has similar requirements in global markets. A regional strategy draws on several important markets and sources of expertise and has differentiated requirements. An example of globalized R & D is GM's efforts to build more vehicles from common platforms using common components, while a regional strategy will produce differentiated products for a limited number of different markets, using expertise only from those particular markets. One example would be a pharmaceutical company that targets the French and British markets with different requirements for drug delivery (the British tend to prefer pills, the French, injections).



**Figure 6.7.** How information flows between home-base and foreign R & D sites

Source: Kuemmerle 1997.

MTI requirements depend also on whether R & D is ‘home-base augmenting’ or ‘home-base-exploiting’ (Kuemmerle 1997). As the titles suggest, home-base exploiting R & D is primarily concerned with using the R & D of the home base and adapting it to local requirements. Home-base augmenting requires links into the foreign R & D systems so as to add extra knowledge to that which exists in the home base (see Fig. 6.7).

A number of management styles and planning and control systems are used in international R & D. These can vary from what is called ‘absolute centralization’, where the overseas laboratory does exactly what it is told, to ‘total freedom’, where it does what it likes (Behrman and Fischer 1980). Both these systems are rare, and management styles more commonly vary between ‘participative centralization’ and ‘supervised freedom’. The actual choice is dynamic and changes over time. It is influenced by the characteristics of the technology and the nature of the company’s culture (De Meyer 1993). As many multinational companies are increasingly investing in R & D in China and India, national-level cultural issues will assume greater importance for MTI in the future.

One of the most important methods of coordinating the international management of R & D is a technology steering committee (Kuemmerle 1997; Reger 1997). Members of such committees need to be sufficiently senior to be able to mobilize resources at short notice and they need to be actively involved in the management and supervision of R & D programmes. In Kuemmerle’s study, members included the heads of major existing R & D sites. In a study of forty-five of the largest pharmaceutical companies around the

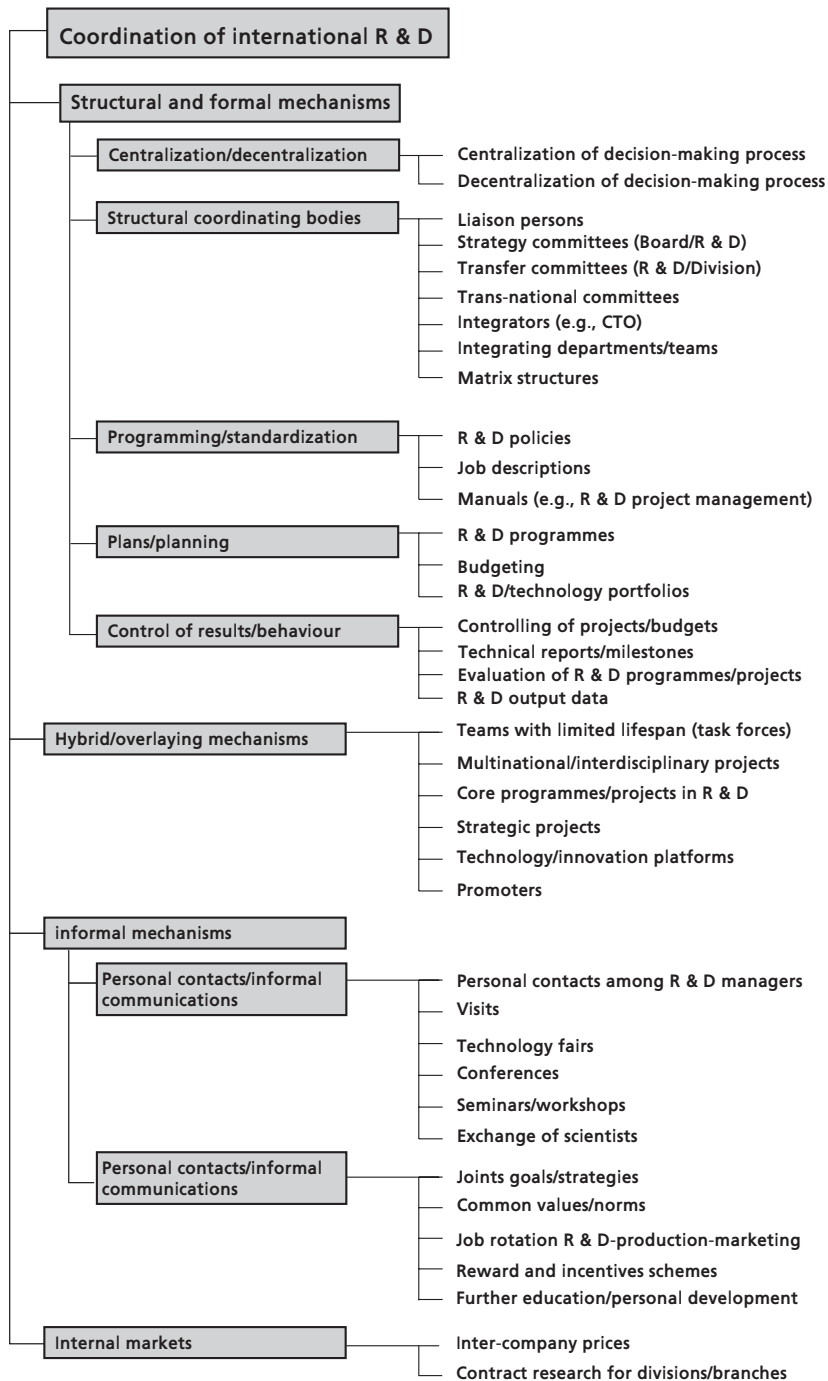
world, it was found that thirty-two operated an international R & D committee (Halliday et al. 1997).

In addition to the problems of integrating the activities of laboratories with other functions in the firm, such as marketing and production (which will be examined in subsequent chapters), another key MTI problem is ensuring efficient technology transfer between laboratories. A UK study involved ten in-depth case studies of leading European chemical/pharmaceutical firms, six of which were among the top-ten R & D spenders in the industry worldwide (Senker, Joly, and Reinhard 1996). It examined technology transfer between laboratories and revealed that few companies had developed satisfactory methods. Each company organized regular meetings of senior research directors from its various laboratories. The meetings were used to discuss research programmes and reports, strategy, regulations, and alliances. Companies exchanged research reports (although these were sometimes in languages other than English). Short-term exchanges (a few weeks) of staff between laboratories were quite common, with staff usually going to other laboratories to learn new techniques, or to train colleagues. Six companies had arrangements for long-term international placements, usually to assist the career development of outstanding young scientists, but these were infrequent. Only five companies seconded staff to the laboratories where they placed research contracts. Another study highlights the importance of inter-firm mobility for knowledge transfer between R & D units. Criscuolo (2005) found that large pharmaceutical firms used long-term secondments and placements to promote knowledge transfer between divisions and that although these arrangements were difficult and expensive to manage they helped to forge new ties between previously separated organizational units inside the firm.

Reger (1997) discusses a number of mechanisms for coordinating international R & D, including: *structural and formal mechanisms* (the use of policies and plans, coordinating bodies and centralized/decentralized structures), *hybrid/overlaying mechanisms* (such as strategic or core projects and interfunctional teams), *informal mechanisms* (interpersonal interchange and personal development), and *internal markets* (internal contracts and research contracts) (see Fig. 6.8).

## EVALUATION AND ASSESSMENT OF R & D

R & D performance can be assessed in a variety of ways, and can include evaluation of effective use of resources, efficiency, timeliness, revenues from new products/processes, and production-cost reductions (Roberts 1995). In addition to Peer Assist and MCA, 'Technology Roadmapping' is used to help organizations assess the direction, quality, and progress of research projects (see Box 6.9).



**Figure 6.8.** Coordination of international R & D

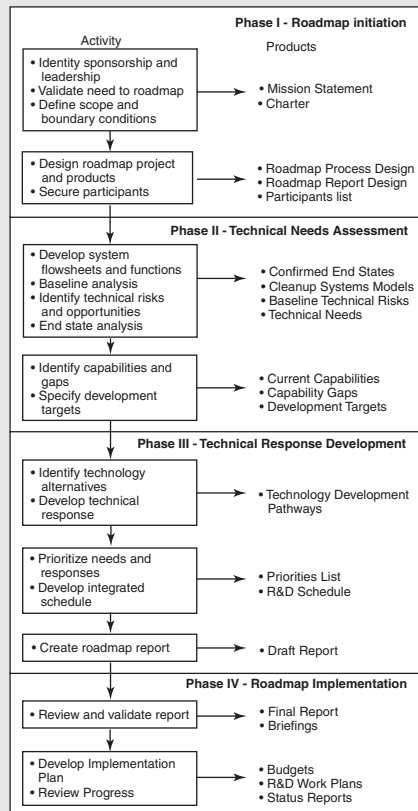
Source: Reger 1997.

### Box 6.10 Technology roadmaps

Technology roadmapping is a framework and process used for assessing and planning potential technological developments. It seeks to align businesses' technology investment decisions with their strategies. It is often used to provide and organize information for technology and R & D investment decisions. The technique—which was developed by Motorola in the mid-1970s—is also used by industry associations and government organizations as part of their technology *Foresight* process.

Technology roadmapping is used for forecasting, investment planning, and providing evidence on technological trends to assist the development of innovation strategy. Firms use the technique to explore emerging technological opportunities, how these might affect the organization's competitive position, and how implementation of projects might be evaluated.

A roadmapping exercise typically focuses on a single technical area, such as mapping likely future developments for integrated photonics, or automotive software. It is usually a facilitated activity, carried out by a group of experts in a particular field. The aim is to build a time-based chart, which establishes technological trends and links these to information about likely products and market opportunities. The team explores technology gaps and identifies required investments. Figure 6.9 provides an example of the stages in a typical roadmapping process.



**Figure 6.9.** A typical technology roadmapping exercise

Source: Dixon 2001.

Technology roadmaps are usually presented as graphical representations accompanied by a report on specific gaps, options, and strategic recommendations about resource allocation and capabilities. Roadmaps usually display a review of technological trends along the bottom of a chart. Likely products and services are identified in relation to these trends in the middle band of the chart, with business and market consequences along the top band.

The roadmap identifies time frames and milestones for developing technologies. It identifies supporting technologies that may need to be developed and the drivers that relate to them. It presents alternative technologies and provides information related to decisions about trade-offs along different pathways and issues relating to increasing R & D investment and coordinating research activities.

Technology roadmapping is particularly useful when there is a good body of knowledge about underlying technologies, drivers, and trends. When the technological and investment environments are uncertain there may be several possible decisions and multiple pathways. The value of roadmapping is enhanced when it is used in conjunction with other MTI tools and techniques.

Traditional investment evaluations cannot be used for R & D. Capital-budgeting approaches, such as net present value (NPV) and return on investment (ROI), are difficult to calculate for R & D and can significantly understate the value of R & D investments. Despite these limitations NPV and ROI are widely used in management practice and can be useful for well-established development projects, aligning potential markets for a new product with the costs of its development. Other measures, such as discounted cash-flow analysis, also fail to include any long-term returns to R & D, and it is difficult to attribute a particular contribution to R & D investment. How much was a profitable new product the result of input from R & D, from sales, or from marketing, from manufacturing, or from business and collaborating partners? Some companies, such as Hitachi, attempt to assign a profit contribution to each project—a notoriously difficult process. Companies such as Philips use a number of other methods, including:

- Determining the value of businesses that would not have been created without investment in R & D.
- Measuring licensing and cross-licensing income from the company's patents (patents from Philips Research, the 3,000-strong central research function, earn enough in licensing income to pay for the research facility).
- Considering option values (Lint and Pennings 2001).

Some companies are evaluating R & D as opportunities, or options, that confer rights but not obligations to take some action in the future. The executive vice-president of Philips Electronics, claims there are a number of advantages in using option-pricing theory in R & D, because:

- Options (calls) limit downside risk. So a decision not to follow up on a research project means only the research cost is lost, not the cost of follow-up investment.

- Any losses following a decision not to proceed might be recovered by the sale of patents.
- Discovering—before your competitor does—that a certain technological option is a dead end, can be valuable.

R & D option techniques emphasize investment values, which alter over time and across projects, as well as perceived investment cost and discovery-value volatility (Newton, Paxson, and Pearson 1996). Research into the option values of R & D projects will provide an important future development. Some interesting findings have emerged already.

- R & D expenditures may be valuable even though no intrinsic value emerges, although this normally would not justify an R & D budget.
- Volatility of both investment cost and discovery value increases option value, since the actual investment may be deferred or cancelled. Whereas uncertainty (risk) decreases the present value of future cash flows, uncertainty (volatility) increases option values.

In one of the few detailed empirical examinations of firms taking a real-options approach to investments, Caldwell et al. (2006) found a higher incidence of innovation in a sample of ninety-seven Australian biotechnology firms among those firms using real options rather than traditional methods, such as net present value.

Research managers need to be conscious of what the management literature has long understood as the problems of goal displacement as efforts shift towards ends that are most easily quantified (Hrebreniak 1978). In *The Reckoning*, an account of the havoc wreaked on Ford by Robert McNamara and his form of managerialism, which insisted on quantifying virtually everything, David Halberstam describes (in a manner that probably resonates with many present-day researchers and engineers) how Ford engineers and R & D workers:

gradually [came] to doubt themselves. Repeatedly beaten on certain kinds of request for their plants over the years, they came to realize that some items would not go through, no matter how legitimate, and so they began to practise a form of self-censorship. They would think of something they needed, realize they could not get it through, and cut the request down so severely that the original purpose was sacrificed. (Halberstam 1987: 498)

McNamara's faith in systems analysis and statistics over any form of qualitative assessments was later, of course, to have an even more devastating impact in the tragedy of the Vietnam War.

Whether the results of basic research can be quantified at all is open to question. In a review of US experience of studies on the benefits of basic research undertaken by, amongst others, the US Department of Defense, the National Science Foundation, and

the Office of Technology Assessment, Steinmueller (1994: 60) concludes that, 'whether significant returns to public basic research investments in specific projects can be measured or predicted with significant accuracy to guide research investments remains an open empirical and conceptual question'.

There are numerous problems with measuring research outcomes, not least of which is the lengthy timescales involved in commercializing research. Furthermore, how do you assess the relative contribution of new, compared to existing, know-how? Aware of the problems of measuring the returns to research of all types, companies are careful to ensure that the most appropriate methods of research evaluation are used for different forms of research. Japanese firms such as Mitsubishi Electric, NEC, Sharp, Toray, and Hitachi evaluate their longer-term research according to its 'fundamentality' and the way it contributes to knowledge.

## Summary and conclusions

R & D is a key source of competitiveness but, as this chapter has shown, it is difficult to organize and manage. This difficulty reflects the broad range of objectives of R & D, the different kinds of skills and personnel involved in it, the difficulties involved in measuring its outcomes, and the increasing challenge of globalization. The challenges of MTI in this arena are accentuated by the large expenditures committed to R & D and the pressures on organizations to deliver valuable outcomes.

One of the major trends in the organization of R & D in the 1990s and 2000s has been an increasing move towards decentralization with the aim of making R & D better targeted to immediate business needs. The dangers of such a move are that it under-emphasizes the importance of longer-term, more speculative R & D, which provides the opportunity to create new markets, and give customers what they did not know they wanted. Historically, there has been a cycle of centralization and decentralization and this may well be repeated, as recognition of the benefits of centralized research returns. The incorporation of centralized R & D activities may be integrated into the emerging distributed networks of R & D organization. The long-term competitiveness of R & D requires a balance of near- and long-term R & D, with a proportion of the R & D project portfolio being in the high-risk, high-return category. As it is very difficult to assess the returns to R & D, a variety of new techniques are beginning to be used to evaluate the benefits. This includes the relatively new field of assessing R & D as 'options'.

R & D management requires both team management and individual creativity, and the issues of recruiting, rewarding, and organizing teams and individuals are central. R & D workers tend to be highly educated and skilled, and the most effective rewards tend to be more complicated than simple remuneration. High levels of task discretion and



autonomy are common, but there is a need for formal organizational decision-making processes. These project management systems take a variety of forms, including those related to specific individuals at particular stages of the project's development. Integrated teams with a common system or product focus have been shown to be effective in the computer and auto industries. The tendency towards the increased internationalization of R & D has many consequences for its management. The organization of international R & D, its reporting structures, funding, and management styles, depend ultimately on the strategy of the firm. With the significant new multinational company investments in R & D in China and India, the ability of managers to integrate inputs from these sources will also depend upon effective cross-cultural management.

# **7 The Management of Product and Service Innovation**

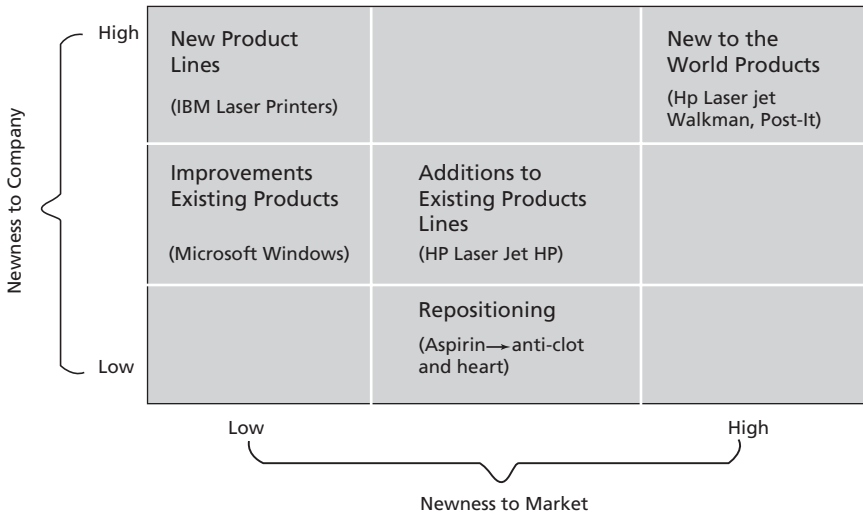
## **Introduction**

One of the primary aims of companies' investment in R & D is to produce new and improved products and services. The results from R & D investment may be intangible. They may, for example, increase the learning and understanding of scientific and technological principles underpinning a company's products, provide options for the future, and create IPR—a subject examined in Chapter 9. The major aim of corporate R & D, however, is to combine technological and market opportunities to produce differentiated goods and information (innovative products and services) that convey competitive advantages. This chapter is concerned with the development of such new and improved products and services.

The overlaps and ambiguities in the distinctions between some of the issues discussed in this book highlight the way innovation involves all aspects of the firm. R & D overlaps with the creation of product and service innovations; design is a feature of and contributes to R & D and product and service development. In practice, firms' best efforts are directed towards breaking down all these distinctions and delivering efficient innovation processes. For our purposes we describe R & D, product and service innovation, and design as separate, but accept that there are very blurred boundaries between them. In this chapter we analyse product and service innovation (PSI) together, treating design as a separate issue despite its intimate connection with innovation in products and services.

## **What is a product or service innovation?**

One of the first issues to consider in relation to PSI is the extent of its 'newness'. PSIs can be new to the world and new to the firm. A product new to the world would be, for example, Hewlett-Packard's (HP) Laser Jet Printer: it was the first-ever produced. When IBM introduced its laser printer, it was a new product line for the firm, but followed HP's product onto the market. New products can add to existing product lines, such as when



**Figure 7.1.** Categories of a new product

Source: Based on Cooper 1993.

HP introduced its Laser Jet IIP, or when Boeing introduced the 747:400, and they can be improvements to existing products, such as Microsoft's various versions of Windows. Products can also be repositioned into new markets. An example would be the use of aspirin as an anti-stroke agent as well as a pain-reliever or a mobile telephone used as a means of paying bills. These different categories are shown in Fig. 7.1.

Box 7.1 describes how a cruise ship company balances different levels of newness in innovation to provide a continuously improved service to its customers.

#### Box 7.1 Innovating in cruise ships: Royal Caribbean International

Founded in 1969, Royal Caribbean International (RCI) is a leading developer and operator of cruise ships. Cruising is an activity especially popular with North Americans between the ages 30 and 50. Cruises generally last from three to fourteen days, and offer a relatively inexpensive holiday. The cruise industry grew rapidly in the late 1990s and the 2000s. RCI operates 20 ships with almost 48,000 berths. It launched nine new ships in the early 2000s. To increase the popularity and attractiveness of cruise ships as a tourist experience, it has sought to innovate in the design and operations of its ships. In 2006, it launched *Freedom of the Seas*, the world's largest passenger liner, which encompassed a number of innovations, including rock-climbing walls, bungee trampolines, and surfing simulators. It also conducted extensive refurbishment and revitalization of its existing ships. Refurbishment and upgrades to existing ships occurs every five to seven years, based on the assumption that customer leisure preferences change over time. The ships therefore provide a platform for experimentation in new types of entertainment experiences, such as the use of a boxing ring on *Freedom of the Seas* following the success of the film *Million Dollar Baby*. In developing a new ship, RCI design teams operate a policy that one-third of the ship should be based on what is known, one-third incremental improvements in existing features, and one-third totally new elements. To search for innovations, it employs a scouting team that visits various tourist hotspots, such as Dubai and Las Vegas, observing new trends in the leisure industry. Some innovations simply require existing parts of the ships to be used in new ways, such as the addition of topless sunbathing areas, whereas others involve a major redesign of

the ship, such as the addition of an ice skating rink on *Freedom of the Seas*. Adding new components to ships, such as a 5,000-gallon saltwater aquarium, requires RCI to be skilled at integrating knowledge and components from many different fields and working with professional consultants from around the world. It has developed highly sophisticated virtual modelling and computer program document exchange suites to help distributed suppliers work together more efficiently. It uses these technologies to enhance its operations. Purchase orders, for example, are sent straight from the galley to central purchasing departments on shore. Because it has a continuous programme of designing and revitalizing its ships, it is able to pass lessons from one project to another, creating economies of repeatability (Davies and Brady 2000). Knowledge about operations, customer experience, and potential new sources of revenue are incorporated in the design and revitalization of the ship by including operations staff in design and production teams. This allows a virtuous cycle of experience and learning between design and operations.

Source: Kalley (2006).

## The potential benefits of PSI

The benefits of PSI are so great that despite many obstacles and difficulties firms continually seek to develop new offerings. This is seen in Box 7.2, which illustrates the difficulties firms encounter in perfecting new ideas and achieving successful outcomes in the market.

### Box 7.2 The continual search for innovation in personal transporters

#### *The Sinclair C5*

Sir Clive Sinclair is a great British inventor and entrepreneur. He founded Sinclair Radionics in 1961 and produced a series of innovations over the next twenty-five years, which included a pocket television, a pocket calculator, and the first generation of portable computers. Sinclair's new product launches were accompanied by slick and colourful marketing campaigns that highlighted the innovativeness, modernity, and beauty of his products. In 1985, Sir Clive launched one of his boldest new products: the C5, a three-wheeled personal transportation device. It was priced at \$800 (around \$3,000 in today's currency). Combining battery-driven engine and pedaling power, it had a top speed of 25 km per hour. The C5 was believed by Sinclair to provide an alternative to cars and bicycles.

The product was a complete commercial failure. It was heavy to pedal, yet too small and dangerous to drive in traffic because of the inability of car drivers to see it. As one owner stated:

I would not want to drive a C5 in any traffic at all. My head was on a level with the top of a juggernaut's tyres, the exhaust fumes blasted into my face. Even with the minuscule front and rear lights on, I could not feel confident that a lorry driver so high above the ground would see me. (*Daily Telegraph*, 11 January 1985, cited in Adamson and Kennedy 2007)

Drivers needed to attach a bright red mast to the vehicle to ensure that they could be seen. The C5 experienced problems with its batteries in cold weather, riders complained of lack of protection from wind and rain, and it struggled with steep hills. The fact that it was manufactured by Hoover led to the cruel joke that it was powered by a washing-machine motor. Fewer than 17,000 were made and eventually debts accumulated. The failure of the C5 forced Sir Clive to sell his computer and pocket calculator business to his competitor, Amstrad.

### *The Segway Human Transporter*

Dean Kamen launched the Segway Human Transporter in 2001 accompanied by great public interest. Kamen had run a highly successful marketing campaign, building up expectations of his revolutionary new product, code-named 'Ginger'. Rumours about the nature of 'Ginger' abounded on the Internet. Part of this speculation was based on comments by senior US business figures about the potential of the new technology. Steve Jobs, CEO of Apple, commented that the product was so important that it would force cities to be redesigned. Jeff Bezos, the founder of Amazon, said 'you have a product so revolutionary, you'll have no problem selling it. The question is, are people going to be allowed to use it?' Kamen had an exceptionally ambitious expansion plan, expecting to reach \$1 billion in sales faster than any other product in US history. The original Segway factory was designed to build up to 40,000 units per month. The Segway was similar to a scooter, but included significant innovations such as parallel wheels and a self-balancing control device based on gyroscopes controlled by computers. It sold for around \$5,000 and had a top speed of 20 km per hour. After the first demonstration of the product, and the initial public excitement about it, three Segways were sold by auction for more than \$100,000 each.

Kamen and his team signed an exclusive sales agreement with Amazon.com to sell the product, and expected to trade between 50,000 and 100,000 units in the first year. After 21 months on the market, however, only 6,000 units had been sold. In September 2003 all Segways were recalled because of a technical fault. The company press release stated:

Hazard: Under certain operating conditions, particularly when the batteries are near the end of charge, some Segway HTs may not deliver enough power, allowing the rider to fall. This can happen if the rider speeds up abruptly, encounters an obstacle, or continues to ride after receiving a low-battery alert.

Since the recall, Segway has expanded the range and type of models on offer. Sales have yet to meet initial expectations, but new uses for Segways have been found in factories, airports, and security firms. There is even an active Segway polo club in California.

### *The Quasar*

The Quasar was an innovative motorcycle developed in the UK in the 1970s by Malcolm Newell and Ken Leaman for Wilson and Sons, a Bristol-based engineering firm. The first Quasar was launched in 1976. The motorcycle had a number of innovations. It had a sleek modern design that protected the driver from wind and rain. It had a comfortable, reclining driver position and numerous safety innovations such as hydraulic side stands to allow the cycle to lean left or right. It was also fast, with a top speed around 175 kph, and had low fuel consumption.

Although it received considerable press attention, only six motorcycles were made and sold between 1976 and 1979. One problem was that Wilson was a manufacturer of transformers and electrical equipment and had only limited interest and capability in the difficult process of manufacturing motorcycles. A few more Quasars were made in the early 1980s, but problems in obtaining components delayed production. With a list price of £5,885 in 1980 (\$26,500 in 2005 dollars), it was expensive; more than three times the price of other high-performance motorcycles. Eventually key members of the design team dispersed or left Wilson and all production stopped. Only nineteen Quasars remain in existence, but there is a small community of strong supporters (see [www.quasarworld.com](http://www.quasarworld.com)).

### *The BMW C1*

First shown at an auto show in Germany in 1992, the C1 was launched on the European market in 2000. BMW has a long tradition of innovation in the automotive sector and the C1 was seen as a way of extending its knowledge and skills in new markets. It was described as an 'innovative mobility product'; a cross between a motorcycle and a car. It was intended to appeal to the urban commuter, providing trouble-free parking, low fuel consumption, and ease of use associated with a scooter, combined with the safety and comfort of a car. The C1 had a top speed of over 100 kmph and was relatively easy to drive. The design itself builds on the Quasar approach, with a covered driving position on a two-wheel motorcycle. This provides the driver some protection from wind and rain. It also incorporated several new design ideas. Safety was based on an aluminium frame with a double roll bar. As the C1 used a

three-point seat belt it was believed the rider would not need to wear a helmet. The C1 was built by an Italian firm, Bertone Carrozzeria, not BMW itself. BMW arranged a partnership with Louis Vuitton to offer a designer CI.

The C1 was expensive; costing over \$7,000 in the UK in 2001, well above the cost of a regular motorcycle (roughly \$2,000) and more comparable to the price of a small car. It was necessary for owners to acquire a motorcycle licence to use it; a strong disincentive for new users. It sold reasonably well for a few years after its launch, reaching 13,200 units by the end of August 2001. However in 2002, sales dropped to only 2,000 and BMW ceased production later that year. It was never available in the USA, and because of safety legislation its UK riders were required to wear helmets. The product suffered from adverse press reaction. A popular UK-based automotive commentator, Jeremy Clarkson, said about the CI: '[T]rying to mate a bike with a car is like trying to mate a dog with a fish. You end up with something that won't do as it's told and makes you wet every time you take it out for a walk.'

Given some of these challenges to PSI, why do firms continually seek to innovate? According to a classic study of product innovation Clark and Wheelwright (1993: 83–4), the potential benefits of effective new product development—and we believe PSI more generally—are threefold.

First, there is the question of *market position*:

Ideally, a new product can set industry standards, standards that become a barrier to competitors or open up new markets, such as the Sony Walkman or Polaroid portable camera. Superior products and services are a means to gain a lead on competitors, build on existing advantages by creating stronger competitive barriers, establish a leadership image that translates into dominant designs in the market, extend existing product and service offerings, and increase market share.

However, PSI often requires new marketing and operations channels, which can be challenging for many firms.

Secondly, there are benefits of *resource utilization*, which can include:

capitalizing on prior R & D investments, improving the returns on existing assets (such as the sales force, factories, and field service networks), applying new technologies for both products and manufacturing processes, and eliminating or overcoming past weaknesses that prevented other products or processes from reaching their full potential. The potential leverage on a variety of resources can be substantial.

Finally,

The excitement, image, and growth associated with product and process development efforts capture the commitment, innovation, and creativity of the entire organization. This success, in turn, enhances the firm's ability to recruit the best people, improve their integration, and accelerate the pace of change. Furthermore, development projects themselves often are the vehicle by which new approaches and new thinking are adopted and take on institutional reality.

Clark and Wheelwright (1993: 84) contend that these benefits are additionally anticipated to 'drop to the bottom line, providing rich financial rewards such as improved return on investment, higher margins, expanded sales volume, increased

value-added, lower costs, and improved productivity'. They also argue that, while the potential benefits of new product development are enormous, unfortunately, in most firms, the promise is seldom fully realized. The many challenges and difficulties of PSI—in both developing the right product and service and doing it efficiently—explains the high incidence of failure.

## Failure in PSI

Research into new product development has long shown that failure is common and has demonstrated the reasons for that failure, which also apply to services innovation. PSI can fail in many ways. For example because products and services:

- Do not meet users' needs.
- Are not sufficiently differentiated from the products and services of competitors.
- Do not meet technical specifications.
- Are too highly priced compared to their perceived value.
- Do not comply with regulatory requirements.
- Compete with the company's other products and services.
- Lack strategic alignment with the company's business portfolio.

Most new products fail in the marketplace. 3M, for example, claims to fail in over 50 per cent of its formal new product programmes.

In the pharmaceutical industry, the attrition rate in the development of new chemical entities is very high (Nightingale 1998). At any one time, between 2,000 and 6,000 new chemical entities are being examined in pre-clinical trials. This number reduces to twenty when clinical trials (experiments with humans) begin. Only three will emerge at the final stages of clinical trials, and these will have to win a place in the market.

PSI is a risky activity; firms introducing PSI face:

- Market risks—uncertainty about demand.
- Competitive risks—what will competitors do?
- Technological risks—will the product or service work?
- Organizational risks—what organizational changes are needed?
- Operational risks—can the product be made and the service delivered?
- Financial risks—large upfront investments are required for uncertain pay-offs (based on Garvin 1992).

As we have shown throughout this book, however, innovation is important for firms and the greater risk to the company's future may lie in not developing them. Furthermore, as Chapter 4 demonstrated, even failure produces learning and may be valuable. 3M sees

its failures as a learning experience. This is a view shared by Maidique and Zirger (1985), who argue that past product failures provide the basis for:

- New approaches to marketing.
- New product concepts.
- New technological alternatives.
- New information about customers that may lead to major product reorientation.
- Identification of weak links in the organization.
- Inoculation of strong elements of the organization against replication of failure patterns.

Even the most successful innovative firms do not have a perfect track record in PSI. Failure is part of the cost of being an innovative firm; nothing ventured, nothing gained. MTI involves an appreciation of the role of failure and of how great innovators can get it wrong, often spectacularly so. Some examples of failure are the stuff of legend in business. Some recent failures are included in Box 7.3.

### **Box 7.3 If you're not failing, you're not trying hard enough**

#### *Nokia's N-Gage*

In 2003, Nokia introduced a new portal gaming device called the N-Gage. The N-Gage combined a gaming console with a mobile phone. It was launched with great fanfare and represented a significant attempt by Nokia to break into the portable games console, a market dominated at the time by Nintendo. Entering the games-console sector was a major break from the past for Nokia. Although Nokia sold over one million units in the first year, N-Gage failed to reach its targets and accounts for only a small part of the games-console/mobile-phone industry. The original N-Gage was expensive, retailing for more than twice the cost of the Gameboy Advance, its chief rival. It also had a number of design flaws that made it unpopular with users. It was uncomfortable to use as a telephone. Nokia had a difficult time finding game developers willing to write programs for the platform and therefore there were few games available when it was launched. The games that were available were not popular. Its screen had a vertical rather than a horizontal orientation, which was unpopular with games players. It was also incompatible with the largest USA cellphone network, working only on the GSM standard. In the USA, it was usually sold in computer gaming shops where it compared unfavourably with dedicated portable gaming consoles.

Nokia did not give up and released an improved version of the N-Gage in 2004. This model had a number of design enhancements, including a larger screen and a more natural talking position. It was also cheaper. This helped to improve sales, but the N-Gage has remained poorly placed in the market compared to Sony's PSP and Nintendo's DS. Despite these setbacks, there is still a community of N-Gage users and developers (see [www.n-gage.com](http://www.n-gage.com) and [www.allaboutn-gage.com](http://www.allaboutn-gage.com)) and Nokia is committed to developing games and gaming platforms in the future.

#### *Apple's Newton*

The Newton MessagePad was introduced to the market in August 1993, under leadership of then Apple CEO John Scully. The Newton was one of the first generation of Personal Digital Assistants (PDA). Apple saw the Newton as a platform that would allow users to manage their daily lives as well as communicate with their friends and colleagues. It was an ambitious attempt to change the nature of personal computing, freeing people from their desks. The Newton had a large interactive screen, an address book, to-do lists, notepad, and calendar. It could be used to send faxes and emails. It retailed in the USA for \$699 and weighed around 400 gm. The Newton used a stylus that allowed its user to write by hand on the touch-sensitive screen. Handwriting was converted to text by handwriting recognition



software, called Calligrapher. It also had an on-screen keyboard. The powerful handwriting recognition software, developed by ParaGraph International Inc., was able to recognize many forms of handwriting and it could also 'parse' language, enabling the user to write something that would immediately be loaded into different programs, such as the calendar. It could also 'learn' users' handwriting, becoming increasingly accurate over time. Reliability, however, was mixed and it required some patience to wait for the machine to 'learn' the users' writing style. Problems with the early generation of Newton handwriting software were mercilessly pilloried in a leading US comic strip *Doonesbury*, leading to poor press for Apple. Working with ParaGraph, Apple developed more advanced handwriting recognition software that helped to correct earlier problems. The new software was very sensitive to the user; as once it learned the handwriting of one user it could not easily learn that of another. But this improvement came too late; the negative reputation of the Newton was established in the public consciousness. The Newton also failed the 'pocket test' as it was too large to place in a coat pocket, unlike the Palm Pilot, its successor in the market. As one user said 'unless you were a kangaroo, you carried your MessagePad in a briefcase or handbag. It wasn't really all that handy' (MacNeill 1998). Apple released seven versions of the Newton from 1993 to 1997. Some of these models were highly priced, retailing at over \$1,000 dollars—close to the cost of a personal computer. The last Newton was released in November 1997.

Sales never reached Apple's expectations and eventually the Newton failure as well as other problems in Apple cost John Scully his job as CEO. Elements of the Newton were reused in subsequent Apple products. The operating system of the iPod was developed by two former Newton programmers and the iPhone has several Newton-like features.

### *The Millennium Dome*

To celebrate the arrival of the new millennium, the UK government sponsored a major new exhibition, located in Greenwich, London. The exhibition, to continue for one year, was to celebrate the best of Britain, combining educational and fun experiences. Prime Minister Tony Blair said it would be 'the most exciting thing to happen anywhere in the World in the Year 2000'. The exhibition was to be housed in a large white tent—the Millennium Dome—based in a deprived area of East London. The UK Government created a dedicated organization (New Millennium Experience (NME)) to manage and operate the exhibition. Public funding for the exhibition was set at £399 million. Organizers hired some of the world's leading designers to create amusement rides, experiences, and educational activities. Although originally conceived by a previous government, the project was eventually seen as a central part of the creation of the national brand—'Cool Britannia'—with high-level government support including a special senior Minister for the Dome.

The building of the Dome and its exhibitions was completed just in time for the 1 January 2000 opening date. The tight schedule, however, left little time to test and trial exhibitions and facilities before they went into action. Things went wrong from the beginning. To open the exhibition, NME invited the Queen and many leading figures from the UK political, media, and business establishment. A small number of security gates at the front entrance left many of the celebrity guests outside the tent on a cold London night on the birth of the new millennium. The first paying guests were also less than impressed with the quality of the 'experiences'. Attendance in the first month was well below expectations. Negative reviews in the press did not help, and some of the amusement activities were found to be less than amusing. After several months of low attendance, the NME took the dramatic step of hiring a new manager, P.-Y. Gerbeau, who was then working at Euro Disney. Gerbeau improved the operations and attractiveness of the Dome, but attendance never reached forecasts. By the end of the year, 6.5 million people had visited the Dome, half the expected number. The project eventually cost over £789 million, £628 million of which was covered by national lottery monies.

The end of the project brought yet more difficulties. It was unclear what was to be done with the Dome itself and winding down the project cost the UK Government several million pounds. For the next six years, the Dome was mainly unoccupied. Plans to reuse the site for a casino or sports facility were slow to be realized, leaving London with a large empty white tent (or white elephant) for some time. It was sold in 2004 to a private consortium and, in 2007, the Dome will be reopened as an entertainment complex, with a 2,000-seat theatre, cinemas, exhibition space, and small theatre spaces. It will also be used as one of the sites of the London Olympics in 2012.

While these examples are clear-cut failures—albeit providing valuable lessons for future successes—it is important to recognize that PSIs can be successful and also fail at different times in their history. This, and the many opportunities and problems of PSI, are described in Box 7.4 on the development of the IBM personal computer (PC) and its successor, the IBM PC Junior.

#### **Box 7.4 Success and failure in new product development: IBM's PC**

The development of the IBM PC in the late 1970s was the fourth attempt by the company to produce a microcomputer; all previous attempts had failed. The PC was developed in a small company operation at Boca Raton, Florida, with a small development team of eleven. It used a highly entrepreneurial approach to development. The team was under tight time constraints of one year to complete the project. The development involved detailed market research, involving the development team visiting many computer gurus and marketing consultants. It operated in a very different way from the traditional 'IBM way'. Contrary to the company's usual practice of designing and making everything in-house, in this case important expertise and component elements were bought in. For example, the team involved a small software developer to design the software, and its central processing unit (CPU) was also designed elsewhere. Close attention was paid to the product's market-entry strategy by carefully establishing the price–performance balance and target-market niche (the cost of the computer was to be \$3,270).

The IBM PC was a huge success as a new product. It was introduced in 1981 and had achieved sales of 538,000 in 1983 and 1,375,000 in 1984, capturing 40 per cent of the PC market. As soon as production capacity caught up with the demand for the product, IBM cut the price of its PC by 23 per cent. This move was viable as high production volumes produced learning curve and scale economies, and thereby enabled high margins. The price cut was aimed at increasing market share and deterring imitators with smaller-scale production capacity.

The IBM PC Junior (developed subsequently), however, was a failure as a new product. It was developed at what had grown into a large operation at Boca Raton, involving over 10,000 employees. The entrepreneurial ethic was replaced by a bureaucratic approach to development, with a complex structure of internal product design and marketing teams. There were few market linkages as a basis for establishing design specifications, and little consultation with outside experts. The Junior was designed to avoid competition with the successful PC and not on the basis of identified user requirements. Its 'toylike' keyboard made it totally unsuitable for word processing (which was to be the main office application) and too costly for the home market (it was priced at \$1,000 compared to \$200 for the top-selling Commodore 64). It also had limited memory, which rendered it unable to compete at the upper end of the market. As a result, the Junior was 'neither fish nor fowl' and very few machines were sold. Subsequently, IBM introduced an optional typewriter keyboard for the Junior with a conventional layout, expanded its memory from 128,000 characters to 256,000 characters, and cut the price of existing models. None of these efforts saved the product and eventually it was withdrawn from the market.

As new products, the PC was a success and the Junior a failure. The market orientation, entrepreneurialism, and preparedness to integrate external inputs that characterized the PC's development were not continued into the development of the Junior. But what was the impact of the development of the PC on IBM as a whole? The software supplier used by the PC development team was Microsoft, the chip provider, Intel. These two companies have subsequently defined the development of the PC market and have grown to become larger than IBM. IBM developed a good product by using other companies' proprietary technology. The technology, however, was not protectable by IBM and sales of the IBM PC collapsed with the arrival of PC clones from companies using the same technology, such as Compaq and Dell. Ultimately, IBM failed because it believed it could do a better job than its initial suppliers and therefore missed the opportunity to acquire or contractually limit Microsoft and Intel. By 1990 IBM had less than 10 per cent of the PC market. The IBM PC was a success, in so far as it assisted IBM to achieve its strategy of moving out of mainframes and using outsourced components. Nevertheless, the strategic advantage was lost because it failed to control the necessary IP.

One of the reasons why projects fail lies in the way they are initially budgeted. Box 7.5, describes the shortcoming of one major technique used to assess budgets.

### Box 7.5 The Mythical Man Month

Many complex and difficult projects are delivered late and over budget. The lists of failure are long and infamous. In construction, close to 60 per cent of all projects are delivered late or over budget. Large military projects are notoriously over budget, often costing three to five times more than was originally anticipated at conception and launch. In the UK, the twenty large active military projects were estimated to be £2.7 billion over budget in 2005 (NAO 2006). Software projects are also rife with failure. Failure is so widespread that it is almost expected. Microsoft's successor to Windows, Vista, was delivered five years later than expected. Apple struggled for years to develop a successor to its OS10. One Booz Allen estimate found product development projects consistently underestimated time periods by a significant degree, that is, 140–280 per cent for incremental products and 350–600 per cent for major new products (cited in Tidd, Bessant, and Pavitt 2005).

Why, then, do managers appear so unable to accurately estimate the costs of performing a complex project? There are several reasons, including over-optimistic forecasts; cost-plus contracts that allow firms to inflate prices after a project is won; and self-seeking behaviour by managers who deliberately underestimate the cost of their project to convince colleagues to support it. It is common for managers to increase their efforts and expenditures on failing projects, leading to deeper and more costly failures.

Fundamentally, it is difficult to predict the costs and timing of developing something new. Apart from the opportunistic behaviour of individuals, there are structural reasons why complex projects are difficult to manage. Projects are often based on estimates of required effort measured in 'man months': the number of hours it would take an 'averagely' skilled person to execute a task. Although this approach is common, it has severe limitations. In a seminal book on software engineering, Fredrick Brooks, who worked as a programmer at IBM in the 1960s, argued that the man month was a 'myth'. Project management was based on the idea that months of effort and individuals were interchangeable. Yet, this is only true when project tasks can be undertaken by individuals with no communication between them. Many tasks cannot simply be partitioned between individuals and then independently accomplished. As Brooks comments, 'the bearing of a child takes nine months, no matter how many women are assigned' (Brooks 1995: 17). Communication between project members is central to completion of project tasks and therefore tasks are interconnected in ways that are hard to predict, programme, and manage. Brooks suggests that the cost of adding new people to a project may actually lower its productivity: 'adding more men then lengthens, not shortens, the schedule' (Brooks 1995: 19). The costs of communication between individuals increase with the number of people involved in a project. This statement leads to 'Brooks law'—'adding more people to a late software project makes it later'. Brooks recognized that one of the major problems in software engineering was that programme managers did not leave enough time for debugging. Brooks suggests that software teams be kept small and intimate; project activities need to be rigorously documented with a clear division of labour; and there needs to be frequent status reporting between project team members. In general, projects teams need to hustle and sustain the integrity of the original project by avoiding addition of unnecessary features or extending the scope of the project. He also recommended that software teams need to devote greater time to debugging, a task that is often underestimated in project design, and programmers should look for opportunities to reuse existing software as much as possible. His work calls for managers to have the courage to ask for realistic budgets and time for software development and to learn to live with failures along the way to the final outcome. Although Brooks saw great potential for improvements in software development, especially through object-oriented programmes, there remains a deep and profound scepticism about the effectiveness of managers to manage and complete complex projects. Problems in software engineering will continue because 'software systems are perhaps the most intricate and complex (in terms of number of distinct kinds of parts) of the things humanity makes' (Brooks 1995: 250).

Brooks' work has been highly influential since its first publication in 1975 and has helped to spawn significant changes in software design and development, including open source and wider beta testing. It has also helped shaped project management in other areas of practice, bringing to the fore issues of uncertainty, system design, and communication in the design and management of projects. Since

complex projects are still confronted by uncertainty, over-optimistic developers, and complex communication patterns among participants, managers will continue to be seduced by the mythical man month, regardless of whether the measure is useful.

## Encouraging Successful PSI

PSI has considerable potential advantages, but also many difficulties and commonly fails. So what can firms do to make PSI successful? PSI requires firms to be both creative and controlled, to share information, but also to protect it as a major source of competitiveness, and to respond to existing market demands as well as produce differentiated products and services using novel technological advances. The complexity of the PSI and the difficulties firms have in dealing with it have invited a huge literature on the subject. In the automobile industry alone, for example, major studies in the 1990s such as Womack, Jones, and Roos (1990) and Clark and Fujimoto (1991) produced enormous detail on the process of producing new cars.

One of the features of successful PSI is continuing effort—it is always unwise to rest on one's laurels. The continuous innovative efforts of a software company—id Software are described in Box 7.6.

### Box 7.6 Continual innovation—the case of id Software

id Software, which was founded by John Carmack and John Romero in Texas in 1991, has become one of the most innovative and successful computer games developers. id Software is responsible for the development of the popular games franchises: Doom, Quake, and Wolfenstein, available on a variety of platforms. In 1992, it developed Wolfenstein 3-D, one of the first games with first person shooters. The game involved a series of missions where individuals travelled through buildings killing Nazis and their attack dogs. The game was banned in Germany because it contained Nazi images, and was subsequently adapted for the German market. Wolfenstein 3-D was one of the first games to use 3-D gaming graphics, based on a technique called ray casting, a type of ray tracing. Ray tracing is a method for rendering images in 3-D, involving tracing the path taken by a ray of light through an image calculating reflection, refraction, and absorption as it meets other objects. The Wolfenstein 3-D approach had many advantages over past efforts, but the images produced were relatively simple, lacking texture and complexity in the look of background objects.

Building upon the success of this product, Doom was launched in 1993 and became a seminal title in the games industry. Doom combined 3-D graphics with a violent first person shooting format and it could be played over a network with and against friends. It was available as a shareware file and was used by 15 million people. It helped to create a subculture of games players, and multi-player tournaments. Further releases—Doom II and Hell on Earth in 1994, and Final Doom in 1996—helped to sustain the popularity of the game. In 2004, id Software released Doom 3, using the same story as the original Doom, but incorporating a modern graphics package. The success of Doom in part was based on technological innovation in graphics, such as binary space partitioning. This method increases the efficiency of rendering digital objects and creates a much richer environment in the game, allowing objects to differ in height, have full texture, and varying levels of light. It also enables players to move around in the games space, encountering dark areas. To enable these images to work, id Software used a flat 2-D area rather than a true 3-D space. The game also had a modular structure that allowed users to replace game content by loading their own modifications, such as new maps and weapons.

Building upon the success of Doom, in 1996, id Software released Quake, another game with first person shooter format. It contained a range of innovations, including a soundtrack by Trent Reznor of

Nine Inch Nails. Quake was the first game with true 3-D space and it used dynamic light sources, ensuring that background light changed as the player was in motion. Many of these innovations were only possible because of improvements in video card technologies in PCs. Quake also incorporated a technique called surface caching. This approach involved the program lighting the surface of objects independently of viewers and storing them in the cache of the computer. This technique allowed the game to operate quickly on early Pentium computers whilst providing rich visual images. Quake was further developed in subsequent years to allow multi-player games over networks, leading to the creation of community of players called Quakeworld.

id Software's success was built on its superior technology and its ability to allow users to modify the game. The firm has the philosophy of only releasing games when they are 'ready' and relying on a single signature: the first person shooter. The success of these games has made John Carmack a superstar in the games-developing community. Carmack has used the proceeds from Doom and Quake to move into rocketry and is attempting to develop a space tourism business.

For more information about id Software, please see Kushner 2003.

It is sometimes assumed that innovation is more a feature of manufacturing rather than services firms. Many services firms, however, display the processes and practices used in managing innovation in manufacturing firms as demonstrated in Box 7.7—Innovation in Services—the case of Citibank.

#### **Box 7.7 The development of new services: the case of Citibank**

Good practices in the development of new products also apply to the development of new services. This is clearly seen in the case of Citibank, one of the world's oldest and largest banks, and the world's most profitable financial services firm according to Forbes Global 2000. It is a key player in the financial area, servicing over forty-four of the *Fortune* 50 largest companies. Whilst Citibank is an extraordinarily well-resourced and successful company it undoubtedly suffers innovation failures. These include difficulties with IT systems, which are inevitable given their complexity, but its successful service development practices show many of the features of organizational, technological, and strategic integration found in respect of new products.

To improve customer satisfaction, Citibank has investigated and applied manufacturing management approaches to its services environment. Methodologies, such as cycle-time-reduction and Six-Sigma methods to detect defects, are implemented globally by empowered teams, which the company claims has resulted in significant improvements in process time-lines, cash management, and customer loyalty and satisfaction. Citibank has over 200 million customer accounts in more than 100 countries, with total assets of nearly \$1.6 trillions, and just below 300,000 employees. It is the largest provider of credit cards in the world. Its consumer finance division, Citifinancial, is the largest consumer finance company in the world and its retail bank is the third largest in the USA. The credit cards, retail banking, and consumer finance businesses together constitute Citibank's 'Global Consumer Group' (GCG) contributing more than half of all profits. If it were a separate company, GCG would still be in the top 10 most profitable companies in the world with 200,000 employees in more than 50 countries operating more than 13,000 customer locations and offering round-the-clock Internet- and telephone-banking services.

Banking is an industry where many large players offer similar products (deposits and loans). A major way of distinguishing between brands or institutions is through the perceptions of customer service and the technology that facilitates it. Citibank's business strategy calls for the use of technology-based products and services to take advantage of the changes occurring in financial services, most notably the emergence of virtual banking and e-commerce. The company and its predecessor organizations used the 'diversified financial services business model' of conglomerating many types of finance companies to hedge against the business cycle and create less earnings volatility. The focus of Citibank, however, has changed towards more organic revenue growth. This is to sell more products rather than focusing on acquisitions and cost-cutting alone to increase profit. Citibank uses the 'innovation catalyst model' to drive organic growth and capitalize on synergies created by a string of acquisitions (Tucker 2003).

The effort is led by chief country officers, working with a full-time 'innovation catalyst' who expedites the process. Many new ideas come from structured 'ideation' sessions with clients. Innovation catalysts work closely with 'magnet teams'—locally empowered, cross-functional groups of senior executives—which regularly meet to review ideas. The innovation catalyst model has been so successful that in one Asian country the magnet team meets every week, and in Trinidad it was responsible for 30 per cent of total revenues (Tucker 2003). The company continually works on a range of innovations from new remittance services to contactless payment systems.

Citibank patents its developments. It had eighty-one patents in the period 1991–2003, fifty-four of which are Class 705 patents in the USA patent classification, commonly referred to as the 'business method' class or 'computer-implemented business method class'. Even though Citibank is not listed in the top 10 patenting firms in business methods, its patents are highly cited, which indicates their technological importance, high value, and licensing opportunities (Wu 2005).

e-Citi is the business unit created in 1997 to pioneer electronic financial services and e-commerce solutions for customers by taking advantage of the Internet and new technologies to create content, extend delivery channels, and customize transactions. Citibank has a bold plan to increase its customer base tenfold, to 1 billion clients by 2012, and innovative projects, such as Banking on Wireless, geared to help its global customers pay bills, trade stocks, and access accounts using mobile phones and PDAs. Digital television is central to this plan. Other initiatives in Citibank include the launch in Singapore in 2006 of the world's first biometric credit-payment solution; MasterCard PayPass, a 'contact-less' payment program that provides consumers with speed and convenience and security by 'tap and go' payments made through Near Field Communication (NFC) enabled mobile phones; introduction in 2007 of a MasterCard PayPass-based keyfob for its debit card customers, and eventually for its credit card customers, and the piloting of an innovative, real-time person-to-person mobile payments service.

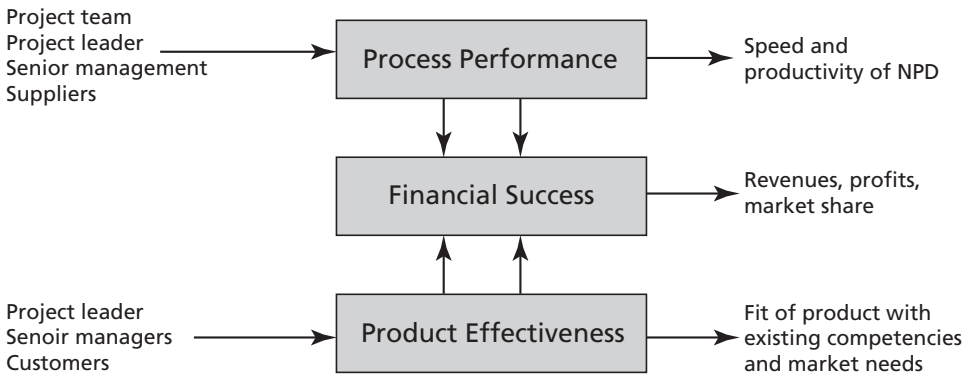
Citibank has succeeded in building a reputation for technological innovativeness over the years. It employed 2,225 technologists in the USA in 2005. The significant role of technology in the customer experience led to the creation of its own heads of Operations and Technology (O & T) for both North America and international businesses, working closely together. Examples of its innovativeness are seen in the way the company took the lead in the development of automatic teller machines (ATMs). In 1999, it pilot tested 'talking' ATMs in California. The screen reader technology behind the talking ATM is the same technology Citibank has made available on its Internet home-banking service—Direct Access. Adapting screen reader technology to ATMs is part of its effort to work with visually impaired customers. The company uses technology extensively in its training activities. The Virtual Classroom e-Learning solution, for example, piloted in UK in 2001 and expanded to other areas of its business, is used to update skills to ensure that its staff have the knowledge and ability to implement the latest technologies.

One of the reasons for the technological focus of the company is the complexity of its global operations. Its Global Transaction Services (GTS) handle more than 1 billion transactions annually, processing more than \$3 trillion in funds each day. GTS leads the industry in its Web-based corporate banking platform (CitiDirect Online Banking), which interacts with 149 Citibank branches and is available to clients in 22 different languages.

Technology also assists with security, essential support for the company's strategy to deliver information over the Internet. In 2000, Citibank Worldwide Security Services (WWSS) built a 'Global Custody' data warehouse, to consolidate information from its global network of securities processing and accounting systems. It provides a means of making data available to both customers and employees worldwide. It also provides the framework for consolidated data storage, information systems needs, and management information and is the central repository for customer information, including holdings, transactions, securities, foreign exchange, and corporate action information.

Citibank has a Chief Innovation Officer—Amy Radin—in its GCG, overseeing innovation strategy (see Box 4.10). She says that 'As a leader in innovative products and services, Citigroup continually looks for ways to make the lives of its customers easier.' Part of the role of the Chief Innovation Officer is an 'Innovation Initiative' aimed at putting the right metrics in place. Citibank used to measure revenues derived from new products, but that was deemed insufficient. A special task force was mandated with coming up with more meaningful metrics that could be used to track progress and be integrated into a balanced scorecard (see Box 4.11), and ultimately tied to senior manager compensation. The team eventually settled on twelve key metrics, including: new revenue from innovation, successful transfer of products from one country or region to another, the number and type of ideas in the pipeline (and expected new revenues), and time from idea to profit.





**Figure 7.2.** A model of new product performance

Source: Brown and Eisenhardt 1995.

As Brown and Eisenhardt's (1995) model shows (see Fig. 7.2), it is important to distinguish between process performance (how efficient the firm is at developing new products and services) and product effectiveness (is the firm producing the right products and services). The latter is essentially a strategic issue and was examined in Chapter 4. The rest of this section will focus on those factors that improve process performance, including internal organizational integration, human resource management issues, and the tools and techniques of project management.

## INTERNAL ORGANIZATIONAL INTEGRATION FOR PSI

Close organizational integration of PSI is critical to its success. The best international benchmarks of PSI performance include Japanese auto and electronics companies, such as Toyota (whose practices are being emulated around the world) and Sony; small US high-tech companies typified by those in Silicon Valley, and larger corporations, such as 3M, which structure themselves to encourage entrepreneurial activities.

There are similarities in the PSI processes of large Japanese firms and the model found in smaller high-tech firms. These include the way PSI is focused in a comparatively small group that is intensely interactive and committed. This organizational model is particularly conducive to information-sharing and good communications. This form of organization includes the functional integration of teams 'concurrently engineering' new products and services. In the 1980s, Imai, Nonaka, and Takeuchi (1988) used the analogy of a relay race to describe western new product development, with each function (marketing, R & D, manufacturing) becoming involved sequentially—one player 'passing the baton' to the next. In contrast, they use the analogy of a game of rugby to describe Japanese new product development, with the various functions with different capabilities simultaneously attempting to reach the same goal. Rugby attracts a wide

range of players with very different body shapes and physical abilities and they are collectively responsible for taking the ball up the field. Concurrent engineering is now commonly practised in US firms, with companies, such as HP, substantially reducing the development time of new products through its use.

Effective managerial and organizational integration includes the minimization of reporting layers and the encouragement of multifunctional and cross-divisional links between R & D, operations, and marketing. While there are many advantages in using the flat, organic organizational structures seen in Japan, these structures are very different from and challenging to bureaucratically organized large firms in other countries. However, the success of Japanese new product development processes has led to emulation in other parts of the world (Lester 1998), and many US and European firms (e.g., DuPont, Siemens, BMW, and Motorola) have adopted the principles of concurrent engineering. Boeing, for example, developed a new philosophy called 'Working Together' to reap the benefits of organizational integration in the development of the 777.

Lockheed developed a well-known method of avoiding the large firm bureaucratic trap and closely integrating the new product development process—the Skunk Works—(see Box 7.8).

#### **Box 7.8. Lockheed's Skunk Works**

Founded in 1943 in Los Angeles, Lockheed's Skunk Works was one of the premier developers and manufacturers of military aircraft in the twentieth century. The Skunk Works designed and built the *U2 bomber*, the *SR-71 or Blackbird*, and *F-117 Flying Hawk or Stealth Fighter*, three iconic Cold War aeroplanes. The success of Lockheed's Skunk Works helped bring to the fore the advantages of dedicated, independent facilities for product development. Lockheed's Skunk Works acquired its name because it was first housed under a circus tent located next to a smelly plastics factory. It was originally called the 'Skonk Works,' named after an outdoor still in the popular *L'il Abner* comic strip. But after being contacted about copyright infringement by the publisher of the comic, it changed its name to the Skunk Works, a name Lockheed trademarked and copyrighted in the 1960s.

Led by a hard-driving and brilliant engineer, Kelly Johnson, Skunk Works focused on the development of new generations of aeroplanes to give the USA critical advantage over the USSR in the Cold War. The first aeroplane developed by the Skunk Works was the *P80 Lightning*, the first US-made jet fighter with a propeller. It went into service over the skies of the Pacific in 1945, after being designed and constructed in a crash programme of only 143 days. To get the project up and running, Johnson recruited a small team of engineers and mechanics from inside Lockheed. The plane was designed with a tight budget under the highest secrecy, with little or no contact with other parts of Lockheed. This approach was encapsulated in Skunk Work's strategy of 'be quick, be quiet, and be on time'. The team borrowed parts of other existing planes, a Skunk Works practice of building on existing components for speed and cost saving.

One of the most successful early Skunk Works projects was the *U2*, which became operational in 1955. To gain insight into the USSR's nuclear capabilities, the CIA funded a secret programme within Skunk Works to design, manufacture, and operate a high-altitude plane that could penetrate Soviet territory and take pictures of ground installations. The USA at the time was increasingly concerned that a 'missile gap' was developing within the USSR. The *U2* was designed to travel at 70,000 feet, above Soviet radar and the range of their jet fighters. It was a lightweight plane with long graceful wings, made from aluminium to reduce weight. Working with Polaroid, cameras were developed to take detailed pictures of a 200-mile strip of land below the flight path. New fuel had to be developed because normal aeroplane fuel would freeze or boil off at high altitudes. Shell developed a special low-vapour kerosene fuel (leading in 1955 to a national shortage in the USA of insect spray based on a similar compound). Over the next five years, the *U2* flew over the USSR many times, provoking the ire of Soviet leaders. Eventually, the Soviets developed countermeasures and in 1960 shot down a *U2*, piloted by Gary Powers. The *U2* remained in service for



many years afterwards flying over China, North Korea, and Cuba. The Cuban Missile Crisis of 1962 was precipitated by a U2 flight over a Soviet missile installation on the island.

In the mid-1960s, the Skunk Works developed the next generation of spy planes: the SR-71 or *Blackbird*. This aeroplane was truly revolutionary, flying at Mach 3.2 at 85,000 feet above the earth. Its construction was a major challenge for the Skunk Works team, requiring the development of new materials and electronic systems. As aluminium loses its structural integrity at 300 degrees and the new aeroengines generated temperatures of 1,200 degrees at full operating power, a new material was required. The Skunk Works team decided to use titanium, a first in aviation. The only US-based supplier of titanium, however, was unable to manufacture it in large quantities. There were also no tools available in the market for cutting, drilling, and shaping titanium. Eventually, the CIA obtained titanium through secret channels from the USSR. Developing the tools to shape the material was more challenging. Titanium is extremely susceptible to corrosion from contact with other materials. A drop of chlorine has the same corrosive power as an acid on other materials, so a single drop of normal tap water could ruin a titanium part. As a result, the Skunk Works team had to spend millions of dollars to develop a new range of tools suited for use on titanium. In addition, because of the high temperatures involved, the usual avionics—electronic controls—did not operate. The team had to develop a whole new suite of electronic systems. Using a special coating laced with asbestos, engineers were able to disguise the signature of the aeroplane on radar, making it the first to use Stealth technology. The *Blackbird* went into service in 1964 over Vietnam and was eventually fitted out with missiles and bombs. It provided detailed photographic images of a range of ground targets and was impossible to shoot down using contemporary military technologies. It set world speed records, travelling from Los Angeles to Washington in sixty-three minutes. It remained in service until 1990 and it is the only aeroplane in US Air Force history not to have been shot down by enemy fighters during its period of service.

In 1975, an engineer in Skunk Works read a scientific paper from a Russian scientist that included a new set of formulae for calculating the signature of different flat shapes in radar. This information allowed the Skunk Works team to create a software program to calculate the radar signature of any two dimensional shape. Using this information, the team set about designing an aeroplane based completely on flat triangle sections, similar to a diamond. If the shape were right, it would be 'invisible' to conventional radar. This was the birth of the *F-117 Night Hawk* or Stealth Fighter Bomber. Using a wooden prototype, Skunk Works engineers were able to demonstrate this shape was 1,000 times less noticeable on radar than a small drone. On the basis of this breakthrough, Lockheed was awarded a contract in 1976 to build two experimental aeroplanes. This required them to overcome the extreme scepticism of a disbelieving US Air Force, which sent an MIT professor to retest the prototype. The project was 'black': that is, surrounded by the highest-level security. As usual, the Skunk Works team worked quickly, borrowing parts from past aeroplanes. The Stealth Fighter Bomber took its maiden test flight in December 1977. The success of the prototype flying against US radar installations convinced the Carter administration to place an order for two fleets of Stealth fighters and bombers. This led to the rapid expansion of Skunk Works, creating new problems for security. The early 1980s also saw an expansion of the military aerospace industry and Skunk Works found it difficult to recruit skilled labour. The expansion reduced the quality of production, leading to expensive and dangerous defects. The aeroplane slipped a year behind schedule, and the first test flight of the production model *F-117 Night Hawk* took place on 18 July 1981. The Stealth Fighter Bomber provided a huge boost for Lockheed, producing \$6 billion in sales. It was designed to penetrate enemy airspace to launch early strikes against highly defended targets, such as radar installations and surface-to-air missile launchers. It was put into action in 1991 during the first Gulf War, penetrating Iraqi airspace and bombing targets with impunity. Each Stealth aeroplane costs \$43 million.

All three projects show the characteristics of what made the Skunk Works such a successful innovator and, although in a military context, hold broader lessons. First, Skunk Works engineers focused on solving problems that were foremost in the minds of their customers, such as the CIA and high-level political officials. By creating technologies that enabled them to gain new information about their enemies, they were able to secure the trust and confidence of a generation of US military and administrative personnel. This trust was essential to ensure support for future high-risk projects. Second, Skunk Works operated under Kelly Johnson's '14 rules', creating its unique product development culture. These included maintaining independence, small project teams, high security, limited administration, strict cost controls,

absolute trust between clients and Skunk Works, limited outsider access, and individual pay related to performance and not numbers of people supervised. These rules were enforced by a strong internal culture of inventive problem-solving or 'skunking'. In addition, there was tight integration among design, manufacturing, and testing activities, with engineers working hand-in-hand with machinists on the one hand, and test pilots on the other. Although this level of introspection and autarky is counter to many of the open and collaborative practices described in Chapter 4, they proved highly effective in Lockheed's circumstances. Third, Skunk Works projects worked on the basis of prototyping, developing low cost, working models that could be used to experiment with and learn from. Not all Skunk Works projects succeeded. Its attempt to develop a hydrogen-powered plane was a disaster and, although a working prototype of its Stealth boat (the *Sea Shadow*) was made, it did not meet the Navy's requirements. The success of Skunk Works led other firms, including Lockheed's competitors, to adopt this organizational form for product development. The military context of these lessons has to be recognized: the company was operating during a period of extreme political paranoia and actual warfare, where motivation and budgeting processes differed from normal business circumstances. It was designing products efficient at surveillance and destruction of people and property. Yet in some situations it remains a powerful model for ensuring the speedy design, production, and operation of high-quality, innovative products. Formula 1 racing teams and some car companies use similar approaches, for example, Chris Bangle, head of design at BMW, created a 'fortress' around his design team to protect them from adverse comments and to shield new ideas from early release in the outside world (Bangle 2001).

The case also offers some insight into the global nature of knowledge and technology. Lockheed accessed titanium for the *Blackbird* and the science behind the Stealth bomber from Russia—the USA's foe during this period of the Cold War.

*Source:* Rich and Janos (1994). To learn more about the Skunk Works and to see Kelly Johnson's fourteen rules, please visit [www.lockheedmartin.com](http://www.lockheedmartin.com).

3M uses different organizational structures for the development of the different types of product that achieve its vision statement: 'To be the most innovative enterprise in the world, and be the preferred supplier' (see Box 7.9). Its view of PSI development follows that of Prahalad and Hamel (1994), who distinguish between firms that develop products that customers do not want, those that develop new products customers do want, and those that develop products customers do not know they want. To develop products customers want, 3M uses an organizational structure with a high level of discipline, accurate schedules, and usually a large team, with a low-risk/low-failure profile. To develop new technologies that may develop products customers do not know they want, 3M uses creative individuals, with little management involvement, operating with a high-risk/high-failure profile encouraged by the '15 per cent rule' described earlier.

Successful PSI almost always requires close integration with the marketing function. Successful innovative firms have a strong market orientation, with an emphasis on satisfying user needs and creating product advantages, such as unique benefits, high quality, attractive price, or innovative features. (Generally, new products and services succeed when emphasis is placed on economic benefits rather than technological novelty.) Good-quality information from the market is essential for understanding these user needs (see Chapter 5). It is important to understand buyer behaviour and customers'

purchase decision processes, for example, in the balance of price/quality/delivery-time sensitivities. Some companies have a targeted sales strategy of identifying early and high-profile adopters—Rogers’ Innovators (see Chapter 3), who can then be cited in sales literature. Lead users and tough customers can be particularly important and influential in generating dominant designs because they are able to articulate their performance and functional requirements in such a way as to focus design choices on clear specifications, which can lead to product differentiation (see Chapter 5).

The level of attention to customers is seen in one of 3M’s key corporate values of satisfying customers with superior quality and value by:

- Providing the highest quality products and services consistent with their customers’ requirements and preferences.
- Making every aspect of every transaction a satisfying experience for their customers.
- Finding innovative ways to make life easier and better for their customers.

## EXTERNAL COORDINATION FOR PSI

When customers are involved in the development of a PSI they can valuably place demanding conditions on the development team. Tough, demanding customers usually

### **Box 7.9 The dangers of listening exclusively to marketing departments: the Post-it note**

Every company has its ‘war stories’ of corporate events, and individuals have their own selective memory of how things occurred. With these provisos, this is an account of 3M’s development of the Post-it note, related by one of the key personnel involved.

The key innovation in the Post-it note is the adhesive—the clever, non-sticky glue. In 1970, Spencer Silver, a researcher in one of 3M’s laboratories was working on a project to develop a new, strong adhesive. Instead of producing a superglue, one of the prototypes was even weaker than 3M’s existing products, yet it appeared to stick to other objects and could be easily lifted off. Initially, the development team did not know how best to use the adhesive and they covered noticeboards with it to which people could attach pieces of paper and messages. Four years later, another 3M scientist, Arthur Fry, remembered Silver’s results when he was singing in his church choir and was thinking of a solution to stop the paper markers in his hymn book falling out. Fry tried some of Silver’s glue on the markers. After experimenting with putting the glue on boards, the idea of putting the glue on a small note eventually came up and was suggested to the marketing department. After conducting market research, the department said there was no demand for the product. The development team persisted and the marketing department twice more rejected the idea. Someone in the development team had the idea of sending the prototype notes to all the secretaries of 3M’s top managers. Shortly afterwards, secretaries began to telephone to ask for more stock. The development team redirected the enquiries to the marketing department, and the marketing department quickly learnt that there was a demand amongst some of the most influential people in the company. The product was launched thereafter.

Another example of the marketing department being overruled is provided by Sony’s 300 different versions of the Walkman. These versions were not developed in consultation with the marketing department, but were produced and examined to see which models sold (Hayes and Pisano 1994). Such cases, however, are exceptional, and more commonly strong marketing input is needed in the PSI process.

produce good designs. Rolls Royce, for example, attributes the success of one of its most successful aeroengines—the RB211—to the demanding requirements of Boeing (Gardiner and Rothwell 1985). Links with customers continue after the products and services have been purchased. Efficient after-sales service not only keeps customers happy, but also allows sales and service staff to become a major source of information on future improvements.

It is difficult to imagine a more demanding customer than a top chef. Box 7.10 provides an example of a company that works with leading international chefs to develop new products.

Integration with the operations domain is also important. In innovative firms this domain provides high-quality and well-planned production and delivery sequences with great attention to quality control, consistent meeting of targets, and flexible production sequences to respond to changing customer requirements (see Chapter 8). Innovative firms have close proactive links between product, service, and process development.

#### **Box 7.10 Innovating in watercress**

Koppert Cress is a small, specialized food company situated in Monster in the heart of the 'greenhouse valley' of The Netherlands. It is a supplier of what it calls 'architecture aromatique', producing a range of watercress, edible flowers, spices, and aromatic herbs to restaurants around the world. It has developed a new range of extravagantly colourful watercress, such as Shiso Purple, and watercress with unusual flavours such as mustard, chocolate, and lemon. Its products are grown in hydroponics with seeds set in special paper imported from Sweden. Koppert Cress has a strong focus on innovation, and attempts to develop at least five new varieties of watercress each year. Its development model is based on the principles of 'flavour', 'colour', and 'health'. While flavour and colour were especially important in the past, health is now becoming more vital (watercress contains several vitamins). It supports this goal by having an informal culture, encouraging staff to relax, have fun, and try new things. Like many small firms, it has no interest in moving into large-scale production, and wants to remain a niche supplier.

It sells its watercress all over the world, especially to the gourmet restaurants of Tokyo, London, and New York. Typical customers include Michelin starred chefs: the most-demanding users imaginable. The top restaurant business is very competitive, and novelty is highly prized. Star chefs compete on ingredients as much as they do on recipes or in preparation, and access to new and exciting ingredients can help stimulate interest in a restaurant. Instead of relying on the formal food market, Koppert Cress creates its own demand by identifying chefs from guides to top restaurants and then demonstrating products on-site. It does not supply the product directly to customers; rather it asks chefs for the name of their primary supplier, and then follows the distribution chain back to the point where it can insert its products. This may sometimes involve five separate steps in the chain to locate the right provider. Distributors and wholesalers cooperate because they get more business. This system has advantages for Koppert as it limits logistics requirements. The price for the final customer can be very high, however, as different supply-chain intermediaries each charge a mark-up.

One of the challenges of developing innovative new food products is gaining acceptance and finding recipes that use them. To encourage uptake of new products, Koppert Cress has developed 'Cressperience', an on-site facility with a full kitchen where chefs develop and experiment with new uses of cress. This provides a chance to learn from demanding user experiences, enabling it to test and think of new products that meet the chefs' desires for more colour, flavour, and more healthy attributes in their cuisine.

To learn more about Koppert Cress, please visit their website at [www.koppertcress.nl](http://www.koppertcress.nl).

As Pisano and Wheelwright (1995: 93) put it, 'it is not only possible to excel at simultaneously developing new products and new manufacturing processes but also necessary'. New products have to be designed for production—that is, they have to be capable of being made and delivered as efficiently and cheaply as possible. A story circulates about a famous British chemical company that built a pilot plant for a new polymer. As a result of a combination of unexpected events the polymer solidified, seizing up the plant. The production engineers contacted the scientist who had developed the polymer and learnt that he too had experienced the problem. Mightily relieved, the engineers asked what he had done to solve the problem. They probably did not want to hear his answer: 'I smashed the test tube.'

There are many benefits from having close relationships between the development and engineering activities of a firm and operations, marketing, and other domains. By having the engineering department physically located on manufacturing sites, engineers have a good level of practical knowledge about operations. And the relationship facilitates a close interchange of information between those responsible for product design and those responsible for the manufacturing technology, ensuring 'design for manufacture'. Pisano (1996) showed that in the case of pharmaceuticals, attention to manufacturing at early stages of drug development could speed up the time of drug development and eventual success of the product in the market. Pisano referred to this integration of manufacturing and product development as 'learning-before-doing', enabling firms to plan ahead for the processes of production while a product is still being developed. Early investments in 'learning-before-doing' can help to lower costs on manufacturing process when a drug leaves trial stages and is sold commercially.

There are advantages in extending the close liaison between PSI efforts and operations to links with shop-floor workers or front-office staff. After Ford had designed the Taurus, 120 assembly workers were brought together to build 200 prototypes of the car. They suggested no less than 700 improvements in the design to assist manufacture. Similarly, integrated PSI activities have to include financial managers. Finance teams can offer valuable advice on R & D and operations, and there are advantages in involving them in the planning of research-intensive periods of projects. Basically, successful PSI requires coherence and coordination across all levels of a company's activities. Clark and Fujimoto (1991: 7) argued that

[W]hat seems to set apart the outstanding companies in product development is the overall pattern of consistency in their total development system, including organizational structure, technical skills, problem-solving processes, culture, and strategy. This consistency and coherence lie not only in the broad principles and architecture of the system, but also in its working level details.

## MODULARITY, PRODUCT FAMILIES, AND PLATFORMS

Research into PSI has shown the value in having ‘families’ of related products, which build on core technologies and have the flexibility to adapt to changing customer requirements. Various terms are used to describe this practice, ranging from ‘robust designs’ (Rothwell and Gardiner 1988) to ‘product platforms’ (Meyer and Lehnerd 1997). A classic case of a product family is Rolls Royce’s RB211 aeroengine. The original engine was designed so that it could be ‘stretched’ into different product configurations. Engines could be offered with improved performance (increasing thrust), re-rated (taking advantage of technical advances), or de-rated (reduced thrust for improved fuel economy). Rolls Royce developed the concept of the product family further in their next generation of ‘Trent’ engines.

Box 7.11 provides an example of Sony’s approach to the Walkman product family.

### Box 7.11 The Sony Walkman product family

The hugely successful Sony Walkman provides an example of an effective approach to the management of a product family—management practices that since their introduction have led to continuing market leadership. The Walkman was launched on 1 July 1979 allowing users to listen to their personal choice of music whilst on the move. It has continually evolved since then, including formats such as the Discman and Minidisc, and currently includes an MP3 range and is incorporated into Sony-Ericsson’s mobile phone range. Sony sold 100 million units between its launch and 1992.

Sony’s strategy employed a judicious mix of design projects, ranging from large team efforts that produced major new model ‘platforms’ to minor tweaking of existing designs. Throughout, Sony followed a disciplined and creative approach to focus its subfamilies on clear design goals, and target models to distinct market segments. Sony supported its design efforts with continuous innovation in features and capabilities, as well as key investments in flexible manufacturing. Taken together, these activities allowed Sony to maintain both technological and market leadership.

Based on their study of the Walkman, Sanderson, and Uzumeri (1995) suggest that there are four tactics of product planning that may be applied to other manufacturers of incrementally improving products.

- Sony pursued a variety-intensive product strategy, developing a large number of models and often pre-empting the competition.
- It decentralized decision-making about new products. Design teams were cross-functional and changes were periodically led by industrial designers and marketers depending on the nature of the problem being faced and the quality of information they had attained (such as in the key US leisure market).
- The company used its industrial designers judiciously, so that it could exploit its creative talents for introducing incremental changes.
- Sony minimized design costs by building all models around key modules and platforms.

The use of common and related components also allowed the company’s investment in flexible manufacturing equipment to be amortized over a longer period.

Modularity and product platforms are especially important in complex products and systems. A number of related strategies have emerged over the past twenty years that



assist firms in managing the design of modules and components and their integration into complex products and services. These techniques focus on Simon's (1996) decomposition of products into modules or subelements, and are used in a diverse range of industries from automobiles to off-shore oil and gas platforms, the development of aircraft, and the production of consumer electronics equipment. The electronics industry, for example, has evolved in a way that means the success of one company supplying components—for example, DVD drives—depends upon the activities of other firms, in a complex web of interconnected suppliers, feeding an integrator—for instance, Toshiba, Sony, or Apple—which assembles the final product. In these industries, firms need design strategies that allow them to link innovation in their particular modules with technological changes happening in other component parts. Cusumano and Gawer (2002) argue that firms such as Intel, Microsoft, Nokia, Cisco, NTT, and DoCoMo, need strategies to coordinate internal design processes with a vision that extends beyond the immediate technical specification for a particular component, focusing on how modules might be used in the wider industry. Innovation in component design often involves combining existing technologies in new ways and applying them to new problems. To develop satisfactory solutions, firms need deep knowledge of different technologies and components and how they fit together (Staudenmayer, Tripsas, and Tucci 2005).

In the development of complex products and services, systems integrators coordinate the overall design process. They choose components and technologies, specifying the interfaces between different systems and combining new components with different vintages of technology (Brusoni, Prencipe, and Pavitt 2001). Design rules have evolved that assist this coordination, linking design decisions with systems analysis and project management (Eppinger et al. 1994; Anderson, Pohl, et al. 1998; Eppinger 2001; Baldwin and Clark 2000). Relationships between components and the dependency of one part on another are often represented in a matrix showing the overall product system, listing constituent subsystems and the patterns of their interaction, interfaces, and dependency on one another. The Design Structure Matrix (DSM)—sometimes known as the Dependency Structure Matrix—is one example of such a tool. It recognizes that design is an information-intensive, iterative process and that in many instances the outcome is difficult to specify before the process begins. Such tools provide a framework to assist participants in reaching a consensus about priorities and relationships. This has proven to be valuable in eliciting and sharing information during PSI and it can increase the value-added by design (see the discussion on design later).

## HUMAN RESOURCE MANAGEMENT AND PSI

The truism that success in business is people centred also applies to PSI. In addition to the creative scientists and engineers discussed previously, PSI needs good managers.

While formal management techniques can enhance the performance of average managers, they are no substitute for high-quality managers who are expert at managing people and change. There is a need for dynamic, open-minded managers who exercise ‘subtle control’ by formulating and communicating a vision of a distinctive, coherent, product concept and delegating sufficient autonomy to encourage motivation and creativity (3M calls the latter a ‘permissive attitude of managers’). Success in PSI often depends on a negotiated balancing act between strategic product vision and tactical problem-solving, and managers have to be able to do both.

Managers need to be good at a variety of activities, including:

- Managing teams, some of which can be very large—the Ford Taurus team, for example, was 700 strong.
- Establishing clear policies and guidance about technical matters and coordinating technical/design issues.
- Boundary-spanning/communications with other domains, particularly with operations and marketing.
- Lobbying/being an ‘ambassador’.
- Gaining, protecting, and managing resources and IPR.
- Creating an ‘impression’.
- Along with top managers and product champions, creating a ‘vision’ and clear set of goals for the new product.

Managers also need to be confident of top management commitment to, and visible support for, innovation. Studies have long shown the importance of enthusiastic and powerful project or product ‘champions’ or sponsors (with significant decision-making responsibility, authority, and high hierarchical level) (Rothwell et al. 1974). So, for example, the team that designed the Ford Taurus wanted to make the car’s body from a single sheet of steel rather than welding two pieces together, thereby reducing welding and air noise, and producing greater rigidity and better-fitting doors. The manufacturing function balked at the price of a new 7,000-ton press costing \$90 million. The Taurus team eventually persuaded the company’s chairman to make the investment, despite his reservations about the cost. However, he believed strongly in the new car and was a driving force behind it.

A significant human resource management (HRM) challenge is, therefore, to attract, reward, and retain talented managers and, through commitment to human resource development and training, to improve the management skills of personnel involved in PSI (see Box 4.10—The Role of the Innovation Director). There is evidence that attention to ‘high-performance’ HRM practices can significantly shape firm-level innovativeness. In a study of 1,884 Danish manufacturing and service firms, Laursen and Foss (2003) found that firms that adopted a bundle of complementary HRM practices were more likely to develop world-first innovations. These practices included:



- Interdisciplinary work groups.
- Quality circles.
- Systems for the collection of employee proposals.
- Planned job rotation.
- Delegation of responsibility.
- Integration of functions.
- Performance-related pay.

They are often used in combination with one another and together they provide a powerful workplace for supporting innovation.

There are a variety of incentives available to encourage good managers, ranging from financial rewards, including salary increases and stock options (favoured amongst small high-tech firms), to peer recognition (seen in the case of 3M and its prestigious Carlton Society Awards). At one stage, Oxford Instruments, a scientific instruments company in the UK, encouraged managers who developed new products to spin them off as related companies with the manager as CEO.

Mechanisms to ensure functional and organizational integration include in-house, on-the-job training and job rotation. Job rotation is an underemphasized, but hugely important HRM practice in PSI, and it is worth examining its role at some length. The transfer of employees between R & D and operations, and between basic and applied research, are the most important means for connecting these activities (see also Chapter 9).

The practice of job rotation encourages the receptivity of staff to new information. Staff work with colleagues from other functions as they rotate and others move into their areas. This improves the level of preparedness of staff to work with, and relate to, people outside their department and functional speciality. This high preparedness also applies, of course, to small firms generally, where functional divisions are rare and staff have to be multi-skilled. As Japanese R & D personnel progress in their careers, they work in a variety of functions, learning about corporate decision-making processes or about product planning, production, and marketing.

## PROJECT MANAGEMENT TECHNIQUES IN PSI

While rigorous planning and control are essential in stable, complex, and relatively mature sectors (such as most elements of autos and computers), they are perhaps less important in uncertain and fast-moving sectors where learning and experimentation are more suitable. In some project-based businesses, where innovation is required in large, long-term, and complex one-off projects, a combination of rigour in planning and adaptability through learning is required. However, all innovation projects require

regular appraisal and the commitment of resources to upfront screening and predevelopment activities. Two examples of project management approaches used in PSI—‘how to do it tools’ in the language of Chapter 4—are described in Box 7.12 below.

### Box 7.12 Two project management techniques: stage-gate systems and quality function deployment

#### Stage-gate systems

One well-known system of appraisal is the stage-gate system developed by Cooper (1993), and used by companies such as Exxon Chemicals, Corning, Ericsson, Kodak, Carlsberg Breweries, and P&G. Essentially, it systematizes decision-making at various stages of new product development. It involves:

- Stop/go decisions at each stage.
- Increased resource commitment at each stage.
- Evaluation by appropriate staff (with increasing levels of seniority at later stages).
- Non-partisan, fair decision-making.

In Cooper’s generic stage-gate process there are five key stages:

- *Preliminary investigation*: a quick examination and scoping of the project.
- *Detailed investigation*: more detailed consideration leading to a business case, including project definition, justification, and plan.
- *Development*: the actual design and development of the new product.
- *Testing and validation*: tests and trials in the marketplace, laboratory, and plant to verify and validate the new product, its marketing, and production.
- *Full production and market launch*: commercialization, the beginning of full production, marketing, and selling.

He adds two other stages, *idea generation* and *strategy formulation*, which are outside the actual process of PSI. A generic stage-gate process is shown in Fig. 7.3.

Gates are predefined with the established mandatory and desirable criteria that need to be met. They bring a valuable discipline to the process of PSI, not only in the sense of providing a sound basis for resourcing competing projects, but also in ensuring that marketing input is continually integrated into a process that sometimes can be driven by technological possibilities rather than customer focus.

The developer of the stage-gate system, Bob Cooper, argues that around 40 per cent of firms introducing it experience difficulties, although benefits have been achieved. The problems lie in implementation—exerting the level of discipline required. He also provides some insights into the future development of stage-gate systems designed to improve their efficiency. These encompass the following.

- *Fluidity*. Increasingly, fluid systems will emerge whereby a project can be in two stages at once. So, key activities of Stage 3 might begin before Stage 2 is completed, reducing lead times and accelerating the entire process.
- *Flexibility*. Stages will be combined, gates collapsed, and activities/deliverables omitted, especially in the case of lower risk projects. As Cooper puts it, ‘Stage-gate must be a roadmap, not a straitjacket.’
- *Fuzzy gates*. In traditional stage-gate processes, gates are either open or closed. With fuzzy gates they can assume various states in between. That is, a project can proceed into the next stage with partial information (a ‘conditional go’), depending on certain events occurring or information becoming available.
- *Focus*. Cooper’s research finds many of the problems besetting product development are the result of poor project prioritization, too many projects, and a lack of focus. The answer, he believes, lies

in effective portfolio management, which examines the range of projects being conducted and considers them in respect of maximizing value, achieving the right balance, and linking them with business strategy (Cooper 1994; Cooper and Kleinschmidt 1996). The management issues in linking stage-gate systems with portfolio management and business strategy are difficult, and are a continuing problem for many firms.

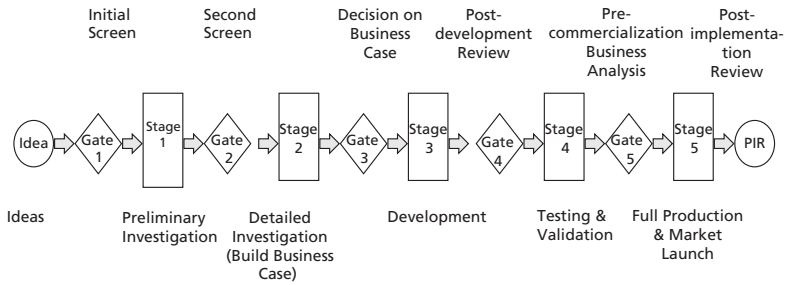
### *Quality Function Deployment*

Quality Function Deployment (QFD)—a technique to link specific customer requirements with design parameters—emerged in Japan in the 1960s as part of Japan's efforts to improve product quality (Clausing 1994; Smith and Reinertsen 1998; Ward et al. 1995). This approach was first successfully used in the Japanese automotive sector and became part of the Total Quality Control (TQC) movement. QFD starts with the definition of customer requirements. It provides a framework to structure customers' ideas or requirements and translate them into specific plans to produce goods that meet those needs. The design process begins by capturing the 'voice of the customer' through a variety of methods: direct discussion or interview, surveys, focus groups, customer specifications, observation, warranty data, and field reports. Data gathered during this process are summarized and represented on what is called a 'product planning matrix' or 'house of quality'. QFD typically focuses on three questions:

- Which attributes are of most importance for meeting perceived customer requirements?
- What design parameters will be important in achieving these attributes?
- What design parameter targets should be the focal point for the new design?

Matrices are used by the design team to translate what it is that the customers are saying at a high level into how the firm can satisfy these requirements through the development of a new or enhanced product. This translation process results in a set of technical characteristics that need to be met. QFD, therefore, is a framework for structuring ideas about what the market appears to require and converting this into how these ideas will be materialized. QFD provides a mechanism for linking people from marketing with those in technology and engineering divisions within the firm, enabling them all to participate in design. The approach tends to be most useful in focusing and agreeing upon product specification within a multi-disciplinary team, and ensuring that important design characteristics are not omitted as the design is developed. Fig. 7.4 shows a typical 'house of quality' QFD matrix. In this example from the Cambridge Institute for Manufacturing, the design team identified six attributes for detailed analysis. These include speed, quiet operation, crisp and accurate sound, cost, size, and reliability. The team established weightings to represent the relative importance of each attribute from the perspective of customers. The next stage involved defining the critical design parameters that would enable the product to meet these performance criteria and thus link them to customer attributes. In this example, the critical design parameters include: number of teeth, lubricant, tooth thickness, and manufacturing precision. The body of the central matrix was completed, with each cell representing a possible link between a design parameter and a customer attribute. A review was made of customer perceptions of the firm's existing products compared with those of competitors, and the analysis was completed by filling in the cells in the 'roof' of the matrix, which indicate the strength and direction of interrelationships among the design parameters.

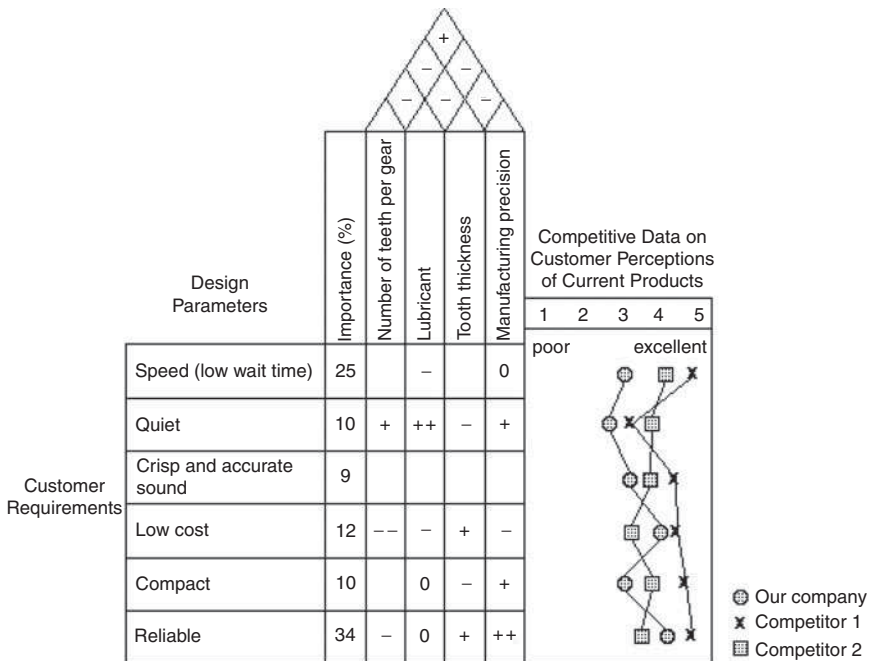
A variety of mechanisms can be used to focus staff on PSI. Perhaps the most dramatic is 3M's strategic aim of 30 per cent of sales being from products developed in the previous four years (Kanter, Kao, and Wiersema 1997). Some Japanese and Korean firms construct crises to focus the attention of the staff. So, for example, Canon originally had a simple strategic aim of 'being an excellent company in Japan'. (These slogans act as important focusing devices in Japan.) When all achievements and measurements



**Figure 7.3.** A generic stage-gate new product process

Source: Cooper 1993.

indicated that it had achieved this goal, the goalposts were moved to ‘being an excellent company in the world’, which at the time it was not. Rather than complacently accepting that they had achieved their aims, Canon staff were challenged by higher objectives. In Korea, constructed crises are a commonly used focusing device in firms (Kim 1997).



**Figure 7.4.** A typical QFD matrix linking customer requirements with design parameters

Source: Quality Function Deployment - IFM Cambridge.

## The role of design in PSI

Design is the process by which choices are made in the selection and refinement of ideas from a range of possible options arising out of creative and experimental work, R & D, and problem-solving activities. It is an iterative method of making choices that links the generation of ideas with the development of new products and services. Design involves imagination and creativity, vision and judgment about alternative options needed to create products or services, and decision-making within the constraints of cost, time, and quality. These decisions can be expressed as three questions:

- Can we afford to make or deliver this idea within our budget and sell it at a price that the market will bear?
- Can the idea be developed and delivered in a timely manner, before a competitor gets there or before it is outmoded?
- Will the quality we can provide meet customer requirements and market expectations of functionality and durability?

Design is an essential part of PSI that focuses the integration of a number of features into the final artefact. These features include working out the form of the final object or service, arranging and structuring components, their functions—individually and together, a plan for their production and delivery, and their aesthetic impact. Design also includes working out how the product or service will be maintained and serviced. In many cases its decommissioning, recycling, or reuse is also considered. Design involves assessing options and risks within an economic framework whilst ensuring elegant and efficient results (Rothwell and Gardiner 1983; Walsh 1996; Roy and Riedel 1997).

There are several different types of design, including:

- *Industrial and engineering design*: the field of developing functional and aesthetic solutions to a particular requirement (including a wide range of specialist engineering activities such as electrical, mechanical, and structural).
- *Production design*: the field of developing an artefact so as to optimize its method of production and the development of the manufacturing and operations processes to make it.
- *Ergonomics*: focusing on the usability of the product.
- *Architecture, space, and urban planning*.

Good design often develops over time, coming from open-ended and uncertain starting points (Simon 1962) in which the process is evolutionary and involves a range of disciplines (Vincenti 1990). Knowledge about the product or service emerges in iterative cycles of cumulative development, where what Simon called ‘satisficing’, or ‘good enough’ decisions are acceptable, and it is often futile to expect a single, ‘perfect’ result.

**Box 7.13 Adding value by design—Japanese housing**

Shimizu is one of Japan's leading construction and engineering businesses, with a long history of investment in R & D and a range of specialist engineering capabilities. For many years it has been developing engineering solutions to control vibration in the event of earthquakes. Its research on seismic control systems has produced methods for isolating buildings from the effects of earthquakes, including 'seismic base isolators' and 'pinned connections' for pile heads. In 2002, it embarked on a new four-year research programme to develop a seismic damping system. This resulted in the use of a water moat around a building to absorb shock waves from earth tremors. A special floating foam product was developed to reduce shock waves on the surface of the water, thus increasing the damping effect. After the initial prototypes had been constructed and tested, Shimizu designers reviewing the project saw an opportunity missed in the original programme that could potentially add value to customers adopting this type of system. They saw two additional uses for the water moat in emergencies, making this type of design more attractive when compared with competing approaches. These included drinking water, should mains water networks be severed, and fighting the fires that often break out following an earthquake.

Local storage and use of water has become a key issue in many parts of the world. Two of Japan's leading industrialized housing companies have developed similar ideas for storing and using water for drinking and firefighting in the homes in the event of earthquakes. Toyota Homes—which constructs around 9,000 houses per year—has designed a swimming pool for leisure use and as a water store. Sekisui House—producing around 70,000 units per year—has developed a borehole water heat pump that can also produce water for residents and members of the local community in emergencies.

Design is a central part of the innovation process, not only intertwined with research, development, and engineering but increasingly, with science itself. Chemists, for example, have become involved in 'designing molecules'. The pharmaceutical industry focuses on 'designing medicines' and 'designer drugs', while materials scientists may be engaged in 'designing materials'. Nanotechnology, coupled with new forms of computational modelling provides one of the mechanisms for making drugs, molecules, and materials 'to measure', designing them to perform with particular attributes and functionality (Ball 1997).

Pilkington launched a new self-cleaning glass in 2001, known as Activ. This innovation was new to the world and resulted from the specification and design of particular attributes, rather than from scientific discovery or engineering trial and error. The product was 'designed' by scientists and engineers who worked on the requirements specification to provide an appropriate solution. The glass was designed to use natural forces to maintain its clear appearance without leaving streaks on the surface and without the need for regular maintenance. The outcome was an innovation that uses a nano-engineered surface with a thin film of titanium dioxide that performs two actions. First it has photocatalytic properties, which break down organic city dirt in daylight. Second, the surface is designed to be hydrophilic, which means that instead of forming water droplets, rain spreads evenly across the glass, washing the dirt off, and drying quickly without leaving streaks. In consequence, self-cleaning glass obviates the need to employ window cleaners in dangerous work on high buildings and eliminates pollution from window-cleaning detergents.

There are many other examples where integrative design approaches are being used by interdisciplinary teams involving product designers, industrial and production engineers, and scientists. The combination of engineering and life sciences, for example, has given rise to a new interdisciplinary field of ‘tissue engineering’ where biochemists and engineers apply knowledge about the principles of tissue growth based on research on living cells to ‘design’ therapeutic strategies for biological systems. In this instance, living tissues are deliberately designed to enable organ replacement, and repair, maintain, or enhance tissue functions. The term ‘regenerative medicine’ is often used to refer to the design of tissues through this new combination of cell biology and materials engineering, with uses from dentistry to a wide range of surgery for joint reconstruction and organ transplantation. The key element in harnessing the combination of design practices and scientific method is to aim to produce targeted functions that were previously only available serendipitously when a new material or property was ‘discovered’ rather than ‘designed’.

Applied mathematicians work as designers when they collaborate with financial analysts or actuaries to create new financial products, such as hedge funds or pension schemes. Computer scientists and programmers work as designers when they build new software for a specific purpose with functions planned to enable particular computer applications. Civil and structural engineers work as designers when they are making choices about the structure of a building, within particular budget, regulatory, and construction constraints.

Customers are demanding ever-greater choices in products and services. Design is the process by which existing customers’ demands, or likely future user preferences, are incorporated into new product and service development. Successful firms add value to their range of products and services through design, by creating and exploiting brand identity and reputations for providing particular aesthetic and functional qualities (Whyte 2003). Spending resources on design can improve firm performance. Marsili and Salter (2006) found that amongst Dutch manufacturers, investments on design were positively associated with innovative performance, including the ability of the firm to develop products that were new to the world. Investments in design are also associated with productivity growth amongst UK firms (DTI 2005).

## THE ORGANIZATION OF DESIGN AND DESIGNERS

Design processes vary across industries, but they all usually focus on a desired outcome with particular users in mind. They involve iteration between what is physically possible—taking results from experimentation, R & D, problem-solving activities, and previous user experiences. Designers often develop a ‘story board’, sketching out how



they will develop a new product or service. Those with formal training will deploy techniques from project management, such as QFD, and use design reviews to hone their ideas.

Designers play with ideas in collaborative processes, involving experts and specialists to focus on the purpose or intent of design. This evolves as the idea, problem, or solution is worked upon. This selection environment eventually limits the range of possible options as the 'design envelope' becomes fixed and then tightens around an eventual solution. The opportunity to influence the design reduces over time. Path dependency sets in and projects become locked-in to particular sets of solutions (Arthur 1987).

Although designers work collaboratively with engineers and scientists, their ways of working differ. Design activities differ from the types of enquiry-based experimentation found in scientific discovery as they are concerned with practical problem-solving and the synthesis of ideas, whereas scientists often focus on predictions and explanation, developing and testing theories, and their analysis (Simon 1996: 4). Design tends to be practical and goal-oriented. Design, engineering, and technological problem-solving normally starts with a functional requirement and seeks to use scientific and engineering principles to help achieve desired goals. The work of engineers and designers may draw upon scientific evidence, but it also includes 'rules of thumb', 'informed guesses', 'routines', and 'norms' based on experience with real world problems. This is sometimes known as *recursive practice*, the steady addition of knowledge about how things work and how they fit together (Constant 2000). Design and engineering is not, however, all routine, humdrum activity or the simple application of problem-solving tools to new problems. As Vincenti (1990) highlighted, it varies from procedures in 'normal design' to experimentation and the development of 'radical design' solutions.

To develop a design, engineers, scientists, and designers usually rely on an informal culture. Team members communicate by sketching and telling stories about related work to develop their ideas. Studies have shown that designers need time for face-to-face interaction as well as for solitary work (Perlow 1999; Salter and Gann 2003; Whyte and Ewenstein 2007). This balance between interacting and working alone, combined with uncertainty over how much effort might be required to reach a satisfactory result, creates tensions that are often reflected in heavy workloads, late nights, and cycles of heroics and overwork (Perlow 1999; see Box 7.14). Designers often solve complex problems by breaking them down into modules or small parts (Simon 1996). By decomposing tasks, they are able to focus on subelements or specific features applying their design knowledge to a narrow range of problems, whilst others integrate completed work to create the final product or service. Designers, therefore, may divide tasks across many different subteams to increase the efficiency and effectiveness of their work.



**Box 7.14 Burning the midnight oil**

Knowledge-intensive work requires both long periods of concentrated solitary effort and frequent interactions with colleagues. These two requirements create tensions for scientists, engineers, and innovators. In an ethnographic study of the working life of software programmers, Perlow (1999) found they often experienced difficulty resolving these tensions and ended up working long hours as a consequence. Software engineers' working days involved constant interruptions as advice and help were sought by colleagues. These interactions were essential for problem-solving, but were very time-consuming. As a result, programmers often had to work late into the evening to enable them to work quietly, alone, away from the noise and distraction of the daytime office. This created a culture and tradition inside the organization of celebrating heroic late-night efforts. Indeed, staff needed to be seen to be working late to be considered part of the team and indicate their willingness to 'go the extra mile' for the firm. To overcome the dysfunction for employees this caused, the firm instituted a quiet time during the morning, where staff were encouraged not to disturb their colleagues. This system initially helped to reduce late working hours, but over time it was abandoned as more staff experienced problems that required immediate attention. The study shows the challenges inherent in managing workload in innovative organizations as managers have to balance individual and collective needs.

The importance of design is recognized by governments, keen to promote its good practice and encourage supportive skills development (an example is provided in Box 7.15).

The importance of design as a business activity is seen in the growth of specialist design companies. These may operate as independent entities (see Box 7.16) or operate as business practices within larger firms, such as WS Atkins.

Independent specialist designers have been offering their services for more than a century. The engagement of professional designers became a normal part of many firms' innovation activities from the 1950s. These design services often focused on aesthetic and stylistic aspects of new product development. In the automotive sector, firms such as Pininfarina (founded in 1930), became famous for styling new models for Ferrari, Maserati, Jaguar, and Peugeot. In 2006, the company employed more than 3,000 designers working for most of the major automotive manufacturers.

Design is an important differentiator in many product markets, and specialist design firms are seen in a wide range of sectors. In household consumer goods, for example,

**Box 7.15 The Cox Review**

In 2005, the UK Government published The Cox Review of *Creativity in Business*. This Review was significant because of the importance attached to the role of creativity and design in business by the Treasury, which had commissioned the report. The Review drew attention to the strategic role of design in connecting the development of new ideas with their exploitation. The Cox Review argued that it is the combination of design, engineering, technology, and business skills that generates effective innovation, rather than the application of these disciplines in isolation. To better support integration of creativity, design, and commercialization in innovation processes, the Review recommended that universities should offer new multi-disciplinary research and postgraduate teaching programmes, with the aim of broadening the design understanding and skills of the next generation of business leaders, creative specialists, engineers, and technologists.

Alessi has employed well-known designers to create special ranges of tableware. It has employed, literally the A to Z of leading designers, from Abdi Abdelkader and Ron Arad, through Aldo Rossi and Philippe Starck, to Marco Zanuso and Enrica Zanzi.

However, most design firms are small. In the UK, which is one of the world leaders in design services, there were 12,450 independent design consultancies operating in 2003. They generated nearly \$10 billion in turnover. There were also some 47,500 freelance designers. In total, design services accounted for around \$1,200 million in exports from the UK (Tether 2003). These design firms draw upon the rich educational and cultural resources of London, including the Royal College of Art and Central Saint Martins, and other renowned UK schools of design and product development. These design schools have developed courses to train next generation product designers to work in design agencies. Since the mid-1980s, these agencies have become as important as the various marketing and advertising services that firms often employ to launch their new products and services.

The nature and provision of third-party design services to firms wishing to innovate has extended into more areas of product and service development. Design firms have grown in size and in the types of consulting services they offer. They play three important roles for innovation:

- (a) a traditional role of providing designs that firms could not develop in-house;
- (b) acting as innovation brokers—bringing together ideas from a wide range of sources and experiences to which their clients do not have access; and
- (c) assisting in the introduction of disruptive and radical innovation, which, on their own, firms may not be able to address using their internal resources.

#### Box 7.16 IDEO

A leading example of a design services firm is IDEO, a company set up in 1991 by two highly respected designers—David Kelley and Bill Moggridge (designer of the first laptop a decade earlier). IDEO is now a highly successful provider of design and innovation services, employing about 500 people in 2006, in offices around the world. It has built a reputation for helping other firms to innovate in their products and services by applying creative techniques learnt in the design studio and design school environments. The company combines ‘human factors’ and aesthetic design with product engineering knowledge to manufacture products for firms from Apple to AT&T, Nike to NCR, and P&G to Prada. Its designs include the Palm V and a range of cameras and toothbrushes. It designed the whale that starred in the film, *Free Willy*. IDEO has contributed to the design of over 3,000 products and works on 60 to 80 products at any one time. IDEO has been described by *Fast Company* magazine as the ‘world’s most celebrated design firm’; by the *Wall Street Journal* as ‘imagination’s playground’; and *Fortune* described its visit to IDEO as ‘a Day at Innovation U’.

The growth of firms such as IDEO typifies changes in the innovation process in which the provision of out-sourced, third-party services is becoming more common as businesses search for ideas from outside. Academic studies of IDEO have shown that it plays a new role of ‘innovation broker’ bringing together good ideas from a wide range of different sources to solve problems for a particular client (Hargadon 1997; Hargadon and Sutton 1997). Hargadon shows how IDEO exploits its ability to leverage knowledge across different networks to bring together new ideas whilst working for clients in forty or fifty industries.

The designers exploit their access to a wide range of ideas and potential technological solutions and the company has developed its own internal organizational routines for managing this knowledge. This has led to new forms of technology transfer providing a means for introducing disruptive ideas into mature businesses which otherwise might not recognize the need to engage in this kind of innovation.

IDEO uses its design thinking to benefit the services industries: for example, it developed Bank of America's popular savings account—'keep the change'. It is seeking greater focus on social causes, addressing themes such as sustainability, design of communities, health and well-being, and enterprise for people in the world's lowest income brackets.

The leaders of IDEO have a very high profile in the international design community. They claim to have a creative culture—'low on hierarchy, big on communications, and requiring a minimum of ego'—that uses a collaborative methodology that simultaneously examines user desirability, technical feasibility, and business viability, and employs a range of techniques to visualize, evaluate, and refine opportunities for design and development, such as observation, brainstorming, rapid prototyping, and implementation. Brainstorming is taken quite seriously, and there are very firm ideas about what constitutes a brainstorming session, how it should be organized, and how long it should last (about sixty minutes optimally). IDEO sells its design methodologies to other companies in the form of courses and training materials.

To enable the company to deal with so many diverse projects, it recruits a wide range of talent, and also enjoys special links with the Stanford University Institute of Design (where David Kelley has a professorial chair). It employs graduates from psychology, anthropology, and biomechanics as well as design engineering. Great care is taken in the selection of staff, with three or four interviews being normal in recruitment, focusing on potential employees' designs and (the way they respond to advice).

## THE TECHNOLOGIES OF DESIGN

Since the 1960s, CAD technologies have gradually replaced the traditional, laborious processes of drafting. The drawing board has been replaced by the electronic pencil in many design activities. Nevertheless, many designers continue to sketch and draw by hand, because this process enables creative thinking (Lawson 1997). Similarly, technologies that enable modelling and simulation are replacing physical testing and model building, speeding up and reducing cost by reducing the number of iterations required of a design (see Boxes 3.3 and 7.17). Simulation and modelling have always played a central role in engineering problem-solving. For engineers, models provide a mechanism for learning about artefacts before and after they have been built. Physical prototypes are expensive, time consuming to create, and often unreliable. Models enable engineers to examine different options and weigh the choices of structural elements, materials, and components against one another. It is commonly accepted that the adoption of technology has changed the way designers and engineers work. More engineering design is done on computers than on paper, although most engineers are still heavy users of paper. Digital tools are cheap and easily available. They often allow the engineer to do more than was possible in the past, and more quickly. They provide the basis for digital models that assist in abstracting physical phenomena, allowing engineers to experiment, simulate, and play with different options (Thomke 2003; Dodgson, Gann,

and Salter 2005). This is leading to a new culture of prototyping in which traditional practices of design are being opened to more concurrent diagnostic enquiry (Schrage 2000). Over recent years this technology has significantly expanded its capabilities, aided by more powerful processors; greater visualization capacities; more sophisticated software allowing new functionality across multiple and more widely diffused platforms; and better data on physical properties. Simulation and modelling are conducted on a variety of technological platforms, including CAD, using a number of techniques such as Computational Fluid Dynamics (CFD) and Finite Element Analysis. Advanced CAD systems, such as CATIA, are routinely used in the design of complex new products, such as the Boeing 777 and Airbus A380, and relatively simple designs for toothbrushes and shoes (see Box 7.17). Simulation and modelling are also conducted using combinations of readily available computer software packages, such as spreadsheets and heatmaps. These tools enable designers to coordinate their work and help in:

1. Interpreting the behaviour of physical properties and developing efficient technical solutions to problems.
2. Integrating different technologies and components.
3. Shaping and representing potential solutions more effectively by encouraging better understanding of the contextual factors affecting design.

The use of CAD for design, modelling, and simulation, coupled with visualization systems that provide easy-to-interpret results, have also enabled closer engagement with customers and end-users (Thomke 2003).

#### **Box 7.17 Technologies for Total Architecture**

In 1970, Sir Ove Arup, founder of the engineering design firm Arup, made what has become a quite famous speech, in which he espoused the pursuit of quality in design. He explained the frustrations caused when one specialist discipline strives for innovation and quality, but other contributions do not, and the overall result is undistinguished. The quest to innovate and improve quality in design led firms to develop integrated services, providing what Ove Arup called 'Total Architecture'. 'The term "Total Architecture" implies that all relevant design decisions have been considered together and have been integrated into a whole by a well-organized team empowered to fix priorities' (Ove Arup, *The Key Speech*, 1970).

The principle of 'Total Architecture' for integrated design applies whether an organization is designing a building, a product, or a service. The ideal of total design is rarely achieved in practice, but innovation is often achieved in striving for it.

In the nearly forty years since Arup gave his speech, CAD has developed to support designers in the development and realization of their ideas. In the past decade a suite of digital design tools has emerged that aim to integrate the different fields of design, including aesthetic form, function, design for production, and performance in use, such as environmental engineering.

The CATIA software program is a computer-aided integrated design tool. It was originally developed by the French aerospace firm, Dassault Systèmes, to support digital design of advanced fighter aircraft, which depend on complex geometries in airframe engineering design. The technology was developed

to simulate engineering and design of difficult curved surfaces through an array of different design tasks from conceptualization, detailed design, engineering analysis, product simulation, assembly, and maintenance. CATIA combined a number of previously separate computer systems including CAE and CAM (computer-aided-engineering, and computer-aided manufacture). The software was acquired and marketed by IBM which improved it further to include an open development architecture with interfaces to enable users to customize applications. The range of uses for CATIA has expanded to include design for product life cycle management, the development of business processes—such as supply-chain and asset management—use of e-business environments and Web-based learning systems.

The original Ove Arup idea of ‘Total Architecture’ has manifested itself in companies, such as Gehry Technologies, which uses the CATIA system to support integrated building design. Frank Gehry’s architectural practice has been responsible for a number of landmark buildings including the Bilbao Guggenheim. It was one of the first architectural firms to adopt CATIA to integrate its design processes and link these to virtual and rapid prototyping systems. Arup engineers collaborated with Gehry to develop CATIA further, creating a software tool called Virtual Building.

Virtual Building provides a range of modelling and simulation techniques, including city planning, simulation of transportation and movement of people in the urban environment, as well as more traditional engineering processes such as thermal, daylight, and acoustic simulation, using computer models of physical properties—CFD. This assists the visualization of problems and solutions in design, construction, and operations using computer simulation. It provides what has become known as a ‘single digital environment’ in which data from different disciplines are added once, and then integrated in a way that others can see and use them. The digital environment encompasses design, engineering, analysis, fabrication, project management, and on-site construction activities. These are represented in the virtual, digital model. The model enables more effective communication between different members of project teams, helping to foster a collaborative working environment in which new ideas for innovation can emerge through interdisciplinary endeavour. These ideas can be shared and developed by groups of specialists who previously would have had no means of connecting with one another as a team. This form of innovation technology also helps to capture these ideas as they are being developed. ‘Design intent’, for example, is an illusive process of idea-generation and choice-making that often occurs tacitly with no obvious record for others to interrogate and learn from. With the right organizational structures and skills, the technologies supporting ‘Total Architecture’ can enable better choices of solutions to be made, capturing and sharing lessons, and optimizing design decisions on applicability and cost.

These technologies help deliver flexibility to firms’ design efforts: a distinct source of advantage (see Box 7.18).

#### **Box 7.18 The importance of flexibility in design**

Flexibility of design is a key element underlying successful innovation. Flexible organizational structures are equally important in enabling firms to react to changes in markets, new opportunities in operations, and new possibilities derived from developments in science and technology. Also important is the flexibility of the technology used in the design process—the innovation technology discussed in Box 3.3. Thomke (1997) compared the productivity of two design technologies used in designing integrated circuits: the highly flexible electrically programmable logic devices (EPLDs) and the less flexible application-specific integrated circuits (ASICs). When they were used in the design of similar products, Thomke found that EPLDs outperformed ASICs by a factor of 2.2 (measured in person months). This he attributed to the more flexible design technology, allowing a greater degree of risk in design (a greater preparedness to remain open to design changes, rather than operating what are commonly called ‘design freezes’). He argued that, in volatile markets, the opportunity to be flexible in the use of design technology provides considerable competitive advantages.

## DESIGN QUALITY

Determining what constitutes quality in design, and developing management approaches that support improvements in design quality, is something of a 'holy grail'. As Utterback et al. (2006) note, when an innovation is inspired because of the quality of design embedded within it, the product transcends immediate technical or utilitarian descriptions as to why it is better than competing products. The idea that good design can delight the user dates back to late antiquity. In the first century BC, Vitruvius, the Roman architect and engineer, described design in terms of: firmness (*firmitas*), commodity (*utilitas*), and delight (*venustas*) (Wotton 1969). When a product or service's fitness of purpose, selection of technology, cost, and overall experience in use are integrated in a manner appropriate to need, they can delight the user. In recent years, QFD frameworks have been deployed to help integrate these aspects of design. Sophisticated customer feedback surveys are used to understand whether the outcome met the original intention.

In the built environment sector, a Design Quality Indicator has been devised to assess the different attributes of firmness, quality, and delight—translated into a modern idiom of *build quality*, *function*, and *impact on the mind and senses* (Gann, Salter, and Whyte 2003). This tool enables professional designers, customers, and users, together with a wide array of stakeholders, to participate in assessment of design quality. They complete a simple on-line questionnaire, the results of which are processed using algorithms to relate different design attributes ([www.dqi.org.uk](http://www.dqi.org.uk)). Higher weightings are given if design adds value because there is coordination between, for example, aspects of build quality and functionality. Excellence in design is achieved when all three attributes of build quality, function, and impact, are developed together within the constraints of the resource envelope (finance, time, skills, and natural resources). The result of good design can often appear very simple, enabling a wide range of users and uses of a product or service, such that it diffuses quickly.

Any measure of design quality should take into account the level of resources in relation to the appropriateness of the particular outcome. For example, it might be expected that a prestige building would involve more design resource and therefore achieve a higher level of value by design than an everyday building. But that is not to say that the everyday building should not embody an appropriately high level of design quality. There are always trade-offs in design. Some of the features that one might wish to measure and eliminate to improve production processes—such as wasted time—may relate closely to those that provide additional value during design—such as time to think and play with different design perspectives. As John Makepeace, the international furniture designer and maker (quoted in Myerson 1995), said:

[A]n artist sets a different benchmark from a maker. A maker will want to get it right ten times out of ten. An artist has more elusive targets. One success out of ten will suffice, with the other nine pieces acting as sketches, prototypes, and support material along the road to that significant artistic result.

## Summary and conclusions

A great deal of research has been done on the importance and process of new product and service development. In this area of MTI, at least, it is relatively easy to be prescriptive. Products can be new to the world and new to the firm. They often take the form of incremental improvements to existing products. Firms can achieve competitive advantages, not only through producing what customers want, but also, on occasion, through producing what they do not yet know they want. The benefits of PSI are many, and extend beyond the simply financial. Assessing PSI encompasses both efficiency and effectiveness factors: how good are firms at developing new products, and are firms producing the right products? The latter is a strategic management issue concerned with whether the firm is cumulatively building its competencies (examined in Chapter 4), and whether the IP produced is protectable (examined in Chapter 9).

Factors that encourage efficient PSI include: internal organizational integration, particularly between R & D, marketing, and operations; HRM, particularly in relation to project managers; and the use of project management techniques, such as stage-gate systems and QFD. Many of the internal organization practices of Japanese firms have been discussed, and the important role of job rotation in encouraging good communications between all those involved in PSI has been described. Much best practice in rewarding and providing incentives for PSI teams, such as opportunities for stock options and spin-offs, are found in Western firms. Many of the practices of PSI in the manufacturing industry also apply to services, as seen in the case of Citibank.

Design is an activity that helps integrate many of the aspects of PSI and combines technological and market possibilities. It is a critical aspect of the innovation process as it enables creative thinking and formal tools to be applied to delivering technical functionality and economy on the one hand, and the opportunity to delight customers on the other.

Despite all that is known about PSI, there are still many instances of failure. These must be seen as learning opportunities, which should ensure that the reasons for the failure are not replicated. Successful firms are the ones that continually seek to improve the processes by which they produce PSI.



# 8 Innovation in Operations and Processes

## Introduction

Innovation depends upon a firm's ability to create new products and services *and* make and deliver them. For established firms this often involves adapting existing facilities and processes. For new start-up businesses and those existing firms that aim to deliver significantly new products and services, it means developing new operations capability. This chapter discusses the key MTI issues involved in successfully delivering new products and services to markets and customers. It focuses on the role of innovation in processes themselves, showing how process improvement delivers value and secures profitability.

## What are operations?

Operations are broadly defined to include the processes that transform inputs into final outputs (Porter 1985; Hill 1985; Hayes, Pisano, and Upton 1996; Slack, Chambers, and Johnston 2006). These processes lie at the heart of products and services delivery and enable technology to be exploited across all markets and industries. Production and operations make, assemble, and test components, products, and services, with the aim of meeting customer demands swiftly and efficiently. They include a firm's logistics and distribution processes: the mechanisms used to reach customers. These processes involve the decision-making, coordination, and communication mechanisms that firms use to transform resources (people, equipment, information, finance, designs, materials, and know-how) into products and services. Technical issues associated with operations are the central focus of many routine engineering and production tasks; they include inventory and workflow control, quality, safety, and supply-chain management. These activities may be out of sight for innovation managers, and for some out of mind. Because of their routine nature they engage with forms of knowledge that Drucker called 'grubby and pedestrian'. As the US production guru Wickham Skinner once noted:

[T]o many executives, manufacturing and the production function is a necessary nuisance—it soaks up capital in facilities and inventories, it resists changes in products and schedules,



its quality is never as good as it should be, and its people are unsophisticated, tedious, detail-oriented, and unexciting.

As this chapter shows, however, this perspective is seriously misguided. The modern factory or service operations facility can also be the laboratory for next generation innovations: places of experimentation and learning. Operations are an essential part of the innovation process. Firms that fail to plan and manage their operations effectively also usually fail to appropriate benefits from their innovations. Operations are far from grubby or pedestrian, and can be central to the whole innovation agenda.

Operations are a source of product innovation, particularly in advanced machinery, equipment, ICT, and innovation technology. These technologies are the products of some firms, used as the production processes of others. Operations are also a source of process innovation, providing new approaches and opportunities through technological change. As with other areas of MTI, issues of work organization and the increasing knowledge content of work are centrally important to innovation in operations. Similarly, the many techniques that can be used in operations and production are most effective when they are informed by a strategy. The focus of this chapter is primarily on the strategic management of operations and production, although some tools and techniques will be discussed. Our concern here is to understand the role of, and strategic opportunities provided by, operations and the ways firms can quickly and reliably produce high-quality innovative products and services whilst maintaining cost advantages commonly achieved by large-scale production in mass markets. The techniques described are applicable to the production of products or services by companies in a wide range of businesses of all sizes, including small firms.

Innovation in processes creates new opportunities to reduce lead times (the time it takes to design and produce a new offering), improve quality, and cut costs. This is often associated with the introduction of new technology, such as rapid prototyping, or the development of new materials, such as nanotechnology (Jones 2004). An understanding of the potential of operations and processes can stimulate PSI, and the development of new products and services stimulates the need to create new processes and operations. Product and process are therefore interrelated and a strong grasp of the field of operations and process engineering is necessary to inform the strategic choices firms make about innovation. MTI is usually engaged up to the stage of initial production of a new product, or launch of a new service, handing over future delivery to production managers and engineers. But production is not necessarily scalable and further refinements to products and services are sometimes necessary, emphasizing the continuing importance of linkages between product, service, and process innovation. The problem of scalability is particularly acute in some industries, such as fine chemicals, where moving from the laboratory bench to industrial-scale production can require very detailed development work and trials. Pisano (1996) shows that in many industries,

process and product development go hand in hand; and indeed in industries such as silicon-chip fabrication, product and process innovation are virtually indistinguishable. In Intel, for example, the design of new semiconductor circuitry is simultaneously the design of its means of fabrication. Using data from the UK innovation survey, Reichstein and Salter (2006) found that levels of process innovation achieved by the firm were partly explained by their ability to introduce new products, indicating that new products may beget new processes, and vice versa.

The close relationship between product and process innovation is shown in Box 8.1.

### Box 8.1 Durex and the history of innovation in condoms

Condoms have a long history of innovation in using new materials and manufacturing technologies. The earliest description of a condom comes from Gabriello Fallopio in 1564. Fallopio used a linen sheath to help protect against syphilis, conducting a trial of his device on 1,100 men. By soaking the sheath in herbs or chemicals it was found that its use lowered the chances of venereal disease transmission. Some claim the invention was made by mediaeval slaughterhouse workers, discovering that animals' membranes would provide protection from venereal disease (Youssef 1993). Popular eighteenth-century condoms were made from the gut of a sheep, goat, or calf. They were 'soaked, turned inside out, macerated in an alkaline solution, scraped, exposed to brimstone vapour, washed, blown up, dried, cut, and given a ribbon tie. It was necessary to soak them to make them supple. The labour-intensive process meant that the products were correspondingly expensive (though reusable) and thus only available to a limited sector of the population (Hall 2001). They were used both as a birth-control device and as an 'implement of safety'. Animal-gut condoms were popular in Europe, but Chinese and Japanese developers also experimented with silk, paper, tortoise shells, and leather (Youssef 1993). The major breakthrough in condoms came with the vulcanization of rubber in 1844 and rubber condoms became popular in the late nineteenth century. The development of teat-ended products occurred only in 1901. The use of latex in the 1930s created cheap, thinner, more elastic, and reliable condoms. Polyurethane was used in the 1960s, but was considered unreliable. The first coloured condom was introduced in 1949 by a Japanese firm. This was followed by the lubricated condom in the 1950s and spermicidal in the 1970s. Modern condoms are highly effective contraceptives and because they are watertight and airtight they are impermeable to micro-organisms, providing protection against sexually transmitted diseases. The female condom was introduced in 1994.

Durex is one of the leading manufacturers of condoms in the world, accounting for close to 25 per cent of the world's four billion annual condom sales. It operates seventeen manufacturing facilities in eight countries. The company had modest beginnings in London as a retailer of 'protectives' imported from Germany. It registered the trademark of Durex in 1929, the word itself based on its principles of *durability*, *reliability*, and *excellence*. It set up its first condom factory in Hackney in 1932 and expanded production during the Second World War. In 1951, it developed the first automated production dipping line, speeding up production. Electronic testing machines were introduced in 1953, and in 1957 it introduced the first lubricated condom on the UK market. In the 1960s condoms became available through the National Health Service and the first condom-vending machine was installed in 1964. Condoms became available in British supermarkets for the first time in the 1980s. Durex expanded its product line with coloured and flavoured condoms in 1996 and it introduced ribbed condoms in 2000. It has since developed 'easy on' condoms and a new condom which is made from a polyurethane material called Duron.

Condom manufacture is a complex process. Latex is a natural product and is very sensitive to handling and minor fluctuations in temperature. Durex has developed a complex recipe to help stabilize latex and ensure its quality. Condoms are made by dipping moulds into latex, and air-drying them. The process involved them being placed in an oven and then removed from the moulds by high-pressure water jets. Before packing, they undergo five tests. One of these tests involves 'each condom being stretched over a metal former and subjected to high voltage. Any breakdown of the film is measured and any minor flaw, even one far too small to be detected by the human eye, results in the condom being instantly rejected'

(Durex 2006). In addition, Durex takes samples from each batch and inflates them with 40 litres of air to see when they break. Afterwards they select some additional samples, fill them with water, and roll them upon blotting paper. If flaws are found, the entire batch is disposed of. Durex has used its competencies in condoms to expand into range of sexual products, including vibrators, lubricants, and massage gels.

## The innovation–operations conundrum

A conundrum exists for any organization that focuses on managing product and service innovation whilst simultaneously deriving benefit from modern operations and production processes. This is because manufacturing products and the delivery of many types of services rely upon the efficient use of stable operating routines. Operations and production processes need to be managed in a predictable and effective manner to achieve process efficiency. Because they demand focused attention, and getting it ‘right first time, right every time’, firms’ operating routines are usually specialized, systematic, and prescribed. Firms such as Toyota have developed highly efficient procedures to continuously improve specialized operations, which deliver value to the company on a daily basis (Fujimoto 1999). But having formal, consistent, and recurrent processes can be an impediment to innovation, particularly when launching a new product or service demands significant changes in operations. This problem relates closely to Christensen’s (1997) ‘dilemma’. In Christensen’s studies, firms that focus attention exclusively on deepening existing technical capabilities, processes, and relationships with key customers, fail to see wider changes in the market that can disrupt their business. Firms that are highly process oriented and focus their capabilities on continuously improving operating routines fail because they are unable to change these routines swiftly enough when they need to introduce new products or services (see Chapter 3).

The primary purpose of operations and production routines is the reduction of variability and uncertainty in delivering products and services to reduce defects and costs, whilst maintaining output and quality. If they are well managed, these operations and routines deliver results and become prime activities, creating focus and organizational cohesion. But for innovators, these ways of delivering success can create problems. It has long been known that good management techniques for operational processes can be the seeds of failure (Hayes and Abernathy 1980). When a firm is successful, it usually focuses on what it is doing well to continue to reap benefits from its practices. It is particularly difficult to make the case for changes to the things that give rise to success, and it is this conundrum—that innovation often requires a break with established successful norms and routines—that makes MTI so difficult. Leonard-Barton articulates the problem of changing successful practices to deliver new products and processes according to what happens to a firm’s capabilities. She shows how *core capabilities*—such as those found in

operations—become *core rigidities* when there is a compelling need to change operating routines and processes to benefit from innovation (Leonard-Barton 1995). Simply put, if a risk-averse organizational culture becomes dominant, driven by short-term operational requirements, it can kill a firm's ability to innovate. Firms therefore need strategies that link exploitation of the existing with exploration of the new—engaging operations with innovation (March 1991). Those firms that are able to attend to the products and processes of the past whilst simultaneously planning and developing those of the future are sometimes referred to as *ambidextrous organizations* (O'Reilly and Tushman 2004).

Overcoming this conundrum requires strong leadership and fine judgement by Innovation Directors and other senior managers understanding that today's process benefits—which as we shall see later are considerable—can be tomorrow's constraints. Clarity of understanding and purpose about next-generation products, services, and processes also helps to attune the organization's operating routines in a timely manner (Sandberg and Targama 2007). In many businesses, resource allocation processes are the source of the problem (see the discussion later). Resolving questions about how to allocate resources between innovation and supporting and delivering routine processes in operations is key to balancing short- and long-term business success. The ways resources are allocated between operations and new product and service development can either accelerate innovation or destroy the possibility of achieving it.

## Importance of operations for delivering innovation

For many firms, revenue streams and annual profits are derived from the performance of their operations. Well-managed operations deliver goods and services at prices that markets and customers are prepared to pay, whilst providing suitable returns. They can also constitute a significant proportion of the activities of a firm. In manufacturing companies, operations and production activities utilize the majority of capital assets (estimated at between 80 and 85 per cent), and can account for 80 per cent of company costs (Brown 1996). Operations are, therefore, a critical determinant of the price of a company's products and services.

Operations also affect important non-price factors in competitiveness, such as quality, delivery, reliability, and responsiveness, the ability to offer variety, and to customize (Blecker and Friedrich 2007). Performance in operations and production processes is delivered by providing variety to meet particular customized requirements in niche markets, and the ability to enable late changes in design that add value for customers. Value is also derived from the ability to deal with frequent product innovation and from good after-sales service and maintenance.

In a study of twenty-three major development projects at eleven US and European pharmaceutical companies, Pisano and Wheelwright (1995) found that problems in manufacturing processes either delayed a new product launch or inhibited its commercial success once it was on the market. Problems of an operational nature have in part been responsible for delays in launching new products, for instance, when Sony's PlayStation 3 and Microsoft's Vista missed their target launch dates in 2006. Delays due to assembly-line problems and parts delivery from suppliers tarnished Ford's ailing reputation at the end of 2006, when it failed to launch the new Ford Edge and Lincoln MKX vehicles.

As operations are so important—in their scale of investment and contribution to immediate financial returns and competitiveness—they often require the attention of senior managers using the application of a variety of the tools and analytical techniques discussed later. These tools and techniques have a long history. The discipline of applying analytical approaches to decisions about resource allocation in production dates back to the middle of the sixteenth century (Voss, Ross, and Chase 2007). Modern operations management originates in industrial engineering, military logistics, and the work of nineteenth- and early twentieth-century industrialists and thinkers such as Charles Babbage, Andrew Carnegie, and Frederick W. Taylor. This approach was applied to manufacturing and became known as 'scientific management' or 'Taylorism'. The development of interchangeable parts manufacture at the Colt Armoury in 1855, and the evolution of the standard production line and scientific management principles created a new framework for thinking about production. These analytical approaches were put into practice most notably in the manufacture of automobiles by Henry Ford (Fordism) whose production system became famous for its focus on *standardization and modularity* as a prerequisite for improvements in quality and efficiency in component manufacture, through the use of *interchangeable parts* (Russell 1981; Womack, Jones, and Roos 1990).

## Industry, technology, and markets

Production processes differ depending upon the type and size of market. This has a bearing on the types of technologies used in production, the techniques used to manage operations, and, therefore, the ways in which new products and services can be launched. Joan Woodward (1965) provides a classic framework that relates the type of process used in a particular industry with the nature of the market (see Table 8.1).

The relationship between types of processes and operations and size of market dates back to Adam Smith. He argued that the division of labour is limited by the extent of the market and specialization is a function of the division of labour. So, for example, in low-volume markets (projects and small batch) there are fewer opportunities to develop

**Table 8.1.** Type of industry, process, and size of market

Type of Industry	Type of Market	Examples
Projects	One-off markets, discrete activities, final output in single units	Building and construction Capital goods Bespoke, personal services
Small Batch	Markets with very small production runs and highly customized goods (usually hundreds of units)	Specialized components such as lifts and elevators Entertainment services with low volumes of shows
Large Batch	Markets with large production runs, where batches are produced before re-tooling (usually thousands of units)	Standard components for electronics products Furniture Packaged holiday services
Mass-production	High-volume markets with very large production runs (often millions of units)	Automobiles Consumer electronics products Clothing
Continuous-flow	Markets with stable demand for continuous output (flow process)	Low-cost airline services Oil and gas Chemicals Energy and utility services

Source: Based on Woodward 1965.

standardized routines and gain from the efficiency of dividing tasks. When markets expand there are opportunities to specialize, dividing work to improve performance across particular tasks, deepening knowledge, and creating systematic routines. Time is saved by employing specialists and avoiding the need to switch tasks. There are opportunities for automating parts of the process by investing in machinery and equipment. This is the logic of *economies of scale*: the drive towards mass markets where prices fall because capital-utilization rates can be increased at little additional cost of production, creating more value to reinvest in the system. This logic drove the development of manufacturing operations in mass markets throughout the nineteenth and twentieth century. As machinery and equipment became more sophisticated in the second half of the twentieth century, however, a new logic of *economies of scope* arose in which flexible manufacturing systems enabled firms to produce differentiated products using the same equipment. This gave rise to the ability to manufacture products customized to particular individuals or requirements (Noble 1986; Chandler 1990; Piore and Sabel 2001).

## Techniques of operations and production management

A huge number of tools and techniques have been developed to support operations and production management. In recent years these have increasingly been underpinned by

software-based logistics, monitoring, and control systems. These range from methods used by managers in making decisions about how much to produce in-house and what to outsource (Lieblein et al. 2002), which includes mapping the value stream; to processes for improving operational performance, such as Six Sigma (an approach to quality management developed by Motorola and made famous by Jack Welch at GE (Pande, Neumann, and Cavanagh 2000)); and lean production techniques (Womack and Jones 1996). Activities such as capacity utilization, procurement, and supply-chain management, together with distribution and customer-relationship management (CRM) all form part of the operations field. They are supported by information systems and use of data-collection methods, such as bar-coded components—and increasingly radio frequency identification (RFID) systems. The use of information in supply-chain logistics has led to a number of significant process innovations including new methods of labelling products such as the use of lasers to tattoo fruit—see Box 8.2.

### Box 8.2 Tattooed fruit

Developed by a Canadian-born, University of Florida particle physicist, Greg Douillard, laser tattooing of fruits represents a major innovation in how food is prepared for sale. Currently, most fruit is labelled with a sticker or Price Look-Up (PLU). This system allows checkout staff at retail outlets to recognize the type of fruit at the cash register. This system has number of problems. First, applying stickers to fruit is a labour-intensive process. Labelling machines often jam and stickers fall off. Indeed, if they are sticky enough to stay on the fruit through the whole distribution network, they are usually too sticky for consumers to get them off at the point of consumption. Also, it is often necessary to manually check if stickers have been suitably applied. Second, the stickers are not organic and require machines to be cleaned each day to ensure they are safe for use. Third, they are ‘dumb’, containing almost no information about different types of products or their origin. This means that it is often difficult for checkout staff to determine whether the product they are pricing is the right one. Choosing fruit in a modern supermarket involves selecting between apples of different grades, locations, organic production, and whether or not they are Fairtrade. As one retailer commented: ‘now at some markets you will have 12 different kinds of apples. You might even have lots of the same kind of apple: conventional Fuji, organic Fuji, Fairtrade. You can’t expect cashiers to know them all, much less to recognize a cherimoya when they see one’. (Moskin 2005) It is hard to contain this information on a single label and therefore many items of fruit are misidentified at the checkout, leading to under- and overcharging.

The laser tattooing of fruit emerged from a chance occurrence when the inventor accidentally sat in on a produce packing conference where there was a discussion about how to get rid of stickers on fruit. The technology developed by Douillard uses a laser to emit a high-intensity light beam to etch the skin of the produce to form an identifying mark. After acquiring a number of patents for this technology over a nine-year period, Douillard used a sealed bid auction to sell the technology to a manufacturer. In 2002, the technology was purchased by Durand-Wayland, a fresh fruit and vegetable grading equipment manufacturer and supplier based in LaGrange, Georgia. After the sale, Douillard joined the firm as its head of its new Laser Marking Division.

Durand-Wayland laser tattooing machines use no ink; they simply remove a thin layer of colour from the fruit (only 9 nm). The machines themselves are modelled on laser-etching machines used in the health-care sector. The machines rapidly print out details about the fruit. It is also possible to print other images on the fruit, such as pictures or store labels. As Fred Durant, president of Durand-Wayland, states:

With the right scanning technology the produce could even be bar-coded with lots of information: where it comes from, who grew it, who picked it, even how many calories it has per serving. You could have a green pepper that was completely covered with coding. Or you could sell advertising space. (Moskin 2005)



Since the print on the surface of the fruit is so small, it ensures that it is not penetrated and therefore exposed to fungi and bacteria. The innovation has so far proved to be popular with leading fruit producers, including Sunkist, which controls 80 per cent of the US lemon industry. In early 2006, tattooed fruit began appearing in US retail outlets and is now diffusing to New Zealand and other countries.

*Source:* To learn more about Durand-Wayland's laser fruit tattooing technology, please see [www.durand-wayland.com/label](http://www.durand-wayland.com/label).

The following sections provide a brief overview of some of the main principles and techniques used in operations and production. They focus specifically on total quality management (TQM), the various generations of workflow control systems ranging from materials requirement planning (MRP) to manufacturing resource planning (MRPII), enterprise resource planning (ERP), and lean production approaches.

## QUALITY MANAGEMENT

Quality is a major strategic issue, as guarantee of quality provides distinctive competitive advantages. Excellent quality in products and services is an essential element of a firm's reputation. Poor quality may lead to the costly reworking and recall of products. Ford, for example, had to recall over 2.7 million cars and pickups between 1986 and 1993 because of defects (Brown 1996). In 2006, Mercedes-Benz was forced to pay \$1.2 million in civil penalties because its vehicles failed to comply with Environmental Protection Agency air pollution standards. The company had to recall 108,000 vehicles and provide new warranties on around 20,000 at a cost of \$59 million. Producing goods without defects, and delivering services without delays and errors, have a central bearing on market expectations. Evidence from marketing and consumer research shows that negative referrals require nine times the number of positive referrals to overturn the damage they cause to a business's reputation (Brown and Reingen 1987; Reichheld 2003; Ranaweera and Prabhu 2003).

Various techniques are used to improve quality. In Japan, quality is embedded in the culture of business and operations such that it is reinforced by the ways in which production teams are structured and work. The ideas of quality systems to remove defects emerged from the work of W. Edwards Deming, a US statistician who first improved quality of operations in the USA during the Second World War, but is better known for implementing his ideas in Japan in the 1950s, resulting in the establishment of the Deming Prize by the Japanese Union of Scientists and Engineers. His work led to the development of a range of quality control (QC) techniques using statistical tools for identifying trends and quality metrics (Clausing 1994).



Systems such as quality assurance (QA) develop procedures and policies to ensure repetitive, high-quality processes (Clausing 1994). QA often utilizes international quality standards, such as the International Organization for Standardization (ISO) 9000 series. ISO 9000 essentially states that an organization should have a QA procedure and that it is the responsibility of the organization to identify those procedures and put them in place. To obtain ISO 9000 certification firms must develop detailed procedures for ensuring quality at all stages of production (for the whole of the production process, not just individual products) and produce strict documentation of adherence. Many firms insist that their suppliers meet these quality standards.

The success of Japanese quality management systems was illustrated in benchmarks established by JD Power in the automotive sector in the 1980s. The company exposed significant variance in quality compared with European and North American manufacturers, who responded by attempting to introduce top-down quality management, inspecting quality into the product. When this failed it led to further development in quality systems, involving employees becoming engaged with the issue through quality circles (see later) and the use of techniques such as TQM (Clausing 1994). TQM is a philosophy and management strategy aimed at embedding quality at all levels and in all activities of an organization. Insurance companies were amongst the earliest adopters of TQM, and now it is used widely in business, from financial services to metal bashing. TQM often puts the responsibility for quality on each employee, who is expected continuously and proactively to assist in overcoming any difficulties in meeting the standards expected by customers. It involves detailed consideration of organizational matters, and requires significant investment in training. Leading companies in advanced manufacturing and service sectors can no longer compete on quality, because their regimes are so stringent that quality is taken as a given. Every firm is expected to be able to produce and deliver services to very high quality standards, which explains why the consequences are so major when things go wrong.

## WORKFLOW AND MATERIALS PLANNING

The management of workflow is an essential element of delivering products and services, and can be a source of competitive advantage. Box 8.3 describes how innovation in aircraft flow in airports has substantially enhanced performance.

The holding of stock (or inventory) of raw materials, part-processed products, and final products has traditionally acted as a buffer for the problem of changes in demand and supply in operations and production; however, with so much capital tied up non-productively in inventory, there are incentives to reduce stock holdings and conduct operations with 'zero-buffers'. MRP is a computerized production scheduling system that emerged in the 1970s and details schedules pushing work into manufacturing lines

### Box 8.3 Increasing capacity at congested airports

Most of the world's leading airports are congested. Large European airports such as Paris Charles De Gaulle, London Heathrow, and Frankfurt International, handle more than 500 flights a day and 50 million passengers each year. Growth in passenger numbers is predicted to double between 2010 and 2030. Expanding these airports is not easy. Building new runways is often constrained by space and is frequently politically unacceptable. Airport expansion often requires many years of planning, negotiation, and large-scale investment. Airports have to comply with stringent international safety regulations and operating standards. The challenge for airport operators is to find ways to increase capacity through minor changes, without expanding the number and size of runways, and maintaining or extending safety standards. Airport systems engineers have effectively implemented changes in airport design and operations based on techniques developed in operations research, leading to more efficient capacity utilization. Throughout the 1980s and 1990s, the major European airports have been remarkably successful in increasing the number of landings and take-offs per hour through operational improvements. For example, in the 1990s, at Frankfurt the number of 'movements' on the runway increased by 28 per cent.

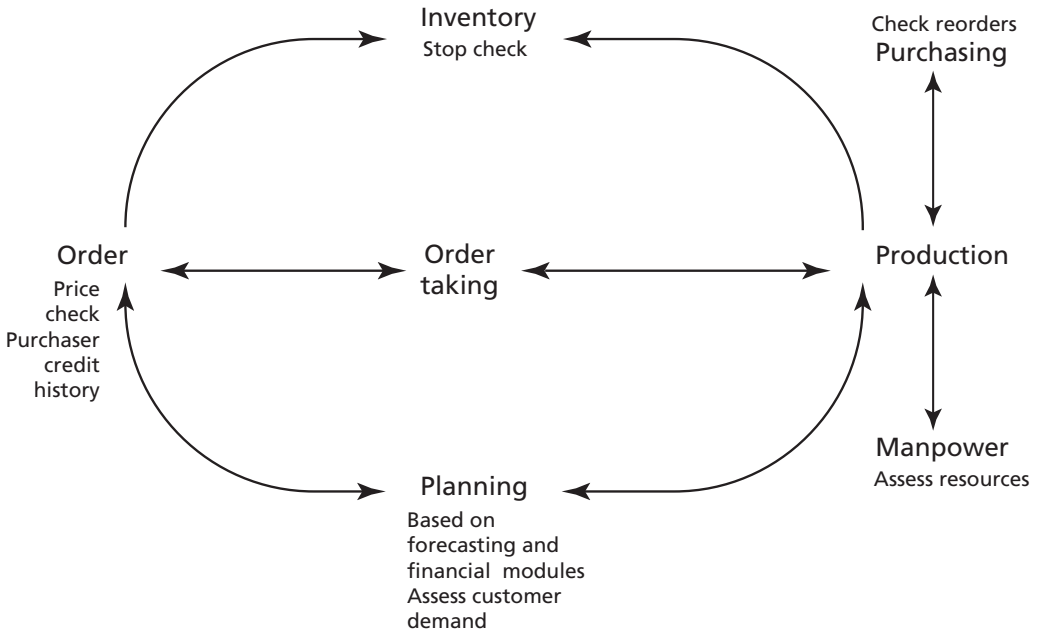
There have been several innovations that have made these productivity improvements possible. First, major airports have created Rapid Exit Taxiway Systems (RETS) to allow airplanes to exit runways at high speeds. This change involved creating new exit runways, extending from the main runway. This innovation increased the number of movements on each runway by two or three per hour. Second, airports have made major efforts to change pilot attitudes toward runway occupancy, and to measure pilot performance. Third, air-traffic controllers have used queuing theory to improve utilization of space on runways, ensuring that different types of planes are lined up in order to enable them to land and take-off at closer intervals. Finally, the landing approaches of different types of aircraft have been optimized to ensure that turbulence from the wake of planes is more effectively separated—wake turbulence from large aircraft can cause small planes to crash. This enables more planes to land at the airport in the same period. All these mechanisms indicate that there has been considerable learning-by-doing in airport runway operations. In developing these innovations, many major airports have collaborated, along with systems engineers from leading universities, to develop and share ideas, ensuring that new practices are rapidly adopted and similar procedures operate across all airports.

*Sources:* De Neufville and Odoni 2002; Tether and Metcalfe 2003.

with appropriate finish dates and process loadings. In this way it requires manufacturing to produce the required parts and push them on to the next process until they reach final assembly stage (Hill 1985). Although an MRP system relies on forecasts being largely correct and customer schedule changes being restricted, it generally results in lower inventory levels and things being in the right place at the right time.

MRP evolved first into MRPII, which includes the capacity to plan tooling and labour allocation and, in the 1990s, into ERP, which is a method of planning and tracking inventory and production. The aim of ERP is to generate and use data to assess how efficiently a company is using its resources to satisfy customers. SAP's ERP products provide software that can link every part of a company's operations (see Fig. 8.1) In the late 1990s one SAP system was estimated to be saving Monsanto \$200 million annually.

These various techniques, starting with MRP in the 1970s followed by ERP in the 1990s, are sometimes seen as 'magic bullets'—ways of 'solving' complex operational problems. As we shall see, however, although the techniques can undoubtedly be useful if managed well, the challenges of effective operations and production are often related



**Figure 8.1.** SAP's enterprise application software

to organization and skills, and their strategic management. Unless these challenges are addressed, the techniques will provide little benefit.

The techniques themselves continue to improve. MRP has become a sophisticated activity within supply-chain management and supply-network strategies for many firms. This involves decisions about the design of supply networks, the role of purchasing and single- and multiple-sourcing strategies (Gadde and Hakansson 2001; New and Westbrook 2004). There are nevertheless significant difficulties in implementing ERP systems. They often require major organizational changes and strict adherence to routines that can stifle innovation. This can lead to expensive and inflexible solutions that do not necessarily fit well with fast-moving, innovative firms or with delivery in bespoke product and service markets.

## Lean production

Lean production is a term that derives from the Formula 1 racing-car industry, and was used to explain the fast and efficient development of engines and the elimination of wasted time and effort. It was used in a worldwide study of the auto industry that contrasted the use of lean production methods found at that time in Japan, with the mass production methods found in the US and Europe (Womack et al. 1990). The

differences in performance were immense, with lean production taking half the hours of mass production methods to design and make a car, in half the factory space, with half the labour, and half the investment in production tools. Using lean production methods, car-makers also produced greater product variety and higher quality.

Lean production, however, has some limitations, and there is evidence that the production systems that produce such high quality and customized outputs also place a cost on their workers, suppliers, and communities, in the levels of stress they absorb in delivering consistently and reliably (Cusumano 1994).

Lean production includes just-in-time (JIT) and supply chain management techniques. JIT is a managerial technique aimed at reducing inventory. It originated in US supermarkets, which managed their systems so that foods were delivered just-in-time to be sold. This meant goods did not have to be stored by the supermarket, thereby reducing storage requirements and the amount of capital invested in unproductive inventory. JIT methods were successfully transferred to Japanese manufacturing firms, which produced and delivered finished goods just-in-time to be sold, sub-assemblies just-in-time to be assembled into finished goods, fabricated parts just-in-time to go into sub-assemblies, and purchased materials just-in-time to be transformed into fabricated parts (Schonberger 1983). JIT is a 'pull' system, with demand pulling components and parts to where they are needed, preventing materials in the system being inactive, and avoiding unwarranted costs of inventory. JIT is now widely used in manufacturing and service companies internationally.

Supply chain management is the other feature of lean production. In contrast to the arm's-length structure traditionally prevalent in Western countries, Nishiguchi (1994: 122) found a *clustered control* structure in Japan in which

firms at the top of the clustered control structure buy complete assemblies and systems components from a concentrated base (and therefore a relatively limited number) of first-tier subcontractors, who buy specialized parts from a cluster of second-tier subcontractors, who buy discrete parts or labour from third-tier subcontractors, and so on... this system absolved those on top of the hierarchy from the increasingly complex controlling functions typical of external manufacturing organizations.

Traditional customer-supplier relationships in the US and much of Europe have been based on a form of 'spot-trading', where tenders for particular work were put out to a number of potential suppliers. The contract was usually awarded on the basis of lowest cost and there was no assumption of continuity in the relationship. Based to a large extent on Japanese and (to some extent) Scandinavian experiences, far greater levels of integration have evolved between suppliers and customers, and a general trend has emerged amongst larger firms towards operating with a few 'primary' subcontractors, who have responsibility for coordinating 'secondary' subcontractors.

Subcontractors benefit from this system through the existence of stable contractual relations, which are usually automatically renewed, improved technological learning,

which occurs as customers make considerable efforts to upgrade the equipment and skills of their suppliers, and improve growth opportunities.

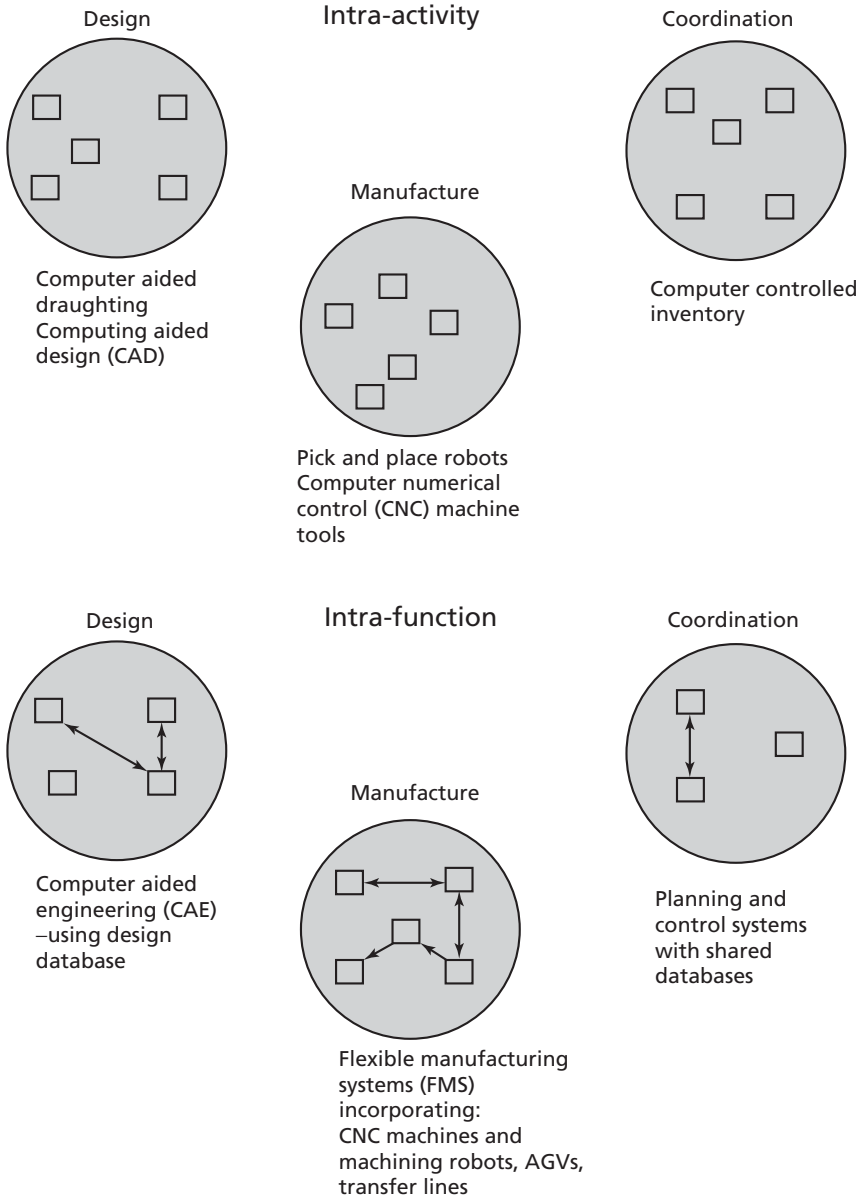
Decisions to outsource or subcontract have great strategic significance. Once capabilities have to be bought in rather than kept in-house, these capabilities are often lost to the firm forever. Consequently, it is important to have strong links through high-trust relationships with suppliers. There is compelling evidence of the advantages to be found in having close, obligational contracting relationships between firms (Sako 1992). Evidence from the construction sector shows that projects where there are high degrees of trust in collaborations or partnerships between suppliers and clients, often result in more predictable and higher quality outputs than those which rely upon more traditional, contractual relationships (Gann 2000). The construction of Terminal 5 at Heathrow Airport in the early 2000s provides an example of this approach, in which the client, BAA and main contractor—Laing O’Rourke—worked with other suppliers using a collaboration framework in which risk and reward were shared. The project was valued at \$8.5 bn—Europe’s largest building project at the time—and was delivered on time and within budget. Lean production therefore also requires lean consumption—the ability of customers to understand how they can get more from their suppliers—enabling a smoother flow of goods and services (Womack and Jones 2005).

## Automation

Automation can take many forms, ranging from the automation of particular activities, such as design or machining or coordination, to the pinnacle of the automated factory, computer-integrated manufacture (CIM). A good way of conceptualizing automation is to use the approach of Kaplinsky (1984), who describes three forms of automation: intra-activity, intra-function, and inter-function (see Fig. 8.2). Automation may also extend beyond the firm and integrate the firm’s activities with those of others. It uses electronic transfer of information, and increasingly e-commerce over the Internet to facilitate inter-company transactions processing systems.

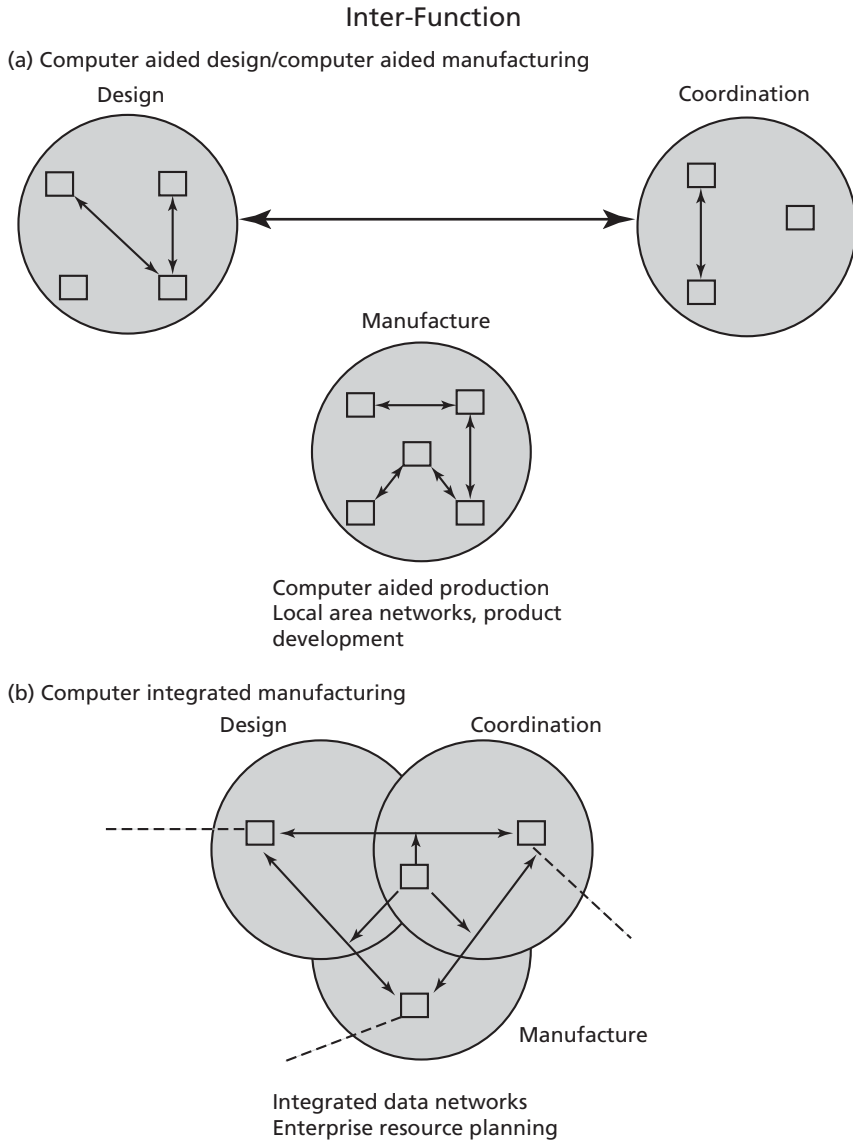
Automation, in the form of CIM, has often been considered to provide the answers to all the problems of operations and has the potential to overcome many difficulties (see Table 8.2); however, the promises of automation are rarely met. Over the years, a number of studies have revealed the problems firms face in adopting these innovations and the failures of automation to meet expectations. These studies point to technical difficulties, strategic shortcomings, and inattention to work organization and skills issues. The problems include:

- Lack of a strategic framework for investments.
- Lack of planning and foresight.
- Inability to adapt work organization and produce the level of organizational integration required.



**Figure 8.2.** Forms of automation

Source: Based on Kaplinsky 1984.



**Figure 8.2.** *Continued*

- Preoccupation with short-term returns, through, for example, labour cost savings.
- Failure to realize the advantages of systemic integration.
- The technological complexity of CIM.
- The need to undergo extensive learning and adaptation.
- A requirement for greater breadth of skills and flexibility in the workforce.

An examination of the success and failure factors in the introduction and use of automation shows that they are similar to those found in new product and service

**Table 8.2.** CIM a solution?

Main problem issues	Potential contributions offered by CIM
Producing high-quality standards	Improvements in overall quality via automated inspection and testing, better production and more accurate control of processes
High and rising overhead costs	Improvements in production information and shorter lead times, smoother flow; less need for supervision progress chains
Introducing new products on schedule	CAD/CAM shortens design lead time. Tighter control and flexible manufacturing smooths flow through plant and cuts door-to-door time
Poor sales forecasts	More responsive system can react quicker to information fluctuations
Inability to deliver on time	Smoother and more predictable flow through design and possible accurate delivery
Long production lead times	Flexible manufacturing techniques reduce set-up times and other interruptions so that products flow smoothly and faster through plant

Source: Based on the work of John Bessant.

development. They are presented in Table 8.3. Some of the major factors that affect the uptake and use of automation and operations and production management techniques include investment appraisal techniques, the extent of organizational integration (both internal and external), and the question of strategy.

Whilst automation enables the benefits of predictability, speed, and efficiency compared with manual processes, many of the new computer-controlled systems used in manufacturing and service operations include instrumentation systems which collect data on *how* operations are performing. Analysis of these data can provide deep insights into how production processes can be improved and products and services redesigned to

**Table 8.3.** Success and failure in implementing automation

Success is associated with	Failure is associated with
Top management commitment at all stages of the project	Lack of commitment
Clear strategic vision, communicated throughout the organization	Lack of clear strategy and/or its effective communication to the rest of the organization
Shared views of project aims and implementation approach	Lack of shared view and unresolved conflicts regarding design and implementation
Multi-function project teams, multi-function perspective	Single function teams, unilateral perspective
Effective conflict resolution within team	Unresolved conflict over key implementations issues
Extensive user education to give understanding of broader implications and purpose of system	Minimal training for operation
User involvement in system design (of hardware/software, jobs, structures, roles, etc.)	Unilateral design, organization expected to adapt to systems rather than change system
Close involvement with suppliers	Minimal involvement
Readiness to re-examine and change existing procedures	Attempt to computerize what is already there
Performance measures that reflect broader organizational effectiveness	Performance measures narrowly defined and related to efficiency at local level
Flexibility in design and continuous monitoring to adapt to unexpected changes	Inflexibility in system in response to unexpected changes in environment

Source: Bessant (1991); Bessant and Buckingham (1993).



**Box 8.4 Innovation in gravestones**

Vermont granite has been the main material used for US gravestones since the nineteenth century. Barre, Vermont, is the capital of the US gravestone industry. The industry employs 1,500 people, 300 of whom are full-time gravestone stonemasons, a highly skilled professional activity. The industry is under increasing strain because gravestones are becoming less popular. In 2004, over 30 per cent of Americans were cremated and the popularity of cremations has increased dramatically over the past thirty years, reducing the need for new gravestones. The industry also faces global competition. Indian and Chinese firms have successfully entered the sector, supplying high-quality gravestones for less than half the price of those from US producers. As a result, US gravestone-makers have had to innovate and have adopted new laser cutters that can reproduce detailed photographs in granite. This involves using specialized cutting machines to replicate pictures, allowing loved ones to capture images of the deceased for future generations.

*Source: New York Times, Thursday, 26 October 2006.*

make them easier to deliver. This facet of modern operations—the ability to ‘informate’ the process—provides new information to support innovation processes (Zuboff 1988; see the case of Rolls Royce later).

Even the most traditional businesses can be affected by automation (see Box 8.4).

## Investment appraisal techniques

Firms tend to use simple quantifiable financial indicators, such as *payback periods* and *discounted cash flows* (DCF), to assess their operations and production investments. These tend to create risk-averse and short-term attitudes. The payback-period method is simple and widely used. A company invests only in those projects that can pay back the original investment in a certain number of years, usually two or three. This method ignores returns post payback period, and minimizes risk.

DCF enables interest rates to be included in investment appraisals. When a long time is required to pay off an investment, the company has to expend more to finance it in interest. DCF is a means of allowing for this in deciding whether to invest. The returns a company expects to make in the future (for example, in five years) are reduced in its calculations to allow for the fact that the company will have to pay interest on that part of the investment for a full five years. That part of the investment that comes back to the company quickly (for example, in one year) is more valuable to the company because it does not have to pay as much interest before it gets its money back. Since returns a long way in the future are ‘heavily discounted’, the DCF method favours investments that give a quick return (although not to the same extent as the payback-period method, which does not count returns after the period).

Even the commonly used return-on-investment (ROI) indicator has problems in respect of operations and production. In addition to encouraging short-term investments:

- It is very sensitive to depreciation write-off variances, which makes comparisons between facilities using different approaches to depreciation unfair.
- It is sensitive to book value and older facilities can therefore enhance ROI artificially.
- It fails to incorporate non-quantifiable information, such as competitor behaviour or the specifics of product markets.

Therefore, according to Brown (1996: 53) 'decisions concerning manufacturing investment, in terms of new processes or technology, have to be made on long-term manufacturing advantage and not narrow financial criteria such as ROI or immediate cost savings'. As with R & D investment, an 'options'-based approach to investment in operations and production has advantages (see Chapter 7; and Trigeorgis 1996). Hayes and Pisano (1994: 79) argue that:

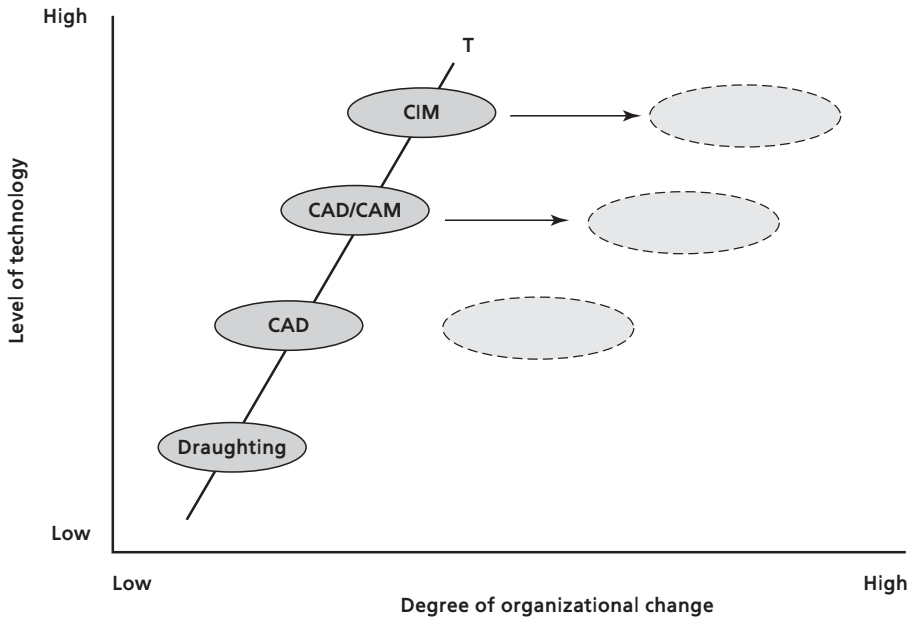
[A]ccording to the new approach to manufacturing strategy, managers should think about investments more in terms of their capacity to build new capabilities. Rarely, if ever, is a strategically worthwhile capability created through a one-shot investment. Capabilities that provide enduring sources of competitive advantage are usually built over time through a series of investments in facilities, human capital, and knowledge. . . . Investments can create opportunities for learning. These opportunities are a lot like financial options: they have value, and that value increases as the future becomes more unpredictable.

An important corollary of this approach is that investment in factories and facilities is different from other investments in the sense that it is 'organic'—that is, it takes time to grow and involves various integrated elements such as machines, people, and organization. Investments in factories and facilities cannot be readily switched on and off. Once the 'organism' is dead it cannot quickly be revived. Hayes and Pisano argue that the capabilities embodied in human capital are analogous to human muscles, which atrophy with disuse and can deteriorate irreversibly.

## The internal integration of operations and production

Perhaps the major problem with the introduction of new operations and production technologies is the inability to adapt the organization to the opportunities the technology provides. The extent of the need for aligning technological and organizational change is shown in Fig. 8.3. The higher the level of technology, moving from intra-activity to inter-function automation, the greater is the need for organizational change.

The importance of work organization issues is seen in the case of CIM. CIM is often seen as a means of improving the flexibility of the production domain. Flexibility is not an easy concept and can mean different things to different people, but, according to Upton (1995), it involves:



**Figure 8.3.** Aligning technology and organizational change

Source: Voss 1994.

- *Increasing product range*: the ability to make a small number of different products, or a large number of slightly different products.
- *Mobility*: the plant's ability to change nimbly from one product to another, minimizing response times and inventory.
- *Uniformity*: the capacity to perform well when making any product within a specified range.

As such, flexibility is an important source of value enhancement from a given capital stock.

In Upton's study of sixty-one paper manufacturers in the USA, he found that the flexibility of the plants depended much more on people than on any technical factor.

Although high levels of computer integration can provide critically needed advantages in quality and cost competitiveness... operational flexibility is determined primarily by a plant's operators and the extent to which managers cultivate, measure, and communicate with them. (Upton 1995: 75)

A wide range of factors influences the way work is organized around particular technologies, and these need to be considered when implementing new process and operations systems. They include:

- Type and extent of investment.
- Batch sizes and product complexity.
- Company size, ownership, and financial circumstances.
- Customer demands from products and services.
- Industrial and social relationships within the firm.
- Existing skills profiles and training programmes.

Much depends on the choices made by managers. Although there are technical constraints (it does not pay to have a highly skilled worker capable of computer-programming watching a machine during the production of large batches), and trades unions might have an influence in determining who does what, managers generally have discretion in the choice of work organization.

Mobilizing the problem-solving capabilities of employees is an essential part of innovation in operations. Giving greater autonomy and task discretion to the individual applies also to shop-floor teams. Quality circles, where workers from a particular work area meet to discuss quality and productivity issues, are one form of team structure that is very common in Japan. Harley Davidson is a US example of a company that addressed quality problems with TQM and devolving responsibility to shop-floor workers to give them autonomy over production decisions. This helped build its reputation as a reliable, high-quality manufacturer.

## The external integration of operations and production

One of the primary challenges of operations and production is integrating the firm's activities with those of suppliers and customers (the final market and/or distributors). Some of the most effective methods of facilitating external integration are found in the practices characterized as *lean thinking* (Womack and Jones 1996). This approach, which is based on research into companies such as Pratt & Whitney, Porsche, and Toyota, builds on earlier work by Womack and Jones on lean production. Lean thinking helps managers specify where value lies, and addresses the activities for a specific product along the value chain, incorporating the activities of a firm and those of its suppliers, customers, and distributors (see Chapter 9 for a discussion of the value chain).

The integration of production activities occurs locally and internationally. Local production networks—the concentration of many small and medium-sized firms in narrow regions with highly interdependent interactions among them and with parent firms—is an important aspect of industrial organization (see Chapter 2). The international networks of small firms also play a central role in diffusing technologies, building skill bases, and achieving flexibility in production, seen particularly clearly in the success of the production networks in the electronics industry in Taiwan (Mathews and Cho 2000).

Large firms have had to learn how to manage international networks to service geographically dispersed markets. To do this, firms have tended to locate parts of their operations offshore in regions with skilled workers, but lower labour costs. Manufacturers have tended to transplant their manufacturing operations close to local markets. Toyota is a good example. It has a strategy of supporting the development of new production facilities through a mentoring system, using an established factory as the 'mother plant', to train staff and exchange personnel to ensure that the new plant operates to the same high standards as existing factories. The evolution from local to international production networks is a feature of the development of Benetton: a company, which, as shown in Box 8.5, pays attention to all aspects of innovation.

### Box 8.5 Innovation across-the-board: the case of Benetton

Benetton, the Italian clothing company, demonstrates the importance of innovation not only in new products, services, and operations, but also in all the firm's activities. It is not enough to be brilliant at one or two areas of activity within the innovation process; innovation depends upon all activities being executed competently. Benetton is an example of a firm that is innovative across the whole range of its activities: from design and operations to distribution, sales, and organizational structure (Belussi 1989).

Benetton enjoyed remarkable and sustained growth throughout the 1980s and 1990s. In 2005 it employed around 8,000 staff and enjoyed 22 per cent income growth over the previous year to produce sales of over €1.9 billion. It is a family company with 67 per cent of shares family owned. It was listed on the stock exchanges in Milan in 1986, Frankfurt in 1988, and New York in 1989. The company began in 1957, when Luciano Benetton, a shop assistant in the textile industry, began to work with his sister, Guiliana, a knitwear factory worker. Luciano 'moonlighted' as a salesman for knitwear, and collected orders for Guiliana to design and make at home. By 1965 these activities had reached such a scale that they established a factory in Ponzano, which employed sixty people. Their brothers, Gilberto and Carlo, assisted the company with administration, finance, and production. Luciano's early decision to sell directly to the consumer through specialized knitwear shops, rather than through retail outlets that sold competing products, was the basis of the Benetton retail outlets, which exclusively sell the Benetton lines. The first such store was opened in 1968 in Belluno in the Italian Alps. By 1975 Benetton controlled over 200 shops and in 1979 it began international expansion with its first stores in North America and Europe. By 1985 it had over 2,000 shops and was exporting 60 per cent of its production. In 1989, it entered the East Europe and former Soviet Union markets and in 1991 it expanded into China and India. By 1995 it had control of 7,000 shops in 163 countries. In 2007 the numbers of its shops has reduced and it operates a retail network of around 5,000 franchised stores, department stores, and mega stores operating in 120 countries. The majority of its sales in 2005 were in Europe (84 per cent), 57 percent were in Italy; 11 per cent of sales were in Asia, 4 per cent in the US markets, and 0.2 per cent in the rest of the world.

Although Benetton is primarily a clothing company, it has diversified into cosmetics, sunglasses, luggage, shoes, and watches. In 1989 it acquired Nordic as an initial entry into sporting goods under Benetton Sportssystem. In 2001 it began selling off its sporting-goods holdings and launched the Sisley youth brand. By 2003 it had completely sold off its sporting-goods division to focus on its clothing division. It is still experimenting with diversification. In December 2006 the co-brand 'Barbie loves Benetton' was launched, a global partnership between Benetton and Mattel. Its primary focus, however, is on organic growth. A Product Development Unit was established in 2004 to connect product, operations, and sales units with two objectives: to improve service to Benetton's traditional customers, the company's global network of partners; and to make more direct contact with the market and the final consumer.

*Innovation in design.* A staff of 300 designers from all over the world creates the collections for Benetton's casuals, leisurewear, and street-wear brands. Design has always been important. In 1965 it was one of the first companies to introduce pastel colours in clothing, immediately spurring huge demand. A system of post-manufacture dyeing was introduced in 1972, which allowed colours to be chosen after the

garments had been made, rather than the previous practice of assembling already dyed material. In an industry where preferred colours change seasonally, this allowed a much quicker response to customer demand. The company adopted the use of CAD in clothing in 1980, which gave it greater ease and control of the design process. Currently, Benetton's dyeing vats are operational twenty-four hours a day.

*Innovation in production.* Benetton claims all its production systems and equipment are renewed every five years. Consistent high quality is one of the fundamental objectives of its production process—from raw materials to finished garments. In its first factory Benetton used old knitting machines modified to produce substantial productivity improvements. Its subsequent use of innovative production machinery included: knitwear-stretching equipment (1972), automated knitting (1979), airlift work tables, and automated dyeing (1982). One of its recent innovations is a computerized knitting procedure capable of producing a complete, seamless sweater assisted by a software program conceived by Benetton specialists. Benetton is the world's largest consumer of pure virgin wool and has computerized every phase of knitting. In 1993 it opened a state-of-the-art production facility in Casterette, Italy, and by 1995 it had built two new robotized factories near Treviso, Italy. Its production system is capable of turning out around 130 million garments every year and is one of the most advanced clothes manufacturing systems in the world.

*Innovation in the organization of production.* In 2005, Benetton had seventeen apparel and textile factories, twelve in Italy, two in Croatia, and one each in Tunisia, India, and Hungary (Reuters 2007). It subcontracts a substantial proportion of its production work. In 2003, charges from subcontractors represented 70 per cent of the company's production costs. The highest value-added portions of the manufacturing process, however, are undertaken in its own facilities. The advantages of subcontracting include the use of external managerial resources and significant reductions in labour costs. Subcontractors have traditionally been located near the company's production facilities in northeast Italy. In the early 1990s Benetton had around 750–800 subcontractors in Italy and, according to Tattara (2006), the number had declined to 520 in 2005. Only 30 per cent of Benetton's current production is based in Italy. Benetton aims to substantially increase production in East Europe and Asia. A joint venture has also been established with the Boyner Group in Turkey to develop production and sales in surrounding areas. Benetton claims this de-localization process has enabled significant cost reductions.

During 2005, Benetton redesigned its production system, evolving from an organization based on divisions (e.g., wool and cotton) to a structure based on various service units, such as planning and quality control, to optimize quality, service, and product delivery times. This system relies on a 'network of skills', which aims to exploit the best industrial capabilities available internationally, into which Benetton know-how is introduced, in each case using the most appropriate production techniques (Benetton 2005). In 2005, the number of articles of clothing produced increased by some 3 million over the previous year.

*Innovation in the distribution system.* This involves a combination of automation and IT with a system of agents and the use of franchising. Stores are coordinated by agents or independent sales representatives as well as a team of area managers employed by Benetton. From its beginning, Benetton has maintained direct control of logistics and invested heavily in automating logistics processes to integrate the production cycle from customer orders to packing and delivery.

At the centre of distribution operations are the Benetton shops, which are described as the 'antennae of the Benetton information system'. The shops report weekly sales figures and, on this basis, can detect micro-level trends. Benetton's directly operated retail distribution network has around 300 shops in the leading international fashion capitals, centrally coordinated in Italy. In 2005 around 18 per cent of the company's revenues derived from its 300 directly operated stores. The main countries where Benetton operates directly are Germany, Japan, and Spain.

The company's agents or independent sales representatives also operate the distribution network, optimize and promote growth, communicate market trends, and provide suggestions, new ideas, and technical support. This system of independent sales representatives was first developed by Benetton in Italy and later applied worldwide during Benetton's international expansion after 1978. In 2005 there were around eighty-seven agents, each responsible for a geographical area. Of these, fifty-five were dedicated to the casual-wear brands (United Colors of Benetton, and Sisley). Agents receive commissions on sales from Benetton in their territories and, sometimes, own stores that sell Benetton products. The representatives operate within Benetton's strict retailing policy. These shops are franchised and they are allowed to sell only Benetton stock (Benetton only sells to Benetton shops). The company defines shop

styles, layout, and sales strategy. In 2003, 44 per cent of Benetton stores were located in Italy, 38 per cent in the rest of Europe, 5 per cent in the Americas, and about 12 per cent in the rest of the world. In the mid-1990s Benetton developed a preference for larger stores offering a wide range of Benetton goods.

There are many advantages from this retailing system for Benetton. The system guarantees outlets for Benetton products and hence reduces risk and uncertainty; it enables direct knowledge of customer preferences; it allows for easier and more efficient planning of production processes; and it allows the shops to be used exclusively for Benetton advertising and marketing.

In the late 1990s Benetton restructured its distribution network to implement a new logistics system in which the warehouse was the system's junction and part of the distribution system rather than just a place for storage (Eunjung et al. 2003). The new system eliminated fragmentation of inventories across the world by concentrating finished goods in three sorting centres in the USA, Italy, and the Far East. Its Automated Distribution System is able to handle up to 40,000 incoming/outgoing boxes daily with a workforce of only 24, compared to the 400 or so people normally required in a traditionally organized operation. The Automated Sorting System sorts and packs the 130 million items produced a year.

*Innovation in information systems.* Benetton has a highly sophisticated information system. The managing director and president of Sun Microsystems—a major vendor—claims 'Benetton is a leader in innovation and is the perfect example of a well-networked enterprise.' Its IT infrastructure and strategy is based on open standards including Unix (both Solaris and Linux), Java technology, and XML. Benetton's information system produces a JIT response to consumer demand, enabling it to get a new product to market before its competitors, and to respond quickly to reorders from both domestic and foreign shops.

In an effort to improve its supply-chain management system, in 2003 Benetton tested the use of RFID on its garments to allow real-time tracking of its inventory and to reduce inventory and the time capital tied up in warehouses (Shim 2003). Cost-benefit analysis was undertaken to examine the efficiency of the company supply chain (production, logistics, and store stock management). It proved to add no significant benefits and Benetton decided to drop it. To perform Web-based sales analysis across its international stores Benetton installed the MicroStrategy Business Intelligence Platform in 2003. In 2002 Benetton installed SAP's enterprise management software system specifically designed for the clothing and footwear industry, in its production facilities, logistics centres, and retail outlets worldwide, to support its financial processes, order fulfilment, supply-chain management, and logistics. *Benettontv* is a new portal for Benetton's agents, clients, shops, and buyers. It provides information to the entire Benetton commercial network in real time, updating everyone on initiatives (new collections, reassortments, display methods, distance learning for employees) and receiving orders via the Web.

*Innovation in marketing and communication.* The company radically altered the face of conventional advertising when it adopted the trademark, 'United Colors of Benetton' in 1989. It was argued to be the antithesis of customary notions of advertising in that an ideology is explicitly promoted through an implied product rather than the other way round (Tinic 1997). Benetton campaigns have contributed to its international recognition, won awards, and been imitated by producers of lifestyle products as well as by competing clothing companies. 'COLORS', a quarterly magazine was launched in 1991, is published in four languages, and sells in forty countries. The company has an Internet site that has received a record number of hits and won critical acclaim. In 1994 it created Fabbrica, the Benetton Group communication research centre, as an applied creative laboratory for writing, composing, design, and interactive photography and film for cinema or video. Fabbrica experiments with new forms of communication and promotes the brand, consistent with Luciano Benetton's belief that 'communication should never be commissioned from outside the company, but conceived within its heart'. The United Colors campaign advertising has been extremely controversial, but having its own volleyball, basketball, rugby, and Formula 1 racing car teams, and a creative journal and its own research school enhances Benetton's image as an exciting and innovative company.

According to Benetton, all these factors in combination explain the company's success. A senior manager once described it as follows:

There is a key to Benetton's success: the possession of a peculiar technology. Not technology in the traditional sense, it is different from 'revolutionary' techniques or unusually sophisticated machines.... Instead, it is about a specific kind of know-how that the Benetton group feels it has acquired. This cannot be acquired in any way except by direct experience.... This know-how enables the company to enter any budding market, develop it, and reap the benefits of its growth.



The Benetton system does have its tensions and shortcomings. Suppliers are ‘locked in’ to its system and this limits their potential growth. Risk is pushed onto the shop owners, and this is compounded by the Benetton policy of no returns of stock. Benetton has not achieved huge success in the USA; complaints about its comparatively high prices, and dissatisfaction with its returns policy, which is that goods have to be returned to the store of purchase are among the reasons for this. It continues to be very dependent upon sales in Europe, and Italy in particular. It is under continual scrutiny as a result of its confrontational advertising, and importantly, the Benetton system of production and distribution is increasingly emulated by its competitors. Nonetheless, Benetton has been phenomenally successful and the key to this success has been innovation across-the-board. Although technological innovations historically have been very important in both design and production and in the information system the company uses, these are combined with the organizational innovations in its production networks, franchising, and agents to create the special ‘know-how’ that the company defines as its core competence. Constant commitment to innovation has always characterized the group’s business organization in areas of marketing and communication, IT, design, production, research, and integrated logistics.

## Innovation in processes

The ways firms make and deliver their products and services are changing profoundly. Radical process innovations create new operations that significantly improve productivity, quality, reduce cycle times, and lower costs, leading to enhanced customer satisfaction and market differentiation. These are distinguished from routine operational improvements that achieve better operational performance through existing methods such as reduction of errors and waste (Hammer 2004: 770). Major innovations in processes relate closely to how firms manage knowledge, capabilities, and resources. They very often require firms to reorganize the deployment of these resources and capabilities to optimize the ways they service customers in particular markets. This form of reorganization is sometimes known as ‘business model innovation’.

Table 8.4 presents examples of process innovations that UK manufacturing firms have reported as being new to their industry. The most common types of process innovations involve the introduction of new machinery and equipment, followed by new production processes, such as adopting JIT systems of delivery, and design technologies, such as CAD and rapid prototyping machines.

A set of operational capabilities lies at the heart of process innovation, based on techniques that evolved from operations research—a discipline that emerged after the Second World War focusing on finding the most efficient or optimal ways of achieving particular goals. The use of operations research in production processes involves the application of mathematical models, statistics, and algorithms to inform decision-making about the flow of goods and services (logistics). A variety of techniques are used to analyse and improve ‘flow’, including *system dynamics*—a method for analysing the ways in which different parts of a social, technical, or natural system interact with one another (Forrester 1961). Systems dynamics attempt to show how changes in parts



**Table 8.4.** Examples of radical process innovations among UK manufacturers, 1998–2000

Types of Process Innovations <i>Subtype of process innovation</i> Examples	Number of references	Share of total (%)
<b>Introduction of new machinery and equipment</b> Automatic noodle making machine Automatic welding of PVC materials Injection moulded tunnel lighting systems	115	47.9
<b>Changes in production processes</b> Modification to cathode processing techniques Introduction of bulk packaging of sleeved products Change from batch agglomeration to continuous lower energy densification	47	16.6
<b>Use of information and communication technologies</b> <i>Use of information and communication technologies in design</i> CAD for design of kitchens Introduction of 3D modelling for design Use of rapid prototype technologies and laser analysis tools	36 20	15.0 8.3
<i>Use of new communication technologies</i> Network complaint management software E-commerce site for sales and services On demand printing—book details are held in electronic format rather than as stock	16	6.7
<b>New management practices</b> Introduction of lean production systems Changing from production line assembly to a single point assembly mode of operation Process improvement plan to reduce process loss through use of statistical process control	21	8.8
<b>Other</b>	21	8.8
<b>Total</b>	240	100.0

Source: UK Innovation Survey 2001.

of a system—such as a production process or supply chain—influence outcomes and activities in other parts of the system. Using this approach it is possible to explore what might happen if, for example, factory output were scaled up and whether inputs would be sufficient to meet the new requirements, and whether distribution channels could deliver higher volumes to customers. Systems dynamics in operations and production processes, therefore, explore feedback loops between stocks and flows in processes, using what are called ‘*causal loop*’ diagrams. These enable production managers to explore issues, such as the ‘bullwhip-effect’ (where the variability in accuracy of information on demand increases as information flows up the supply chain), and ‘error amplification’ (where the use of inappropriate periodicity of reporting can result in errors that compound over time, misleading decision-makers about how much to produce). These are found as a consequence of inaccuracies in, for example, demand forecasts up and down supply chains (Disney and Towill 2003). System dynamic models of supply-chain operations can therefore improve the ways in which inventory and other resources

are positioned and utilized in the launch of new products and services. These data are being used to create what are called ‘agile’ supply chains, enabling managers to develop new ways to compress total cycle times, reducing lead times (Mason-Jones and Towill 1999). Operations research and logistic system dynamics have evolved greatly since the mid-1970s. They have developed from the period of mass production, which relied on holding expensive large stocks of semi-finished goods and where techniques such as ‘queuing theory’ were used in attempts to reduce the problems caused when stocks backed-up due to the need for buffers in manufacturing systems—to lean and agile JIT techniques, which aim to provide immediate signals of variations in demand, completely eliminating the need for stocks and wasteful queues in operations.

The use of statistical analysis of all the contributors to performance can produce radical new insights into the ways things should be done (see Box 8.6).

#### **Box 8.6 Moneyball—Innovation in baseball**

Oakland Athletics has been one of the most successful US baseball teams since the mid-1990s. Its success was founded on the fundamentals of good sports management, such as coaching, training regimes, and support from fans. The Athletics or, ‘As’ as they are known, have also been innovators in the way players are selected to be on the team, allowing them to remain competitive with other teams even though they spend much less on players’ salaries. The As’ approach is described in Michael Lewis’s book *Moneyball*. Its innovation was to use insights from statistical analysis of baseball data to influence the formation of teams. Many of the statistical tools used were developed by hobbyists working outside baseball.

The Moneyball approach focuses on player selection. There is an annual draft of young players into the baseball league. Players may enter the draft when leaving high school, around the age of 18, or when they leave tertiary education, normally around the age of 22. The draft is intended to level out competitive imbalances by enabling the worst-placed team of the previous season to make the first selection from among the best young players in North America. Baseball players often require several years’ professional training before they are ready to play in the Major League, and only a few players go straight from high school. Frequently, young players spend several years in the ‘farm’ teams building up their skills and strength. Statisticians working for the Athletics analyzed young players’ performances and discovered they were often very erratic: some were very successful, whereas others were complete flops. They found a player’s performance in high school was a poor predictor of future performance. For college players with four years or more experience, however, past achievements could be an accurate guide to future performance. It allowed a longer time series and therefore the statistical trend line of players’ performance could be more easily assessed. This finding led the Athletics to focus their efforts on drafting college players rather than high school players.

The Athletics’ statisticians also noticed that players with high on-base percentages tended to be undervalued in the market for players, often commanding lower salaries than players with more flashy statistics such as a high number of home runs. Yet, when they analysed the factors that contributed to run scoring in the game, a player’s on-base percentage was a more reliable indicator of their contribution to the team’s overall ability to score runs than the number of home runs they hit. With this information, the Athletics were able to draft and sign players with high on-base percentages, often choosing players that others were not interested in.

The statisticians also found that players coming back from long-term injuries were often undervalued in the market. This was natural given the risk of further injury. High-skilled veteran players, however, bounced back from even severe injuries late in their careers and therefore signing these players at a low wage was often a good investment. Using this approach, the team had a continuous pool of skilful players that other teams had probably passed over. The success of the Athletics has led to widespread imitation by other baseball teams. It has also helped change the notion of what is required of a successful baseball-team manager. Previously, general managers were almost exclusively recruited from the rank of former

professional players and coaches. Now it is not uncommon to see individuals with little or no baseball experience, but with considerable statistical skills, appointed as general manager. Their success has also led newspapers and other media to present new sets of statistics on player performance that better reflect the importance of on-base percentage.

Source: Lewis (2003).

There are a number of drivers underpinning process innovation, including the need to find ways to manufacture and deliver new products and processes, improve operational productivity and quality, and to comply with regulations. The role of the production facility has evolved to the extent that in many industries, the factory is becoming a laboratory (Ball 1997; Gershenfeld 2005) and a major focus for technological learning and process innovation (Pisano 1996). As Kenney and Florida (1993: 65) put it, 'the factory is no longer a place of dirty floors and smoking machines, but rather an environment of ongoing experimentation and continuous innovation'. In some industries, improvements in operations have been used to improve the innovation process itself, for example, high-throughput screening in pharmaceuticals. Production facilities aim to create innovative, differentiated products and services economical to produce, capable of being customized to meet specific requirements (Kotha 1995). Innovation in production processes themselves has become a mainstay for profitability and market expansion. Process innovation, particularly in the form of incremental continuous improvement, known as *kaizen* in Japan, is a key driver of profit for many firms.

During the 1990s, a downturn in the world economy led in part to a particular form of process innovation known as *Business Process Re-engineering* (BPR) (Hammer and Champy 1996). This took hold across industries, particularly in North America and parts of Europe. In some companies it resulted in 'downsizing' and a focus on what firms thought were their core businesses, sometimes hollowing out the firm to the extent that it lost technical capability and became too weak to innovate outside a narrow focus of activity. As we saw in Chapter 2, many companies are changing from functional to process-based organizational structures. BPR has enjoyed great success as a technique designed to assist this reorganization. It has not, however, produced noticeable productivity increases (Lester 1998), and has had many negative consequences, particularly job losses. The principle of organizing by process is valuable nonetheless, provided it takes account of existing company skills and routines, and is supported by appropriate technology. This process view of the organization has had benefits in creating a focus on how firms combined resources and capabilities in related activities to improve efficiency and reliability of delivery, removing non-value-adding activities (Hammer and Stanton 1999).

In Japan, firms took a different approach to their operations and processes, maintaining a wider range of in-house capabilities and longer-term perspective on future business opportunities. Japanese enterprises belong to an interactive, dynamic learning system

in which companies continually adapt and change in response to learning from past experiences, competitors, suppliers, other sectors, and from overseas (Fruin 1992). This enterprise system is an inter-organizational structure of management and coordination in which there are many interdependencies between factories, firms, and networks.

In the 2000s, the business process-focused approach and learning-organization approaches appear to be coming closer together as markets become increasingly international and firms develop more sophisticated systems for developing and delivering products and services. In many industries such as automotive manufacturing, IT, retail, travel and financial services, oil, gas, and utilities, the need to source goods and components from low-cost producers and deliver them to customers in markets around the world has led to significant process innovation. Innovation in operations, including use of new technologies such as the Internet, has transformed the delivery of products and services in retail (from Wal-Mart and Tesco to Amazon), financial services (First Direct), travel (easyjet and lastminute.com), and logistics (Maersk, Exel, and TNT). Wal-Mart, for example, is a skilled user of information systems, being the first retailer to adopt bar codes and use electronic data interchange. It works closely with its suppliers, sharing sales data, to streamline and automate its supply chain. By the end of 2006, Wal-Mart required all its suppliers to tag their pallets and supplies with RFID to identify shipments to assist in tracking every item it sold.

Manufacturers, such as Dell, have used process innovation to develop new business models. Dell's business model, for example, is based on a particular set of process innovations driven by its strategy of being an efficient 'distributor'. The Internet provides a means for Dell to communicate directly with its end-customers and coordinate networks of suppliers to build-to-order and deliver personal computers. In developing these 'distributor' innovations, Dell deliberately sought to minimize investments in in-house R & D, relying upon the ability to source technologies developed by component manufacturers in its supply chain. This reduced operating costs and improved flexibility, but has also made it reliant upon technological developments from outside its direct sphere of control. Dell's approach to innovation focuses on meeting customer requirements through improvements in its processes. This has resulted in major innovations in online delivery and operations technology, rather than in products. Dell owns hundreds of patents to its processes—such as build-to-order software configuration systems—and has developed a range of shared operating standards.

In some industries, a focus on process innovation, derived from operations and production capabilities, has given rise to the need to integrate components and subsystems to create what have become known as *integrated solutions*. The business of systems integration is itself a major process innovation (Principe, Davies, and Hobday 2003). New business models have emerged from the capabilities to integrate systems and provide customers with solutions rather than stand-alone products. The growing importance of the service sector in many industrialized countries has created an opportunity for firms to innovate to find ways of improving productivity in service delivery. The ability to

harness ICT to capture data about the entire process from design, through production, to the ways in which products perform in use has enabled some firms to develop this model further, providing bundled products and services.

Rolls Royce, for example, no longer relies upon making and selling jet engines (the product) as its source of profit. Instead, it has placed instruments in its engines with digital, real-time diagnostic capabilities that generate very accurate data about engine performance during overall life cycles. This has enabled Rolls Royce to develop better knowledge about engine robustness, safety, and efficiency and to innovate in the provision of new services for maintenance, with accurate operating cost predictions and guarantees, such that airlines are able to buy 'Power By The Hour' (Rolls Royce's trademarked product/service offer). As Chapter 4 showed, IBM is an example of a firm that transformed its business model based on radical innovation in processes, moving away from computer hardware manufacture into high value-added services. The capabilities underpinning these professional services include integration of information systems with strategic management, creating what IBM calls a new discipline of *services science*. This involves bringing together disciplines of computer science, operations research, industrial engineering, business strategy, social and cognitive science, and legal expertise.

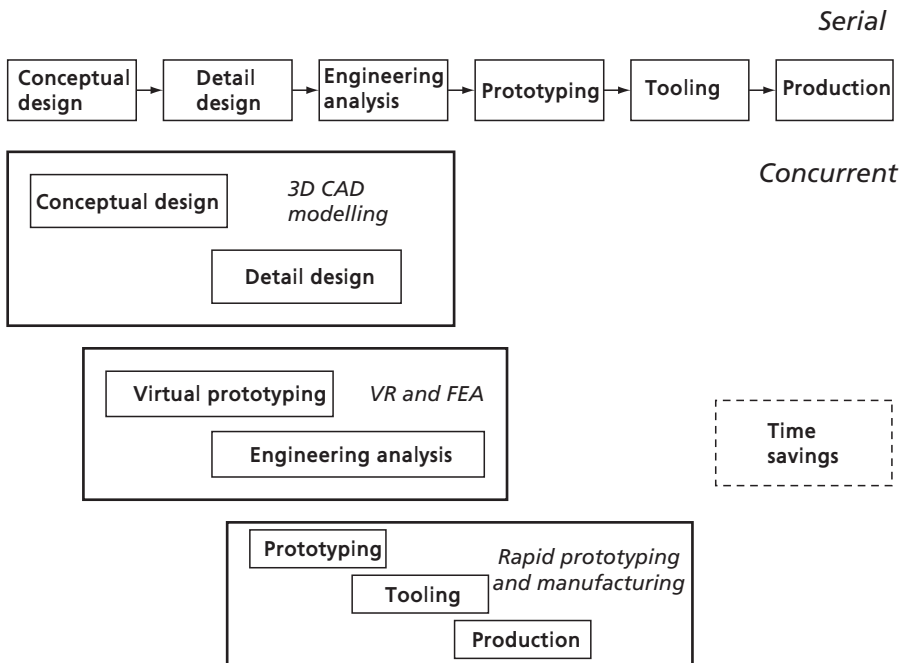
One consequence of innovation in processes has been a growth in flexible production systems aimed at improving economies of scope so that firms can provide customized products and services profitably in smaller markets. In some cases this is leading to highly differentiated markets and, in areas such as medical technology, the ability to service markets of one, where bespoke solutions are provided for each individual (see Chapter 5 and von Hippel 2005). The ability to deliver differentiated services using flexible operations means that companies can increasingly target the provision of such services. Rather than providing common, mass-market functional benefits from services—such as the means to travel from A to B—providers are able to tune their services to focus on the customer experience. Tuning operations to this level of bespoke provision has resulted in what are called 'experiential services' (Voss, Roth, and Chase 2007). These new services typically involve establishing an emotional connection between the customer and the organization or brand. Virgin Atlantic, for example, provides a service 'journey' in which each stage forms part of a new experience, from ordering a flight online, to being picked up at home by car or motorbike, to the experience in its lounges (haircuts, massage, beauty therapy, etc.), a good night's sleep in-flight, and a shower on arrival, before transport by car or motorbike to the destination. The new role for operations is to design and choreograph the service delivery system that encompasses all these experiences. As Voss et al. note, operations strategy has to deal with increasingly complex 'service encounters', involving multiple interactions and delivery channels as services move from 'experience' to 'destination'.

In some industries this trend is placing an increased focus on the organization of production in projects (see Table 8.1). Innovation in the processes and operations of project

delivery has led to new business opportunities for project-based forms of organizing production (Gann and Salter 2000; Davies and Hobday 2005). Mainstream manufacturing companies use project-based approaches in their product development processes. Toyota, for example, uses a multi-project management technique, which enables product development teams to use an operations approach to reducing lead times in designing and developing new vehicles (Cusumano and Nobeoka 1998).

Manufacturing production systems are changing with the development of new technologies to enable firms to move from virtual to rapid prototypes to real artifacts, on the same equipment. The advent of rapid prototyping machines, which take their instructions from digital CAD models of product designs, enable product development teams to assess key product and process attributes during refinement of designs for production. Rapid prototyping enables quick fabrication of physical models, functional prototypes, and small batches of parts, including moving elements. It provides physical representations that are cheaper and quicker to make than traditional hand-built models with a key advantage of reducing lead times in moving a new product to the manufacturing process (Dodgson, Gann, and Salter 2005). Figure 8.4 illustrates the speed advantages that concurrent developments using rapid prototyping bring to operations.

Virtual and rapid prototyping are continually evolving technologies. The ability to use low-cost, 3-D printers to fabricate individual artifacts is becoming an increasing



**Figure 8.4.** Time compression through rapid prototyping

Source: Pham and Dimov 2003.

possibility. This in itself is likely to produce innovations in the ways that businesses and consumers receive and use products. It is possible to download instructions from the Internet so that children can print, or fabricate, toys in their own homes. This could revolutionize the ways in which some goods are consumed. For example it is possible to envisage that people might download artifacts in their homes rather than buy them in the high street. 3-D printing is beginning to replace subtractive engineering, which operationally requires many sequences of 'tooling' to make complex parts. It is even possible to print moveable parts that are not possible to cut and shape using conventional milling machines. 3-D prototyping—or additive manufacturing—could be used to make one-off components directly, taking instructions for complex parts scanned and made from materials that will then form part of the final object. This could revolutionize parts of the medical sector where tissue engineering and regenerative medicine could be combined with the new techniques of prototyping and manufacturing to make bespoke body parts from living tissues.

## Summary and conclusions

Operations are an essential part of the innovation process. They play a dual role of facilitating new product and process delivery by providing the means to turn designs and prototypes into marketable goods and services. They also contain the information about activities, problems, and challenges that can lead to innovation in products and services themselves. Major innovation in operations can also deliver substantial benefits to producers and users.

MTI faces a substantial challenge and a considerable opportunity from developments in operations. The challenge is to create an environment within which innovation can flourish, but also one that benefits from the discipline and predictability of well-managed, systematic, routine operations. In some companies this creates a conflict between the need to devise new processes whilst supporting existing methods of production that provide profitable activities in established markets. The opportunity comes from the potential to harness innovations in processes—such as rapid prototyping using 3-D printers—to manufacture products or deliver services that were previously impossible, or too expensive to make.

Innovation in operations and processes provides opportunities for major changes in business models, particularly in the shift from delivering products to providing bundled products and services and, in some industries, experiential services.



# 9 Delivering Value from Innovation

## Introduction

The ultimate aim of MTI is to improve the competitiveness of firms by adding value to what they do. In previous chapters, we focused on how firms configure and organize internal resources and collaborate with external actors to develop innovations. We have seen how firms that are able to innovate can gain great commercial advantage. Commercializing technology is a fundamental element in building value and sustaining competitive advantage. In this chapter, we explore the commercialization process. We focus on the critical choices managers have to make when deciding how to capture value from their innovative efforts. We focus on the paths to market for innovations, appropriability regimes, formal and informal methods of protection, marketing of new products and services, and the process of technology transfer.

Investments in innovation can be commercialized by marketing and selling products or services, or marketing ideas through the sale of IP (Arora, Fosfuri, and Gambardella 2001). Every firm needs to establish how best to position itself using either of these approaches to generate returns from its innovative activities. We focus on how choices about whether to go to the market with products or ideas leads to different strategies for capturing—or appropriating—value from innovation. We review different types of appropriability strategies and their effectiveness. These strategies may use legal protections, like patents, or rely upon factors like secrecy and speed to market. Technology is not bought for its own sake but for what it can deliver to its users, and that part of the firm whose role it is to interface with customers—marketing—has an important role to play in commercialization. The commercialization process sometimes requires the transfer of technology to where it can be used profitably; and this aspect is examined.

## Positioning in the value chain

A fundamental challenge for firms is deciding where to position themselves in the value chain. The value chain comprises all those activities that add value in a productive



system, including research, development, design, operations, production, marketing, and support services (Womack and Jones 1996). Firms may seek to specialize within one activity or integrate a number of elements, such as development, operations, and support services. Such choices will have major implications for appropriability strategy, which needs to be matched with firms' positions in the value chain. Organizations that focus on upstream activities, such as design, need to use different approaches to those firms specializing on operations. Firms can migrate within the value chain as a result of strategic choice or competitive pressure (Jacobides, Knudsen, and Augier 2006). Through innovation some firms move down the value chain, specializing in downstream services, while others focus on upstream activities, providing designs for other firms to manufacture and operate (see Box 9.1). Simply, there is no single position within the value chain associated with greater possibilities for appropriating the benefits of innovation. Intel has been a supplier of single components to the computing industry over the last thirty years, for example, whereas Dell has focused on distribution and marketing of personal computers to business and individuals. Both firms have long histories of success. Profits in a value chain may migrate over time as some elements become standardized, while others become highly specialized. Thus, firms need to continuously reassess their positions, seeking opportunities to move to where they can extract the greatest value from their capabilities.

### **Box 9.1 Sega: movement along the value chain**

Some firms need to revise their strategy and reposition themselves in value chains to ensure their survival. The experiences of Sega are instructive about the challenges of maintaining industry leadership in a fast-changing industry and the need to reassess strategies. Although based in Japan, Sega was originally founded by an American, David Rosen. It began life as a jukebox manufacturer. Over time, it built up its capabilities in games development and manufactured a number of products for Atari, one of the best-selling games consoles of the 1980s. In 1989, Sega launched its own games console: the Sega Genesis or MegaDrive. Supported by popular games from Electronic Arts and other developers, this console became the industry leader in 1990. From then until the mid-1990s, Sega was the dominant player in the games-console industry, developing a range of popular and unique software titles such as Sonic the Hedgehog. These games become industry standards for their 'gameplay' and graphic design. In 1995, at the same time that the Sony Playstation was introduced, Sega launched the Saturn. The Saturn allowed players to play over the Internet. But Sega lacked support from third-party games developers for its new console and, under pressure from Sony's Playstation, it saw a steep decline in market share. To arrest this decline, it introduced the Dreamcast in 1998. Although it was fairly popular in Europe and Japan and offered Internet services, it failed to catch on in the USA and Sega's market share continued to decline against Sony and Nintendo. As a result, in 2001, Sega decided to exit the console industry and focus on developing games. This allowed it to exploit its competencies in games design and develop its popular titles for a variety of platforms, including Microsoft's Xbox, Sony's various Playstations and Nintendo Wii as well as mobile phones. Sega's decision to focus solely on game development represented a major shift in its position in the value chain, moving it from competitor to collaborator and supplier reliant on other firms' platforms to sell its product.

Regardless of their position in the value chain, innovators often fail to reap the returns from their innovative efforts. As Schumpeter argued, the rents from innovative efforts often dissipate quickly. Innovation, therefore, provides only temporary monopolies. There are many fast followers: skilled competitors able to overcome leaders by copying or by drawing on assets those first to market do not have. The capture of value from an innovation is a competitive and uncertain activity, requiring awareness of the dangers of opportunistic behaviour by others. In many cases, failure to commercialize is due to the fact that capabilities for developing innovations often differ from those that capture value. Innovative capabilities for formulating strategy, such as searching, selecting, and learning, need to be complemented with capabilities for configuring and deploying (see Chapter 4). Successful commercialization commonly requires people and organizations with different skills from those of the originators and developers of the innovation. It also requires knowledge of the commercialization process and of how best to manage it.

## Private and social returns to innovation

The failure of many to appropriate the value of their innovations raises an important social question. What is the proper balance between allowing innovators to capture value from their risk-taking efforts, and society's desire to increase the diffusion of innovation as a public good? Imagine a world where all ideas, technology, software codes, and business methods are freely available. Such a situation would almost certainly ensure their high rate of diffusion. There would be no barriers to the exploitation of existing drug treatments, for example. Protease inhibitors, the central element in the AIDS treatment cocktail, could be freely manufactured by any company in the world, increasing the availability of these life-saving drugs for millions of poor and disadvantaged people. However, what would be the incentive for firms to invest in creating new ideas, with all the costs and risks that this entails? One suspects very little. Imagine another situation where governments allow innovators to protect all the value of their innovations. In these circumstances, access to an innovation would be controlled by the innovator who would be able to set the price for its products or services. This would have the effect of greatly rewarding innovators, increasing the incentives to innovate. Although the rate of innovation would probably increase, the cost of access to these innovations would also increase as their owners could charge monopoly prices. The scale and rate of diffusion of these innovations would be in the hands of a few. As a result, there might be more innovations, but the level of their diffusion would likely decline. This tension between social and private returns is best described by Kenneth Arrow, a Nobel Prize winning economist, who suggested the imperfect nature of appropriability of innovations may

give rise to an underinvestment in private efforts to innovate (Arrow 1962). To overcome this reluctance it is argued government needs to provide innovators with a degree of protection for their efforts, such as patents, or increase social investment by subsidizing the costs of private innovative efforts through tax credits and other measures. These two objectives—to allow innovators to gain from their efforts, and to support diffusion of innovations—need to be carefully balanced (Dosi, Marengo, and Pasquali 2006).

## Selecting paths to market

Different types of innovation confer varying levels of protection for the innovator (see Box 9.2). All innovations rely on information and knowledge that is only partly protectable. In this sense, knowledge is the greatest public good. Once a person knows something, it is possible for someone else to know it as well. Good ideas travel fast and can be seen to be obvious after they have been found. Indeed, it is often hard to stop a person from learning something that is useful to them as they may be actively searching for it. In this sense, knowledge is what economists call non-excludable. Unlike a tangible good, such as a car, where ownership by one person excludes its ownership by another, it is hard to exclude knowledge from being owned by others. We cannot stop readers from telling someone else something they have learnt from this book (nor would we want to).

Some innovations are very easily copied; others, however, require detailed knowledge and experimentation to be made effective. The partly non-excludable nature of knowledge in the innovation process can be seen in many areas. Even simple products, such as pizzas, can be subject to highly differentiated knowledge appropriation. A pizza produced in Naples (Italy) is very different from a pizza produced in Naples (USA). Many differences are related to access to appropriate ingredients; it may be hard to find good mozzarella in Naples (USA) for instance. But differences may also result from the skills of chefs. Long traditions of pizza-making in Naples (Italy) ensure that the subtle skills of their makers are highly refined—often passed down from one generation to another. The pizza-loving customers of Naples' (Italy) pizzerias are extremely demanding, expecting a quality of pizza that is beyond the normal experience of customers in Naples (USA). So, even if the recipe and ingredients of the Neapolitan pizza were available in Naples (USA)—which they are not—it is very unlikely that you would find a Neapolitan pizza in Naples (USA). In the case of more complicated products, such as neurotechnology medical imaging systems for analyzing brainwaves, these products can only be imperfectly copied by others because of the need for experience and knowledge of how to make them. This means that the nature of knowledge underpinning an innovation is subject to different levels of excludability.

### Box 9.2 Xerox, Apple, and the Graphical User Interface

An example of the multiple paths innovations have to market and the way successfully innovative firms miss opportunities is seen in the development of the Graphical User Interface (GUI). The GUI was invented by Xerox, a pioneer in computing. In the 1970s, Xerox's main market was in photocopiers and it dominated the market, making large profits. It wished to maintain its position of technical leadership and established its own 'Skunk Works' (see Box 7.8) in Silicon Valley, called Xerox PARC (Palo Alto Research Centre), away from its normal business locations. The aim was to provide funding for radical innovation at a location where there was already a growing cluster of developments in electronic products and software design, in the hope that the newly recruited scientists and engineers would come up with another technology as successful as the photocopier. It developed the GUI as a research project that began in 1973. The first computer with a GUI was the Xerox Alto. It had an interface with features we commonly associate with modern operating systems, including windows, menus, icons, and scroll bars. Originally, the Alto was developed to demonstrate what was possible with the new technology. Although fifty were manufactured, none were ever sold commercially. In part, this was because they were prohibitively expensive to build, costing \$29,000 in 1976. Xerox decided to pursue this innovation further with the Xerox Star, developed in 1981. It was a major improvement over the Alto with a more visually appealing GUI, smaller in size and lower priced at \$16,600. The product once again failed to capture the market, as it was still too expensive for business users compared to the IBM PC (see Box 7.4).

Steve Jobs of Apple Computers became aware of Xerox's Alto project and recruited several people from Xerox PARC. Research directors at Xerox PARC were reluctant to provide details of the GUI to Steve Jobs and refused to allow him to visit. He approached executives at Xerox's headquarters in Connecticut who, believing that nothing useful was coming out of Xerox PARC, overrode the local decision, giving him permission to visit the laboratory. To gain even more information about the project, Apple arranged with Xerox executives to exchange its shares for information about the GUI. This arrangement worked well for Apple, giving it access to some of the basic principles of GUI development. In 1978, Apple established two projects to exploit the GUI approach: the Lisa, a high-priced business computer and the Macintosh, a low-priced personal computer. Project teams competed for resources within Apple and there were strong tensions between Lisa and Macintosh product development teams. The Lisa was launched in 1983. It embodied a number of innovations, including multitasking and virtual memory. It had a long start-up time, however, and a high price of \$10,000. There was little software for the Lisa and business users that purchased it did so only in the expectation of future releases of core business applications, such as spreadsheet programs. Given these problems, it was a commercial failure. Steve Jobs had already moved from Lisa to the Macintosh project and the latter's launch saw great fanfare and excitement. The original Macintosh had a small screen, but little software (only MacWrite and MacPaint), but at \$2,000 it was affordable, and popular with computer users who despaired at the lack of user-friendly programs for the IBM PC. The Macintosh became one of the iconic products of the 1980s, transforming the way computers worked and allowing Apple to capture almost 20 per cent of the global computer market. The GUI was later adopted by Microsoft Windows.

Apple did not originally contest Windows' use of the GUI, partly because it was relying on Microsoft to develop programs for the Macintosh. As the full extent of Windows' success became apparent, Apple launched a legal suit against Microsoft. The suit failed because the GUI was not protected by IPR and Apple had 'taken' the GUI from Xerox.

During the development of the Lisa and Macintosh projects, Steve Jobs added a sound—'sosumi'—to indicate when something was done incorrectly on the computer. Reputedly, this was a speeded-up recording of Jobs telling a colleague 'so sue me' when confronted by yet another legal case, this time from Apple Corp (the Beatles recording company), which threatened Apple computers over the use of the Apple logo. Since 1978 there have been repeated legal cases between Apple Corp and Apple Computers over competing trademark rights. The English High Court handed down a judgement in favour of Apple Computers in May 2006 and the two companies announced settlement of the long-running dispute in February 2007.

**Table 9.1.** Appropriability regimes

	Tight	Loose
Knowledge	Codified	Tacit
IPR	Protectable & enforceable	Not protectable or enforceable
Technology	Hard to replicate	Easy to replicate
Network effects	Allow customer lock-in	Few switching costs
New entrants	Constrained	Open
Size effects	Economies of scale	Scale no advantage
Example industries	Chemicals, Banks, Pharmaceuticals, Instruments	Food, Consulting, Retailing, Software

APPROPRIABILITY REGIMES

Differences in the character of knowledge shape the ability of firms to appropriate the benefits of their innovations across different industries. These variations can be thought of as different *appropriability regimes* (Teece 1986; Levin et al. 1987). Industries where innovators can effectively capture returns for innovations are associated with a ‘tight’ appropriability regime. In these industries, innovations can be codified and patented, for example, a new drug in the pharmaceuticals sector. Given the character of technology, it is possible to apply for and gain effective and enforceable IPR. The technology itself may be very hard to reproduce, and knowledge about the product is in the hands of the maker. Firms may also be able to benefit from network effects, locking in customers to their products and making it hard for them to switch to new, more attractive alternatives. Innovators may also control access to markets, taking up ‘shelf space’ and limiting opportunities for successful entry by competitors (Shapiro and Varian 1998). In addition, the successful production of the innovation may require economies of scale; the ability to produce the products or services in great volume and at declining cost. This presents a severe disadvantage for new entrants lacking the resources necessary to build and maintain large facilities or assets. Industries with tight appropriability regimes include chemicals, banking, pharmaceuticals, and instrumentation. In each of these industries, innovators are often able to reap the majority of the returns to innovation (see Table 9.1).

However, there are many industries with ‘loose’ appropriability regimes. In these industries, knowledge about product and services can be easily obtained and reproduced. There is little or no effective IPR protection and any that exists is hard to enforce. It is simple for customers to switch from one product to another. Markets are open to new entrants, and manufacture of products and delivery of services does not require large investments. Industries with loose appropriability regimes include food, management consulting services, design engineering, retailing, and software. In these circumstances, innovators are unlikely to capture value from innovation for as long as followers can quickly match their products and services (Teece 1986).

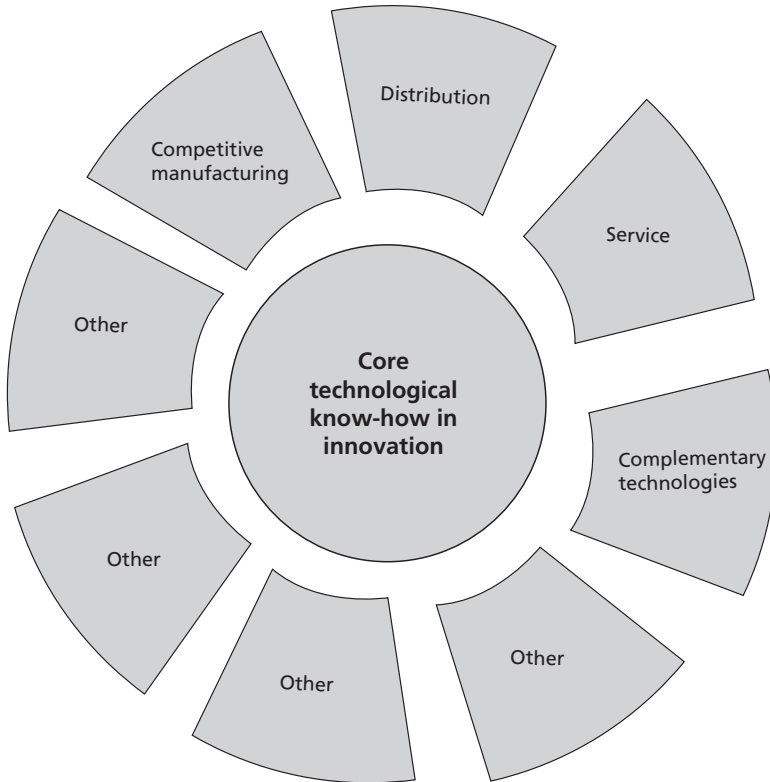
Although the appropriability regime of an industry is largely independent of the activities of individual firms, managers do make choices about how best to appropriate returns to innovation (Teece 2000). Their choices, however, are strongly shaped or bounded by the nature of the appropriability regime within their industry. The decision to apply for a patent may be inappropriate in an industry characterized by a loose appropriability regime. In consulting engineering there are few patents and firms compete instead on what they know and can do for clients and make little effort to protect their IP using formal methods. By contrast, for a biotechnology company obtaining a patent and enforcing it may be a core business activity—a matter of life and death for the firm. The decision to use different approaches to capture value from innovation must be made with an awareness of the appropriability regime surrounding the firm.

## COMPLEMENTARY ASSETS

We have shown that innovators can lose out to fast followers. One problem faced by innovators is that the resources and capabilities required for developing an innovation can be very different from those needed for its exploitation. Of central importance in determining who is able to capture value from an innovation is the ability of the firm to access *complementary assets* (Teece 1976, 1986). Complementary assets are bundles of know-how and activities that surround the successful commercialization of a technological innovation (see Fig. 9.1). Any innovation requires the integration of a range of activities along the value chain. Complementary assets can include access to distribution channels, after-sales support, marketing, and manufacturing. It may also include software combined with hardware or services integrated into physical products. The importance of complementary assets can be seen in the commercialization of the IBM PC (see Chapter 7). Critical to the success of the PC was the ability of IBM to convince the distribution and supply chain that it would support its new machine with the full range of IBM skills and capabilities.

Mobilizing complementary assets requires considerable effort on the part of the innovating firm. Large firms, such as IBM and P&G, have significant, established assets regularly used to commercialize numbers of products. Innovating for these firms is almost a daily occurrence. For small and less resource intensive firms, however, it is often necessary to work with others to gain access to complementary assets they do not possess. Small firms may need to ‘piggyback’ on the capabilities of other firms to see their innovations realized (see Box 9.3).

Firms of all sizes have to make choices about whether to work with incumbents or even competitors to commercialize an idea. Such collaborations, as we saw in Chapter 5, can be extremely difficult to manage. They may require the firm to build new links with actors beyond their usual partners and markets (see Box 9.4).



**Figure 9.1.** Representative complementary assets needed to commercialize an innovation

Source: Teece 1986.

### Box 9.3 Accessing complementary assets: Pixar and Disney

The experience of Pixar provides lessons on how small firms can collaborate with large firms to gain access to complementary assets. Pixar is one of the leading developers of computer-animated films, including *Toy Story*, *A Bug's Life*, *Monsters Inc.*, and *The Incredibles*. It began as the computer graphics division of Lucasfilm, led by John Lasseter. In 1986, Steve Jobs bought the division from Lucasfilm for \$10 million and named it Pixar. It had forty-four employees at the time. Pixar's film-making strategy was to focus on a small number of projects, with high-quality scripts, and use of innovative computer graphics. It takes close to two years to complete the animation of a Pixar film. Unlike other Hollywood studios, Pixar production teams have a high degree of continuity from one project to another. This approach allows them to build knowledge cumulatively over time. Innovations in one project, such as the development of representations of animated water, are subsequently reused. To gain access to the complementary assets of distribution and marketing channels, Pixar, in 1991, signed a collaboration agreement with Disney for five films. It was a very successful arrangement, providing Disney with a new product range and Pixar with access to distribution and marketing. By 1997 Pixar had 375 employees and it renewed its agreement with Disney. In 2003, it released *Finding Nemo*, a blockbuster computer animated film. As a result of this success, Pixar no longer needed Disney to market and distribute its films, and considered ending its relationship and going it alone. Disney's own computer animation division had a poor record by comparison. The fear of losing its relationship with Pixar led Disney to acquire Pixar in 2005 for \$10 billion. Pixar now operates as an independent division within Disney, with responsibility for all Disney's computer animated film projects. The sale of Pixar left Steve Jobs with \$3 billion worth of Disney stocks as a return from his 1986 \$10 million investment.



**Box 9.4 Combining complementary assets: IBM and Aviva**

A major challenge for technology and service providers, such as IBM, is to integrate their capabilities with the skills of their customers. An example of how two firms can combine assets to deliver new services can be seen in the UK car insurance market. Formerly Norwich Union, Aviva is a large UK-based insurance firm and long-time IBM customer. It faces fierce competition in its UK car insurance division. To gain advantage in this market, it sought to develop a new type of insurance based on the 'pay as you drive' philosophy. Instead of paying a yearly fee typical of car insurance, drivers pay for each mile they drive in the course of the year. This product would be attractive to intermittent car users, who would also be the least likely to have an accident, partly because they would likely be within an age group that had fewer accidents. Working with technologists at IBM, Aviva piloted an electronic system to measure the position, speed, and direction of over 5,000 private cars over a two-year period. This system logged the position of each car every second of the journey and the information was plotted on a map. This information was used to calculate the premium for customers based on usage. By combining Aviva's know-how of insurance and IBM's technical ability, Aviva was able to create a new distinctive service. The added advantage of this system is that it allows Aviva to target its offering to the part of the market that is least likely to make a claim, thereby attracting valuable customers and reducing the market of low-risk individuals for competitors. The 'pay as you drive' service was launched in the UK in early 2007.

*Source:* Nick Leon, Tanaka Business School.

Entrepreneurs who start up firms based on technologies with significant commercial potential face the biggest problems in accessing complementary assets. Although many firms of all sizes face these problems, they are particularly acute in technology-based start-ups where working with external partners may be counterproductive or even dangerous (Shane 2004). The most extreme danger here is outright theft. Ideas are often 'leaky' within communities of practice. As new firms hold few complementary assets, the danger of leaky knowledge can act as a strong disincentive to collaboration. The threat of competition from incumbents remains in the air (Gans and Stern 2003). If technology entrepreneurs are entering the product market, they may wish to avoid detection by incumbents by limiting their external interactions with any party that can flag their presence to incumbents. Interactions with customers, suppliers, partners, and consultants may leak information about the new venture's technology to potential competitors.

Established firms and technology entrepreneurs face many of the same problems when considering collaboration or exchange of knowledge with external actors, who also may operate in loose appropriability regimes. Some competitors may have access to complementary assets that may be greater or more effective than the incumbent firm's own. Yet, for these incumbents, being open to collaboration may be just as important as it is for technology entrepreneurs.

## THE PARADOX OF DISCLOSURE

Managing external linkages and exchanges involves dealing with information asymmetries. To gain access to and convince potential partners of the benefits of collaboration,



it is necessary to establish a degree of mutual understanding (see Chapter 5). Partners require a certain amount of information about ideas to develop judgements about their potential commercialization. In other words, they need to know quite a lot about the idea before they buy into it. The difficulty here is described by Arrow's (1962) *paradox of disclosure*, whereby 'when trading ideas, the willingness-to-pay of potential buyers depends on their knowledge of the idea, yet the knowledge of the idea implies that potential buyers need not pay in order to exploit it' (Gans and Stern 2003: 338). When negotiating contracts, disclosure may increase the bargaining power of the buyer and reduce the power of the innovator, especially in the absence of credible threats and IPR protection.

## THE MARKET FOR IDEAS

The decision over whether to cooperate or compete with established firms has significant implications for what managers need to do to profit from innovation. One option for the new firm is to proceed through the market for ideas. Here the goal of the new firm is to sell its innovations by directly licensing technology or ideas, selling consultancy or know-how, making alliances, or attracting a firm to acquire the new venture. The market for ideas is primarily an activity that involves selling for the highest possible price. It can be difficult for new firms to garner these prices because of the paradox of disclosure. Successful exploitation often requires both some enforceable IP alongside some of the techniques described later in the section on IPR pricing, and a degree of guile on the part of the new firm (Sherry and Teece 2004).

Some firms specialize in selling ideas or technology (Arora, Fosfuri and Gambardella 2001). They do so through the development of highly specialized expertise in capturing and protecting IP. Some firms, such as the British Technology Group, operate as brokers between the suppliers and users of IPR—see Box 9.5.

### Box 9.5 An intellectual property broker: the British Technology Group

The British Technology Group (BTG) was established as a public-sector corporation from the merger of two existing public organizations in 1981. It was privatized in 1992 by means of a management buyout and floated on the London Stock Exchange in 1995. Historically its major business was the development and exploitation of wide-ranging technology drawn from public-sector sources (universities, research council establishments, and government laboratories) and brought into industrial production by private-sector firms, under licence. In 2005 it announced that it would focus on medical innovations, especially in the fields of ageing, neuroscience, oncology, and drug repositioning. BTG describes its business model as a bridge in the gap between companies, research institutes, and universities needing to gain returns from their research expenditure, and the pharmaceutical industry needing to fill its pipelines with innovative new medicines. Essentially, BTG manages the commercialization process. It earned around \$60 million in royalties in 2005.

The company has had marked successes. It assisted in the development and exploitation of magnetic resonance imaging (MRI), the Hovercraft, Interferon, and Pyrethrins (which in the 1990s gave it

25 per cent of the world agricultural insecticide market). It also played an important role in the establishment of Celltech, the UK's first biotechnology firm, and, by extension, commercial biotechnology in the UK (Dodgson 1990). It faced (perhaps unjustly) criticism, however, for its failure to patent a particularly important development in biotechnology. There have been a number of distinct stages in its strategy over time as it moved from a public- to a private-sector organization, and from a broad to a more narrowly defined technology focus. We contrast its strategy and roles in the periods 1992–2000 and after 2005.

In 2000, BTG claimed to be the largest technology transfer organization in the world. Its activities were diverse—it dealt with a broad range of new products, processes, computer software inventions, and know-how. It was highly international, with 75 per cent of its income derived from business outside the UK. Despite a post-privatization rationalization of its portfolio, by 1993 it had protected over 1,500 inventions and had 500 licensees worldwide. Of the more than 10,000 inventions protected by BTG and its predecessor the National Research Development Corporation, less than 800 had made money and of these only a dozen had provided million-dollar-plus returns (again highlighting the point made in Chapter 3 about the skewed returns to innovation). At least two, however, had made over \$100 million in licensing income.

In 2000, BTG employed 180 people, many of whom were scientists and engineers experienced in both academia and industry. It received over 500 inventions a year to assess, and proceeded with around one-third of them. Acceptance of an invention required a favourable assessment of its commercial potential by an executive in one of BTG's operating divisions. All these executives had academic and research backgrounds as well as managerial and commercial experience in their field of technology. Once BTG undertook commercially to exploit an 'invention', it assumed responsibility for all patent actions and costs. At this time BTG's patent department was one of the largest in the UK. Once it obtained a patent, BTG worked to identify industrial companies that might be interested in using the invention, and negotiated licences. Finding appropriate licensees was assisted by its database of over 6,000 companies' technological interests. Licensing agreements varied in complexity, but usually involved an initial down payment (to deter those who were not seriously interested). Royalty levels were commonly around 5 per cent for patented technology, although they rose to 50 per cent for software.

Guaranteed annual royalties were often written into agreements, particularly where exclusivity for manufacture and sale in particular regions, usually for a limited period, was a requirement. Minimum licensing royalties were also negotiated to ensure that licences were effectively used and not bought just to prevent the development of potentially disruptive technologies. BTG protected inventions on a speculative basis, at no cost to the inventor or his or her institution, in anticipation of future licence income, which it shared with the inventive source on a fifty-fifty basis once BTG had met its patent and legal costs. The inventor received the first \$7,500 of any licence income.

By 2000, BTG could be seen to have a number of strengths in its contribution to industrial innovation:

- Preparedness to take a long-term view. It often supported projects with a 10–15-year time horizon. It had the 'critical mass' and ingrained tradition to persevere with technologies despite knowing how long they might take to turn them into commercial products and processes.
- Great depth of knowledge and experience in the protection of IPRs. It had detailed knowledge of patenting systems around the world, and particularly in the USA. On one occasion it fought a lengthy and successful legal battle in the USA with the Pentagon over infringement of Hovercraft patents, and it boasted about its reputation in the USA as a 'vicious patent litigator'. The scale of its activities enabled BTG to compete with universities' own patenting organizations. It was much more successful than universities in dealing with large projects.
- Provision of high-quality technical, legal, commercial, and patent resources in a model that was widely perceived as being the best in the world and was emulated in many European countries and in Japan, Korea, and Australia.

Although this model demonstrated many virtues from a commercialization perspective, the company began to face growing financial difficulties, and in 2004 it introduced a new strategy. BTG significantly reduced the size of its technology portfolio and cut its staff by fifty. It decided to focus on medical innovations. In 2005 it had a core of fifty technology assets at various stages of development. Around one-third of these are in the physical sciences, and are not being added to; all active investments are in the medical sciences. The company claims that its operations in future will focus on patenting, licensing, creating companies, and offering IP services (a small part of the business that includes royalty auditing for third parties and IP mining). It aims to acquire six new projects a year and be involved in the active development of up to fifteen others by 2009. BTG is making direct investments in preclinical and clinical development programmes to increase the value of the drug or medical technology by demonstrating proof of concept. It plans to invest up to \$20 million in this activity by 2009. It is engaged in creating start-ups. The company has continued to make financial losses, with a substantial loss in 2005, but with a new CEO and CFO it is optimistic about its future. In line with the advantages of technological focus, described in Chapter 4, and the range of challenges confronting commercialization, BTG is demonstrating the value of greater targeting and coherence in strategy.

There are a number of Internet-based innovation brokers that negotiate between buyers and suppliers of technology (see Box 9.6).

#### **Box 9.6 InnoCentive: building a marketplace for ideas using the Internet**

Based in Andover, Massachusetts, InnoCentive is one of a number of companies attempting to create a 'marketplace of ideas'. The firm aims to connect problems to problem-solvers. Its approach builds on a long tradition in the pursuit of scientific and technology breakthroughs of offering prizes for solutions. The most famous historical example was the £20,000 prize offered by Great Britain's Longitude Act of 1714 for the measurement of longitude (Sobel 1995). Originally established by Eli Lilly & Company in 2001, InnoCentive operates independently, acting as impartial and confidential broker or matchmaker between problem-seekers and problem-solvers. InnoCentive works with problem 'seeker' companies to articulate a scientific description of the challenges they face, and agree a financial award for their solution and a deadline for their completion. Most of the problems managed by InnoCentive are relatively small and focus on technologies—problems for which experts with the right mixture of skills can quickly find solutions. Over thirty major corporations have signed up to InnoCentive, using it to find solutions to problems that they cannot quickly or economically solve internally. The firms pay a fee for the service to InnoCentive, which also collects a share of the solvers' fee. The firm recruits scientists and engineers to build up a community of problem-solvers, and by 2006 it had signed up 90,000 professionals from 175 different countries. When a problem is posted, it emails individuals it believes are most likely to be able to provide a solution. All IPRs of solutions belong to the problem-seeker not the problem-solver. Alpheus Bingham, the president and chief executive of InnoCentive describes the service offered by the company thus: 'We are talking about the democratization of science. What happens when you open your company to thousands and thousands of minds, each of them with a totally different set of life experiences?' (Taylor 2006). Since its establishment, InnoCentive has attracted problem-solvers from all over the world, especially Eastern Europe and Russia, where there are many low-paid, but well-trained scientists and engineers. By 2005, over 250 problems had been solved using the approach. In researching InnoCentive, Lakhani et al. (2007), found that solvers tend to come from disciplines far removed from the problem itself, allowing them to bring new skills to bear. Solvers spend between eight to ten days on a problem, to which there is often more than one solution. The first person to satisfactorily solve the problem reaps the financial rewards; on occasion, solvers have developed solutions that have wider use than the initial problem and seeking companies have paid prize money to these individuals. Although the impact of InnoCentive is modest, it represents a new way of forming connections between people

and problems that enables solutions to be found by broadcasting to an external community of potential solvers. The InnoCentive approach requires problems to be codified and relatively narrow in order to be solved in reasonable time and for a modest fee. As such, it is a useful supporting mechanism for firms whose problems cannot be easily resolved inside a firm, but it is not a substitute for internal R & D or product development processes.

For more information on InnoCentive, please see [www.innocentive.com](http://www.innocentive.com).

Where there is little or no enforceable IPR, small firms' technology is often simply taken by more powerful incumbents (Arora and Merges 2004). There are many examples of large firms taking over small firms and this threat of theft of their technology can play a core role in the strategies of entrepreneurs. Box 9.7 shows how small firms can protect their IP when working with large firms, and build a business based on their own IPR.

### **Box 9.7 An intellectual property company: the case of the Orbital Corporation Ltd**

Orbital Corporation Ltd, formerly known as the Orbital Engine Company (OEC), is a business based on IP. Originally its strategy was to become a manufacturer of engines, but this vision was not realized. Instead it managed to create a viable business through the careful management of patents and licensing and the offering of engineering services based on its expertise and R & D investments. In 2006 it was licensing its technology to companies as diverse as Bajaj—India's largest producer of that country's ubiquitous autorickshaws—and Bombardier in Canada, which manufactures ski-jets. It also had a joint venture, Synerjet, combining its leading-edge technology with Siemens VDO Automotive's manufacturing expertise to produce integrated fuel systems in facilities in the USA, Europe, and China.

The company was founded by Ralph Sarich in West Australia in 1969 to develop an orbital engine. The highly innovative orbital engine incorporated an orbital rotor guided by four specially shaped cranks in a multi-compartment combustion chamber. The engine was believed to be significantly more efficient and lightweight than existing automotive engines. Some complex technical problems arose concerning seals and it became clear that auto-engine manufacturers were not prepared to retool their manufacturing plants to produce the engine (the engine was not 'designed for manufacture'—see Chapter 8). The orbital engine was never developed commercially.

Using some of the related technology developed during the design of the orbital engine, OEC turned its attention to a more conventional two-stroke engine. It produced a new engine, the OCP, which OEC hoped would revolutionize the US car industry. This obviously did not occur. While many car manufacturers, such as GM, Ford, Toyota, Honda, Volkswagen, Jaguar, Renault, Peugeot, Volvo, and BMW assessed OEC's technology, they were not convinced of the advantages of two-stroke engines. OEC's engine did not allow the car manufacturers to deal fully with increasingly stringent emissions regulations, and improvements to existing four-stroke engine technology limited the potential advantages of the new technology.

The history of OEC and the roles of Ralph Sarich and his family are somewhat controversial. At its peak, around 1992, the company employed nearly 400 people and made a pre-tax profit of over \$20 million. Subsequently, staff levels were reduced to around 300 and in the mid-1990s annual financial losses were common. The company received substantial government support, and investments from a major Australian company, on the basis of a number of speculative engineering opportunities, many of which were never realized. The founder and his family, having undertaken significant risk, gradually sold all of their shares, making a substantial profit. By 2000 OEC had recovered and its position was very positive. The company's technology was by then being integrated into a significant proportion of the outboard-motor market, and was being used in the development of scooters and in a small number of experimental cars.

How did the company make the transition from being product-based to becoming IP-based, from the market for products to the market for ideas? It is speculative whether the transition would have

occurred so readily had the original entrepreneur remained with the company (although, according to some, he did display considerable pragmatism when it came to such changes (Sykes 1998)). On the basis of the analyses presented in Chapter 4, this question could be reframed as whether the company would have made the transition from an entrepreneurially to a professionally managed company. The basis of the transition was the use of some of its technology related to the orbital and OCP engines, particularly its expertise in direct fuel injection (df/i) and some proprietary testing equipment. Using these technologies (with the df/i proving particularly attractive to engine manufacturers), it developed a strong patent position. It registered over 100 patents in twenty-one countries, spending up to three-quarters of a million dollars annually on patent protection. Its patenting strategy involved registering an inner and outer ring of patents. Registering such a 'family' of patents has been found to award greater protection, and is commonly practised by large Japanese companies. The outer patents were used to provide early warning of potential competitor infringements. The integrity of its patent position is illustrated by the case of Ford, which examined the patents for two years before acknowledging that it needed to negotiate a licence (Manley 1994). OEC's patent position is further strengthened by the fact that its major investor was Australia's largest company, and could bring its resources to bear in any potential litigation. The company owned 540 patents in 2006.

Having protected its IP, the company used a sophisticated approach to attract licensees. This approach included the following characteristics: an 'approach plan' for each target firm, gauging the interest of key individuals before making the corporate contact, establishing the nature and location of organizational power centres, anticipating idiosyncratic questions, and researching the position of the potential client in respect of OEC technology. Its licensing strategy involved minimizing the decision-making time of potential clients and maximizing the effect of interest from the competition, securing total technology licences as opposed to licences for individual components, high fee payments (upfront fees for major automotive companies wanting to study the technology ranged from \$20 to \$30 million), non-exclusionary licences, agreements not to depart from essential OEC designs in later R & D, and agreement to provide R & D feedback (Willoughby and Wong 1993; Manley 1994). OEC's licensing and contract engineering income totalled around \$100 million in the six years between 1990 and 1995. In 2006 it made a small profit on sales of around \$14 million.

Sometimes the power relationships between large and small players is reversed, as seen in Joe Eszterhas' sale of the script of *Showgirls* to the major Hollywood studios. Eszterhas was one of the most successful Hollywood scriptwriters of the 1980s and early 1990s with films such as *Basic Instinct* and *Jagged Edge* to his credit. In 1995, the major studios were desperate to win the rights to his latest script, assuming that it would lead to a major blockbuster. Eszterhas and his agent set up an auction for their as yet unseen script. The auction started a period of frenzied bidding among the studios, ultimately leading to a bid of \$3 million. At the time, Eszterhas only had a two-page treatment of the film. He was selling his reputation, and the script he eventually delivered turned into one of the biggest box-office flops in Hollywood history. Since then, Eszterhas has failed to score a major box-office hit and many of his scripts, which he has sold for great personal gain, have not even been turned into films.

Small technology entrepreneurial firms do not necessarily need to be the developers of the core technology in their firms. As shown in Box 9.8, it is possible for small firms to see the potential of others' IPR, and build businesses around them.

**Box 9.8 Datadot: using IP to build a business**

The Australian firm Datadot was founded in 2001. It uses very small microdots to imprint physical objects with a marker, to deter thieves. The technology of micro-identification was first developed for military and espionage uses. It was not until the development of laser-etching technologies in the 1990s that the technology was more widely adopted. One of the first uses of the technology was in casinos, which marked their poker chips to protect them from counterfeiting. The original technology used by Datadot was developed by a US firm, after unsuccessfully trying to build a business, sold the technology to Ian Allen, a former insurance broker. Allen proceeded to further develop the technology to ensure it could be quickly applied to objects by spray guns. This involved developing specialized machinery, based on in-house designs. The original technology for the microdots was protected by US patent.

The main use of the technology has been for protecting cars from theft. Most automobiles contain only two identification markers. However, Datadot spray guns can apply 10,000 dots to the underside of a car in minutes. Car thieves take stolen cars to 'chop shops' where they are cut up, reconstructed, and the resulting automobile is sold on to an unsuspecting customer. Without this new technology it is very difficult to prove that a car has been stolen, especially after it has been 'chopped'. The dots contain information about the product, including manufacturer, owner, and purchase details. This information is held on a secure database. The dots are visible under ultraviolet light and virtually impossible to remove and reproduce. After a spate of thefts in 2002, the following year Subaru applied Datadots to its WRX in Australia. After this, thefts of WRX fell 93 per cent in one year. High-end car manufacturers such as Porsche and BMW have also adopted this technology. Several countries are considering making microdots compulsory for all cars. To realize the benefits of this technology, Datadot had to manage a range of processes simultaneously, including the development of IT systems for secure information storage and retrieval, development of specialized manufacturing machinery, winning over lead users, such as Subaru, gaining government approval, and raising funds to support the business. It has been able to exploit a technology originally developed by someone else to create a new technology-based business. Datadots are now used in a wide number of areas, including expensive shrubs and trees planted in public spaces, and oysters—the farmers spray their oysters to prevent theft.

Source: [www.datadot.au.com](http://www.datadot.au.com).

## THE MARKET FOR PRODUCTS

A more common route is for the new firm to proceed through the market for products (Gans and Stern 2003). This involves the new firm deciding whether to compete with existing products in the market or to complement them. To go through the market for products, it needs to ensure that it has a novel proposition that is significantly distinct from what is on offer from potential competitors (see Chapter 7). Firms with new products often need to try to coordinate and manage a range of activities along the value chain, frequently simultaneously. They have to move quickly to establish a market presence before detection by incumbents. This involves selling the novelty or distinctiveness of the product in comparison to what is already on offer in the market. An example of a successful entry to the product market is Green and Black's, maker of organic chocolate bars. Originally, the firm focused on offering chocolate products

to the narrow niche market of ecologically and health-conscious chocolate consumers. It avoided competing directly with incumbents, such as Nestlé and Cadbury and their popular, but relatively ‘downmarket’ chocolate bars. Green and Black’s was the first UK firm to be awarded a Fairtrade mark for its work in ensuring that a significant portion of sales was returned to cocoa-plant farmers. After initial success in the specialist part of the market, it expanded into a range of different products, including hot chocolate drinks, ice cream, and the popular chocolate bar market, competing directly with incumbents. Its success attracted entry by established firms into the ecologically conscious part of the chocolate market. These firms were much less successful than Green and Black’s. As a result of Green and Black’s success, Cadbury Schweppes purchased the firm in 2005 and it now operates as a stand-alone business, within the Cadbury Schweppes group, directed by its founder Craig Sams.

New firms may be able to rely on the way incumbents can be slow to respond to innovation. As we have seen, incumbents may suffer considerable inertia, being unwilling to change the products, services, and strategies that have provided past success. Over time, incumbents will try to meet the challenge of successful newcomers. Established firms can fail to meet this challenge, especially if the nature of the competitive advantage underlying newcomers is significantly different from that of incumbents.

Cooperation with existing firms is also a mechanism used for entering the product market (see Chapter 5). This approach has several advantages as it enables new firms to specialize in what they are good at, which is often only development of the new technology itself.

## How to commercialize

There is a wide range of methods that firms can use to capture returns to their innovative ideas. Some of these methods are formal, and use legal protections, whereas others are informal, relying on secretiveness or being first to market. No single method of appropriating returns from innovations is totally effective, and successful firms often combine methods to ensure value is returned (Levin et al. 1987). In the chemical industry, for example, it is common for firms to patent some parts of a technology and keep other parts secret—known as ‘parallel protection’ (Arora 1997). Research on the effectiveness of different methods of protection for innovation shows that informal methods are more common than formal methods. This is especially the case for process innovation. Table 9.2 reports results for a large sample of US firms in the early 1990s. Table 9.3 reports the responses of UK firms for the period 1998 to 2000. The approaches most commonly used by firms in both studies to protect innovations were secrecy, followed by lead times (speed). In contrast, respondents indicated that patents were rarely effective



**Table 9.2.** Percentage of product and process innovations where protection method was effective

Method of protection	Process innovation (%)	Product innovation (%)
Secrecy	50	51
Patents	23	38
Complementary manufacturing	43	46
Complementary sales/service	31	43
Lead times	38	53
Other legal	15	21

Source: Cohen, Nelson, and Walsh 2000.

in protecting innovations. As we might expect, given the differences in appropriability regimes described earlier, the importance of different methods varies by industry, with some industries reporting patents as being highly effective, while others focus on secrecy.

## INFORMAL METHODS OF PROTECTION

There are a number of informal methods for protecting ideas and new products. Firms may not have a choice as to whether they have access to these methods; it often depends on their position vis-à-vis competitors and the type of knowledge they are trying to protect. Informal methods can often be less costly and quicker to operationalize than some formal methods. Informal methods include: the use of secrets; exploitation of benefits by being first in the market (first-mover advantage); or protection deriving from the complexity of product or process, or the need for large-scale production facilities and specialized assets.

**Table 9.3.** Mechanisms used to protect innovations, UK firms, 1998–2000

	Manufacturing		Services	
	Used (%)	Of high importance (%)	Used (%)	Of high importance (%)
Lead times over competitors	64	24	45	18
Secrecy	58	21	46	16
Confidentiality agreements	56	22	47	21
Complexity of designs	56	14	35	9
Trademarks	40	16	31	12
Patents	36	17	16	7
Copyrights	35	10	30	11
Registered designs	32	11	18	6

Source: UK Innovation Survey 2001 (authors' calculations).



### Appropriation by secrecy

Secrecy as a method of protection requires firms to carefully manage the external release of its knowledge or information to employees, customers, collaborators, and competitors. Secrets may be embedded in operating routines, which can be largely informal and experience-based, making them difficult for others to copy. Toyota often lets competitors visit its factories and learn about its system of production. It does so because it knows the difficulties that would be involved in replicating its system and ways of doing things, which are local, historical, and specific to Toyota. More commonly, however, firms undertake efforts to limit access to their personnel and facilities. It is often difficult to find the names of individual staff on corporate websites, which is based on firms' fears of losing staff to competitors.

Firms attempt to ensure secrecy by non-disclosure, confidentiality, and subsequent employment agreements (Liebeskind 1997). These mechanisms may force their employees to take 'gardening leave', that is, spending a period away from the industry before they work for another firm in it. Employees may also be subject to 'golden handcuffs' that make it financially unattractive to move employment. There have been a number of examples of legal disputes between European and US car-makers as managers and engineers leave one firm for another, taking valuable knowledge with them. Secrets may be formally protected by use of Trade Secrets legislation, which relies on confidentiality agreements made to stop employees from revealing secret or proprietary knowledge during and after their employment or association with a business. University researchers are often required to sign restrictive non-disclosure agreements in collaborative research with industry.

Despite their best efforts, it is often difficult for firms to keep new products secret. Apple has fought a losing battle to keep its users' website from leaking information about future releases of products prior to their announcement at major industry events. In 2004, Apple found that news on the Mac mini was being discussed on these websites before it was officially launched. Apple tried to deal with the problem by attempting legally to close the website down, an approach that failed due to the freedom of information in the USA. It has tried to limit leaks by its staff. In some cases, efforts to control the disclosures of staff infringe personal liberties. In a boardroom dispute at HP, the telephone calls and email messages of members of the Board of Directors were monitored. This effort to ensure secrecy led to private investigators listening in to *Wall Street Journal* journalists' telephone conversations. Although this effort was successful in discovering who on the Board was leaking information to external parties, it was illegal and led to the resignation of the Chair of the Board.

Firms often make elaborate efforts to ensure that information about new designs does not leak out. New cars are test-driven with plastic covers over their features. However, it

is difficult to enforce secrecy, especially when it has public value (see Box 7.8 on the way Lockheed accessed technology and knowledge from the USSR).

### **Appropriation by first-mover advantage**

As we saw in Chapter 4, innovations may provide temporary monopolies to firms first to the market. It is sometimes better to capture the returns from a new product or service by providing it rapidly to customers before competitors appear on the scene, rather than going through laborious and time-consuming work to get formal IPR protection—by which time, competitors may have been able to get a lookalike onto the market.

### **Appropriation by complexity**

Complexity of products and services may also provide a mechanism for firms to appropriate value from their innovations. Many products rely on combinations of a wide range of different technologies, components, and systems. Their integration often requires deep knowledge of component technologies and the ability to specify the interfaces between different subsystems (Brusoni, Prencipe and Pavitt 2001). Aero-engines, for example, require their makers to master a range of technologies, including compression, combustion, turbine, rotors, digital predictive maintenance systems, and an array of design and production technologies such as computer-numerical control (CNC) milling and boring, welding, computer-simulation techniques such as CFD, vibration engineering, and materials technologies such as the use of advanced ceramics. This technology has become so sophisticated that there are only three manufacturers capable of competing in the production of jet engines worldwide and the accumulation of their expertise is a prohibitive barrier to new entrants. In a study of these three major aero-engine manufacturers, Prencipe (1997) found that all three firms patented in similar areas, indicating that they all had to maintain similar technological competencies, and showed that firms need to know about a range of technologies broader than those embedded in their own products. In particular, they need considerable information about the technologies used in different components to be able to successfully integrate them into their own products. The complexity found in CoPS, discussed in Chapter 2, is another mechanism for erecting barriers to entry and protecting innovation.

### **Appropriation by scale and specialized assets**

Firms may rely on the fact that producing and delivering the product or service requires considerable specialized capital investment and capabilities in operations that are not easily replicated (see Chapter 8). Innovators may also be able to use unique or rare in-house resources, such as specific instrumentation.

In addition, especially in services, the ability to access a network of clients, develop a reputation for delivery or innovation, and previous experience may allow firms to profit from their innovative activities. For example, Arup, the engineering consultancy, used its knowledge of subway design in Hong Kong in designing an extension to the New York subway.

## FORMAL METHODS OF PROTECTION

Greater focus on knowledge as an asset increases the importance of formal IPR protection. Formal methods of protection include patents, trademarks, industrial designs, and copyrights (the definitions that appear later are based on Blakeney (1989) and the World Intellectual Property Organization ([www.wipo.int](http://www.wipo.int))). The process of applying for and defending IPR protection requires considerable resources. Over the last twenty years, there has been a rise in the use of IPR to capture returns from innovative activity. In 2004, the number of patent applications in the world reached 13.8 million. There were also 1.9 million trademark applications in the same year (World Bank 2006). Annual patent registrations in the USA exceeded 342,000 in 2003, compared with around 164,000 in the 1990s. The number of patents granted was over 169,000 in 2003, from 90,000 in 1990 (NSB 2006). Many firms put enormous value on the ownership of IP protected by patents. Table 9.4 presents the top 15 firms patenting in the USA in 2004.

Some companies, for example, IBM, which received \$935 million in royalties in 2005, rely heavily on income from IP. The ownership of IP in the twenty-first century can be likened to the ownership of physical property (land) in preindustrial societies. It is an important basis of commerce, and its ownership indicates wealth and achievement. With good management its owners flourish and those without it are highly dependent, and excluded from important aspects of business.

Failure to protect IP can have major commercial implications. Chapter 7 discussed the problems faced by IBM when it failed to control important technologies. Cultivation of the popular kiwi fruit was developed following extensive R & D in New Zealand. Failure to protect this research or to register the trademark has resulted in the successful production of this fruit in South Africa and Latin America, with the resulting loss of potential markets for New Zealand. In neighbouring Australia, the fruit is sometimes known as Chinese Gooseberry, further denying its national identity. Champagne, on the other hand, enjoys the status of being a Protected Designation of Origin (PDO), otherwise known as a 'protected geographical indication' (PGI), which provides producers of sparkling wine from the Champagne region in France the right to enforce the use of the name 'Champagne' to describe their product alone—sparkling

**Table 9.4.** Top 15 Firms in the World by US Patents Granted in 2004

Ranking	Firm	HQ country	Industry	Number of US patents
1	IBM	USA	Software and computer services	3,251
2	Hitachi	Japan	IT Hardware	2,181
3	Matsushita Electric	Japan	Electronic and electrical equipment	2,175
4	Canon	Japan	Electronic and electrical equipment	1,855
5	Hewlett-Packard	USA	IT Hardware	1,822
6	Micron Technology	USA	IT Hardware	1,758
7	Sony	Japan	Electronic and electrical equipment	1,725
8	Samsung Electronics	Korea	Electronic and electrical equipment	1,644
9	Intel	USA	IT Hardware	1,607
10	Toshiba	Japan	IT Hardware	1,523
11	Fujitsu	Japan	IT Hardware	1,500
12	Siemens	Germany	Electronic and electrical equipment	1,413
13	NEC Corporation	Japan	IT Hardware	1,334
14	General Electric	USA	Diversified	1,256
15	Philips Electronics	The Netherlands	Electronic and electrical equipment	1,250

Source: Department of Trade and Industry, R&D Scoreboard 2006, [www.dti.gov.uk](http://www.dti.gov.uk).

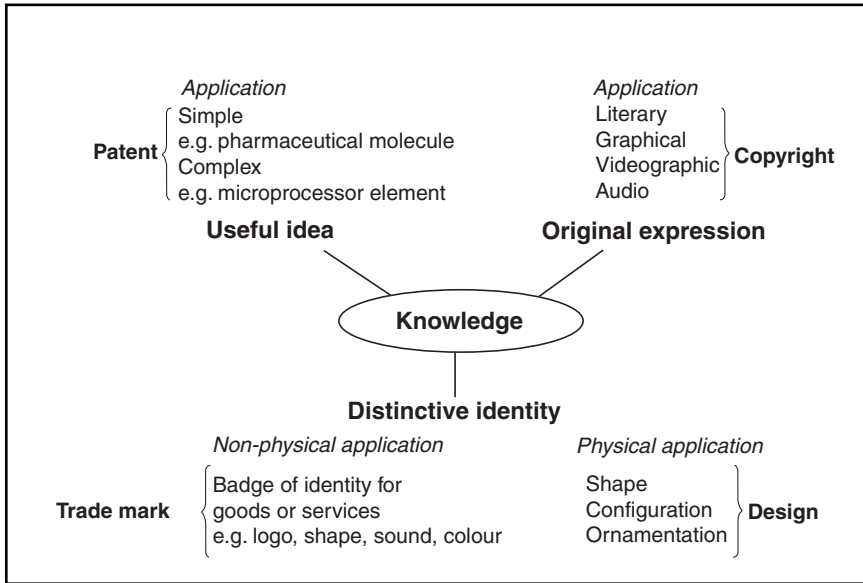
wines from other regions cannot be sold as ‘champagne’. This right is enforceable across the European Union and is becoming recognized through reciprocal agreements worldwide.

As discussed earlier, the characteristics of IP are very different from those of products. Because of its characteristics, if commercialization is to occur, and firms are to enjoy returns on their investments, IP has to be protected. *Gowers Review of Intellectual Property* (2006) describes how knowledge can be protected as a useful idea by means of a patent, an original expression by means of copyright, and distinctive identity by means of trademarks and designs (see Fig. 9.2). Specific categories of rights for circuit layouts and plant breeders have also been established.

## Patents

Patents were examined in Chapter 3 as a source of information for innovation. Patent laws were introduced in Venice in the fifteenth century. The purpose of patents was described in 1807 by Thomas Jefferson, who sought to ensure that ideas moved freely between people, and their originators received some reward which did not jeopardize the rights of those who in the future wanted to improve on them:

Certainly an inventor ought to be allowed a right to the benefit of his invention for some certain time. It is equally certain it ought not to be perpetual; for to embarrass society with monopolies for every utensil existing, and in all the details of life, would be more injurious to them than had the supposed inventors never existed; because the natural understanding of its members would have suggested the same things or others as good.



**Figure 9.2.** The instruments of IP and common applications

Source: Gowers 2006.

Here we focus on how patents are registered and protected. Patents are:

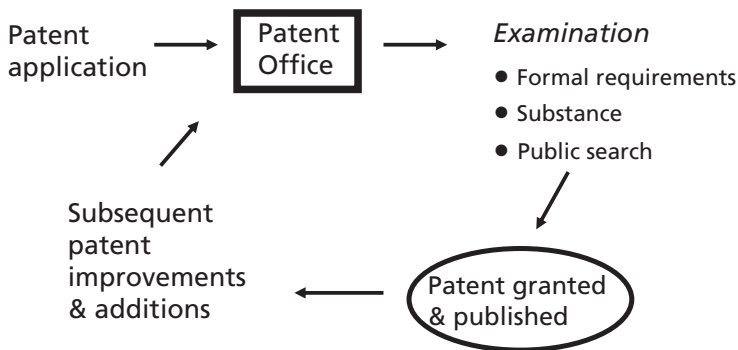
statutory privilege granted by a government to an inventor and to other persons deriving their rights from the inventor, for a fixed period of years, to exclude other persons from manufacturing, using, or selling a patented product or from utilizing a patented method or process.

Patents are usually awarded for a period of twenty years (in some countries they can be extended, or renewed to continue to apply). After this time the invention is in the public domain. To gain a patent an inventor or a representative submits an application to a patent authority, usually a national or regional patent office.

Patent laws vary internationally, but usually patent applications must:

- Contain a description of the invention, and all drawings referred to, disclosing it in a manner sufficiently clear and complete for it to be replicated by a person skilled in the art.
- Be presented in the context of the state of the art.
- Provide a novel solution to a technical problem, involve an inventive step (a ‘creative advance on existing knowledge’), and be industrially applicable (non-theoretical). It must also be shown to be an ‘inventive step’ that could not simply be deduced by a person with general knowledge of the area.

The registering of patents can be extremely complicated and costly, and often requires the professional skills of a patent attorney. The process of registration involves the patent office examining the patent to see if formal requirements have been met, then examining its substance. This involves searches of other patents and may involve public inspection before a new patent is granted. The patent examination process can take time. At the European Patent Office (EPO), the average time between application and award is twenty-eight months. When the patent is granted, it is published and laid open for public inspection. The patentor can add subsequent patent improvements or additions (see Fig. 9.3). The granted patent covers only the national or geographic area of the patent office and therefore many inventors patent in several countries at the same time, although patent holders may apply for patents for the same invention across several territories. Individuals or entities holding patents can sell and trade them. Patents do not provide a right to exploit an invention; rather they provide a right to prevent others from its commercial exploitation. Patent holders may license or give permission for other parties to use their inventions on mutually agreed terms. Generally there is more value in holding a ‘family of patents’, which protect ideas in related areas, than isolated, individual patents.



**Figure 9.3.** The patent application process

In some cases, governments override the rights of individual patent holders on behalf of the wider public interest. It is salutary for patent holders to note that most patents can be circumvented by sufficiently energetic competitors who want to pursue an idea, and are willing to invest resources in finding a way to engineer an alternative approach.

Table 9.5 reports the reasons why firms use patents, based on a large-scale US survey. Table 9.6 outlines the main reasons for patenting revealed by a comprehensive survey of European inventors. These studies show the main reason for patenting is to prevent copying and imitation. Patents are also used for commercial exploitation of a technology and to block other firms from developing it. Patents are used strategically to help protect the firm from legal action by other firms. Patents can help firms enhance their reputation. Many firms use the number of patents they produce as a marketing tool to

**Table 9.5.** The reasons for the use of patents among US firms, 1994

Reasons to use patents	Process innovation (%)	Product innovation (%)
Measure performance	5	6
Licensing revenue	23	28
For use in negotiations	37	47
Prevent suits	47	59
Prevent copying	78	96
Blocking	64	82
Enhance reputation	34	48

Source: Cohen et al. 2000.

document their scientific and technological prowess. IBM often lists the number of its patents in its advertising. They may also be used in negotiations to facilitate collaboration, cross-licensing, or joint ventures. For example, when Sony and Samsung agreed to collaborate in the development of the next generation of flat screen TVs, they agreed to share some IP. While for firms such as IBM, patents are an important source of income, this reason was cited by only a small number of firms in the USA and European study.

The value of patents is highly skewed, with very few being of great value (Scherer 1999). A survey of European inventors found that only 1.5 per cent of all valuable patents are worth over €100 million. The vast majority of economically valuable patents were worth less than €1 million (Gambardella, Guiri, and Mariani 2005).

Patenting is largely a team activity and most patents involve more than one inventor. Most co-inventors are part of the same organization and live physically close to one another. Some studies have calculated that even after people move to another location, initially they are likely to patent with the same people. After three years this geographic pattern changes and individuals begin to patent with colleagues close to their new location. European inventors' patents largely arise from the efforts of formal research projects, but more than 13 per cent of patents came from pure inspiration and 10 per cent resulted from an unexpected by-product of other work activities. In other words, serendipity matters in generating ideas for patents.

**Table 9.6.** The importance of reasons to patent among European inventors, 2003

Reasons	Average score
Prevention from imitation	3.88
Commercial exploitation	3.86
Blocking patents	3.14
Reputation	2.39
Licensing	2.18
Cross-licensing	1.94

Note: Scale 0 = not at all important, 5 = very important

Source: Gambardella et al. (2005)

### Box 9.9 Patents or prizes?

As patents can provide temporary monopolies for inventors, they should be an incentive to innovate. As we have seen, however, patents often work better in theory than in practice (Teece 1986). They are expensive to acquire, and difficult to enforce and trade. They are used by large firms to create ‘thickets’, slowing down the diffusion of innovations and limiting opportunities for new entrants (Ziedonis 2004). Few patents have potential financial value and small firms often lack the capabilities and resources necessary to turn their patented technology into a successful business. Indeed, considerable amounts of social resources are spent on acquiring, defending, and disputing patents, often to little purpose. Could these social resources be diverted towards activities that might provide greater stimulus to innovation?

One option available to governments and others to support innovation is to offer prizes as a stimulus to innovation. Awards have a long tradition in science and technology. In Chapter 5, we saw how InnoCentive uses prizes to encourage problem-solving. Government procurement remains the main mechanism for offering prizes to new firms for solving problems. The US government through its Small Business Innovation Research Program dedicates over \$2 billion each year in contracts to small businesses that solve problems for different government departments, such as the Department of Defense (see Chapter 4). In the UK, the National Endowment for Science, Technology, and the Arts (NESTA) invests up to \$100,000 in start-ups with high economic potential, offering mentoring and support to these firms. Other countries have also successfully used their procurement systems to stimulate innovation, encouraging private actors to work on public problems.

It is possible to imagine prize-based systems running alongside the existing patent system. At present, the patent system does not seek to differentiate between the novelties of different patents. Once an inventor has been able to demonstrate that his or her invention achieves a uniform standard of novelty, this can be recognized in a patent. Expert technical assessments performed by patent officers is also used to judge the degree of novelty of an invention. Governments could create a fund that would be administered through a ‘national prize office’, operating alongside the national patent office. Inventors could submit their technology to both the prize office and the patent authority. For a novel invention made by a small firm both a patent and a financial prize might be awarded. Such an award system would be difficult to organize and might become polluted by rent-seeking behaviour as many government grant schemes for R & D projects have been over the past thirty years (Davis 2004). However, they might be a useful complement to existing patent systems, helping to mitigate the problems of patenting for small inventors and providing a stimulus to innovation.

## Designs

Designs are defined as ‘the ornamental or aesthetic aspect of a useful article’ and cover the overall appearance of a product providing its unique appearance, including its shape, configuration, pattern, and ornamentation. A registered design can be a valuable commercial asset, giving the owner protection over the visual appearance of the product. Designs must be novel, distinctive, and replicable in commercial quantities. An example of a good design is an edition of Speedo’s swimming briefs, which were awarded an Australian certificate of design.

## Trademarks

Trademarks are ‘a sign which serves to distinguish the product of one enterprise from the products of other enterprises’. A trademark must be visible and can include names, existing or invented words, letters, numbers, pictures, symbols, and even sounds. A trademark identifies a certain quality and image with goods and services, and can be



### Box 9.10 University patenting

Since the early 1980s, several OECD countries have experienced rapid growth in university patenting. These changes have been driven in part by changes in law, such as the US Bayh–Dole Act of 1980 (Mowery and Ziedonis 2002, Mowery et al. 2004). Originally these laws were designed to encourage technology transfer from universities to industry by making universities disclose their innovations. However, universities have become increasingly active in protecting their IP for financial gain. In 1983, US universities and colleges were granted 434 patents. By 1993, this figure was 1,307, and by 2002 it had increased to 3,450 patents. US universities and colleges received \$242 million in gross revenues from patent licensing in 1993 and more than \$1 billion in 2002 (NSB 2006). The University of California owns the most patents, with 439 in 2003, followed by the California Institute of Technology and Massachusetts Institute of Technology with 139 and 127 respectively. These data should be compared with the patenting performance of private firms shown in Table 9.4. IBM, for example, registered nearly 3,000 patents in 2005. In the UK, in 2003–4, universities applied for 1,308 patents and were granted 463 patents, of which 280 were from non-UK patent agencies. The total patent stock of UK universities is 5,707 patents, almost half of which were granted by non-UK patent offices. The total income from this IP, however, was extremely modest, at only £38 million pounds in 2003–4. In the same year, the highest earner in income from IP was the University of Birmingham, and the University of Southampton had most patents with seventy-five. Recent changes in the law in France, Italy, Denmark, and Japan have expanded opportunities for universities to patent.

As we saw in Chapter 3, the effect of these changes remains a controversial topic in public policy. Many governments are keen to promote greater use of formal IP by universities. It has been suggested that university patenting can be beneficial in promoting technology transfer from academia to industry. There is little evidence to support this view. Studies of biomedical research show publications (academic productivity) and patents tend to go together, yet biomedical research is a special case given the close links between discoveries in basic research with industrial practice. To date, few studies have explored the effect of patenting on research in other disciplines and how it is influenced by concern over appropriating value from knowledge. There are several reasons to think that an increased focus on patenting by universities and their staff may have negative effects. These include delays in publishing research, reduced focus on teaching quality, undermining the culture of open science, hampering fundamental long-term research, and limiting future academic investigation (Geuna and Nesta 2006).

In the USA, research has shown that quality (measured by the number of citations to these patents in subsequent patents) of university patents has declined over time (Mowery et al. 2001). A comparison of university patents before and after 1980 (the effective date of the Bayh–Dole Act) shows a decline in the quality and breadth of US university patents. The Bayh–Dole Act appears to have encouraged many inexperienced academic institutions to obtain patents that have proved to be less significant than those issued to more experienced universities. In contrast, evidence suggests that Bayh–Dole had little effect on the content of academic research undertaken at leading universities, such as Stanford and Columbia. The legal changes in the USA concerning biomedical research and patenting have opened up new opportunities for universities and much of the growth in patenting is in these areas.

The rise in university patenting can also be seen in Europe. Although historical data on European university patents is scarce, there is some evidence of increasing numbers in the 1980s and 1990s. Most of this increase, it is argued, is related to changes in biomedical research rather than policy efforts (Geuna and Nesta 2006). For those universities active in patenting, the level of income generated is low and it is unclear whether it will produce significant future returns. Despite this, government pressure for universities to develop formal IP continues to grow and the universities have responded and are becoming increasingly skilled at creating formal IP from research.

A key concern with university patenting is not simply whether patents are granted or enforced, but what is the licensing strategy of the university. In general, US universities are increasingly seeking to limit access to research developed by academics by offering exclusive licenses, which can hinder technological progress (Washburn 2005). The evidence suggests that efforts such as the Bayh–Dole Act may hamper technology transfer from universities if universities seek to limit access by others to key research tools. These factors may also be at play in the countries of Europe and others, such as Australia, where increasing efforts to promote IP protection may lead to less technology transfer. This suggests that a focus on IP by universities needs to be balanced with their primary role of promoting openness and new knowledge.

an important marketing tool. The Qantas kangaroo image, which appears on all its aeroplanes, is a registered trademark.

## Copyright

Copyright protects the original expression of ideas, but not the ideas themselves. It is free and is automatically allocated to the originators of works of art and literature, music, films, sound recordings, and broadcasts. Copyrighted material covers written material, paintings or drawings, films or tape recordings, for seventy years from the time of the first broadcast in the case of films and tapes, and for seventy years after the death of the author or artist in the case of written, painted, or drawn material.

Strong IP laws encourage firms to export their technologies. A World Bank (1998) study found that the strength or weakness of a country's IP system has a substantial effect, particularly in high-technology industries, on the kinds of technology that many US, German, and Japanese firms transfer to that country.

The patenting of computer software and business methods remains contentious. Countries that are members of the WTO have an obligation under TRIPs (Trade-Related Aspects of Intellectual Property Rights; see Box 9.11). Agreement to make patents available for any inventions in all fields of technology. Discrimination according to the field of technology is specifically prohibited under the TRIPs Agreement. However, business system inventions can be excluded from patentability if they are not considered as being within a 'field of technology'. A review of whether patents should be granted for computer software and business methods was conducted by the UK Patent Office in 2001 and concluded that ways of doing business should remain unpatentable in the UK. A major fear is that business system patents will become pervasive, creating inefficiencies and dampening initiative without a corresponding increase in innovation. In the European Union and Canada business methods have not been patentable, but they can be patented in the USA, Japan, and Australia.

### Box 9.11 Trade-related aspects of intellectual property rights (TRIPs)

IPRs are created by national law and thus apply only in a single national jurisdiction, independent of rights granted elsewhere. Establishing a global IPR regime thus requires cooperation among national governments to harmonize their separate laws. Numerous international treaties to promote such cooperation have been negotiated over the past 100 years. Most are administered by the World Intellectual Property Organization (WIPO), a specialized agency of the United Nations. WIPO conventions—for example, the Paris Convention for industrial inventions and the Berne Convention for copyright of literature, art, and music—require their signatories to grant national treatment (foreign firms are treated in the same way as domestic ones) in the protection of IPRs, but typically do not impose common standards of protection. New global rules on IPRs are forcing a reassessment of past strategies for acquiring, disseminating, and using knowledge.

The 1994 TRIPs Agreement was built on existing WIPO conventions and laid the foundations for global convergence toward higher standards of protection for IPRs. It requires signatories to apply the principles of national treatment and most-favoured nation (MFN) status to IP protection. Unlike most other international agreements on IPRs, the TRIPs Agreement sets minimum standards of protection

for all forms of IP: copyright, trademarks, service marks, geographical indications, industrial design, patents, layout designs for integrated circuits, and trade secrets.

In each area the Agreement defines the main elements of the protection: the subject matter to be protected, the rights to be conferred, and the permissible exceptions to those rights. For the first time in an international agreement on IP, the TRIPs Agreement addressed the enforcement of IPRs by establishing basic measures to ensure that legal enforcement is available when infringement occurs. Disputes between WTO members over TRIPs obligations are subject to the same dispute-settlement procedures that apply to other WTO agreements.

The provisions of the TRIPs Agreement became applicable to all signatory countries at the beginning of 1996. Developing countries were granted a four-year transition period with the exception of obligations pertaining to national and MFN treatment, and an additional five-year transition for product patents in fields of technology not protected before 1996 (this applies to pharmaceutical products). The least-developed countries were granted a transition period extending until 2006, again excepting national and MFN treatment.

The TRIPs Agreement has been extensively criticized by developing countries, NGOs, and academics (Braithwaite and Drahos 2000) as it provides a framework for transferring resources from developing to developed countries.

## Licensing

As we saw in the case of OEC, valuable income streams from IPR can be derived through the use of licensing if they are carefully managed. Pilkington's float-glass manufacturing process, developed during the 1950s, brought substantial licensing income into the firm well into the 1980s. A licence is the granting by an owner of IPRs, or the proprietor of know-how, of permission to make use of all or some of those rights and information.

Firms license their IPRs in order to exploit their existing competencies and technological assets. According to Bidault (1989), these include market, production, and technology advantages. Potential *market* advantages derive from the use of licences to open up new markets for a firm's technology and, by doing so:

- Use local knowledge.
- Avoid overseas and domestic marketing costs.
- Assess market viability.
- Sell semi-finished products or parts that are not 'strategic' (forcing the licensee to import key components).
- Assist in the diffusion of the licensor's technical standards.
- Give products a *local* image, to please consumers and governments.

Potential *production* advantages derive from the use of licences to improve the cost or quality of supplies and:

- Avoid expensive overseas manufacturing.
- Avoid domestic manufacturing.
- Use the comparative advantage of the licensee (in technology or natural resources).
- Overcome supply constraints of governments.

- Extend the product range (if the licensee has more extensive production capabilities).
- Prevent the licensor from having to acquire additional capacity itself.

Potential *technology* advantages derive from the use of licences to receive income or access to other technologies and:

- May involve peripheral technology the licensor does not want to exploit itself, but licensing can also involve core technologies.
- Discover whether the technology may have applications in other markets where the licensor has no experience.

Firms purchase licences for a number of reasons. These include:

- Overcoming the problems associated with the absence of R & D capacity.
- Avoiding much of the cost, delay, and risk of R & D.
- Enabling the acquisition of complementary technology.
- Improving the quality of existing products.
- Launching new products.
- Increasing efficiency.
- Penetrating new geographical markets.
- Taking advantage of market protection from government, and its information provision capacities.
- Speeding up learning and accumulation of know-how.
- Building on existing relationships.

Systems of cross-licensing are common in the pharmaceuticals and electronics industries. These usually occur when both partners have a similar level of technological competence; instead of the firms resorting to financial payments, technology is paid for with another of equal value.

There are numerous problems with technology licensing (Bidault 1989). These mainly derive from the differential access of the parties to information. A licensee, for example, may not know the real cost and potential of a technology on offer, and may choose overpriced or inappropriate technology. A licensor may be concerned with the prospect of the licensee becoming self-reliant once the technology has been transferred, and renege on the licensing agreement. Another problem concerns the question of pricing IPR, and this will be examined in the next section.

## Pricing IPR

There are a number of difficulties with remuneration for the sale of IPR, rather than products. First, unlike a product, IPR is intangible and decisions about its value are often speculative and can sometimes be assessed by only a few people (mainly scientists and engineers). Second, the IPR that needs to be purchased is also the information that is

needed to make a rational decision as to whether or not to buy it: this is encapsulated in Arrow's paradox of disclosure and is described by Vaitos (1974) as 'the irony of knowledge'. There is a danger that the information necessary to inform a potential licensee of the value of IPRs may be sufficient for that firm to gain enough knowledge to proceed independently, so the pricing regime occasionally has to account for that risk. The dangers of premature disclosure (which can destroy the value of IPR) places additional emphasis on the need for strong protection.

Two broad forms of remuneration are used in licensing: fixed and variable. *Fixed* payment is a negotiated lump sum, paid in one or more instalments. This form of payment guarantees the level of income to the licensor, and places most risk on the licensee. *Variable* payment is proportionate based on an agreed scale, in the form of a *royalty*. Royalties are very common and are paid annually or quarterly as a proportion of sales or units sold (and, rarely, profit). The licensor in this system takes most of the risk (success depends on the licensee), but potentially can receive high profits if the licensee is very successful. Much depends upon good risk assessment and belief in licensees' competencies. For the licensee, this system implies reduced risk, as payments are spread over time and depend on success. However, success implies substantial payments, and there is often a commitment to continuing scrutiny by the licensor.

To overcome some of the uncertainties, firms usually apply variable-rate royalties on a sliding scale of payments depending on success (often determining a maximum and minimum level), or a system of lump sum plus royalties repayment—as used by BTG. To overcome the 'irony-of-knowledge' problem, as in the case of OEC, firms ask for disclosure fees when it is necessary to reveal technical and commercial information to demonstrate benefits. These fees are sometimes deducted from royalties. Option fees are sometimes paid by licensees for delays to the signing of an agreement while further research is undertaken, and before the 'option' to buy is taken up (Bidault 1989).

When technology is difficult to price, there may be advantages in cross-licensing, or collaboration (see Chapter 5). Exchange of information over the course of a number of projects should end up in balance (in the estimation of participating scientists and engineers).

## Standards

Another method assisting the commercialization of technology is through the establishment of technical compatibility standards, often referred to as 'technical standards'. Firms that are involved in establishing standards have the advantage in that their design and production facilities already meet their technical requirements. Should they decide to do so, other firms will have to meet those requirements to compete.

Technical standards are a set of technical specifications adhered to by a producer. Technical standards can be established by standards authorities, such as the ISO, by voluntary agreement within an industry, or may exist *de facto* in line with the standards of predominant companies. When a particular set of specifications gains market share such that it guides the decisions of other market participants, those specifications become a *de facto* technical standard (e.g., the IBM PC architecture which has become the technical standard for the IBM-compatible PC industry). Firms and other organizations often promote and sponsor *de facto* standards in the pursuit of commercial benefits. The vast majority of standards, however, are not *de facto*, and involve negotiation between companies, academics, standards authorities, and other government departments. Standards achieved through a process of deliberation (sometimes legally enforced) are referred to as *de jure* standards. There are numerous international standards-setting organizations that enact *de jure* standards in the interests, and with the support, of technology producers and users. For example, Bluetooth, as a standard for short-range wireless communications technologies, has been supported by a large number of prominent companies. The success of Bluetooth, at least in part, is due to the structure and design of the international standardization ‘club’ that promotes it. With *de facto* standards, products are commercialized before standardization occurs, while with *de jure* standards the products are commercialized after the standards are determined.

In recent decades, the developments (described in Chapter 2) in globalization and technological change, and the convergences and complexity of technological systems, have resulted in increasing needs for technical standards. Indeed, the number of technical standards has rapidly increased since the 1970s. This is because technical standards greatly simplify the process of developing and designing the components of systems and realizing potential complementarities of subsystems, hence facilitating the development and diffusion of new technologies. In telecommunications, for example, the introduction of global standards—Global System for Mobile Communications (GSM standard)—has created a common base for designing and adapting products. It has also created a global market. Sales of products no longer depend on various domestic standards, and as a result new mobile phones and value-added services can be sold globally, thereby increasing the scale of production and reducing prices.

Standards are argued to have a wide range of benefits, including:

- Reduction of transaction costs, by improving recognition of technical characteristics and avoidance of buyer dissatisfaction.
- Provision of physical economies by simplified design, production economies, and ease of service.
- Advantages to buyers through interchangeability of suppliers, better second-hand markets and spare-parts suppliers, and enhanced competition for sellers.

Because of these benefits, to be able to pick and promote the winning standards is of increasing importance not only to management, but also to policymakers.

The standards-setting process is a social and political event, which takes into account consumers' behaviour, behaviour of suppliers of complementary assets, industry consortia, and regulatory bodies. As standards have competitive value, their formation is often complicated and controversial. Competing standards may exist, as in the case of analogue and digital high-definition television. Parallel standards can exist side by side. The evolution of standards can be a lengthy, complex, and highly contested process. In 2006, the ISO had membership of 158 national standards bodies, over 3000 technical bodies, with 193 technical committees, and 540 subcommittees. It has over 16,000 standards including over 7,000 in IT. At present the standards-making bodies in ICT include over ten major standards groups, and many hundreds of working-level groups. The European telecommunications standards body, European Telecommunications Standards Institute (ETSI), has twelve technical committees, fifty sub-technical committees, and several hundred working parties. It has become more difficult for the standards-setting process to rely exclusively on formal standards bodies. Nowadays, standards are increasingly set by consortia with less strict government requirements. That firms see fit to participate in so many committees reveals the commercial importance of technical standards.

Standards can have an anticompetitive element. This is obviously the case in *de facto* standards, where control is exercised by single companies, but there are also examples of collusion on the part of firms and governments to provide exclusionary standards. Laming (1992), for example, provided the case of Prometheus, a collaborative European 'intelligent highways' research programme, designed to develop a technical standard to exclude competitors (non-European firms have to comply with the standard, and this takes time and allows European firms an advantage). In some countries the benefits of standardization are disproportionately internalized by small groups of firms and, thus, become potentially a strategic instrument for these firms to achieve dominance in an industry. This explains why market rivalries involving sponsored standards have been increasingly common, especially in the computing and telecommunications industries. Incumbent firms are more likely to reinforce their incumbency by using their dominant technical and market positions in standards-setting activities. For example, dominant suppliers, though sometimes lacking technical innovativeness, can anticipate technological change, and thus reinforce their incumbent positions, by influencing the standard-setting process in their industry.

In the case of competition between standards, positive feedback loops work more or less in favour of the more widely adopted standard (a larger installed base), and therefore the market can potentially become locked into such a standard or system/network. Sponsors of the winning standards are therefore more likely to be successful. The success of the QWERTY keyboard—described in Box 3.12—is a classic example of a large installed base that leads to a certain product design becoming the industry standard.



### Box 9.12 Standards in mobile payments

Mobile payments are wireless transactions of monetary value from one party to another using a mobile device such as a mobile phone or PDA, key ring, contact-less card, or handheld computer. They are considered to be one of the most important elements of the future for mobile commerce. Indeed, some consider it to be the 'killer application' for the development of the industry.

Technical standards are critical to the global development of the mobile payments sector. The commercialization of mobile payments requires stability and predictability in the area of systems infrastructure and standards, before a mass market can be developed. Consumers and retailers want a unified standard; they do not want to worry about which mobile device uses which system. The challenge for the development of mobile payment technologies, as a critical enabler of m-commerce and mobile services delivery channels, is to create cooperation between competing cross-industry players—especially the mobile communications industry and the financial (payment) services industry—to develop consensus about standards. Industry standards are necessary for promoting secure transactions while enabling ubiquitous payment interoperability among different devices and networks. Standards have the capability to allow consumers to use mobile devices to make purchases at stores, with authorization and payment data flowing securely through the cellular phone networks operated by mobile communications carriers and then to financial institutions.

The success of mobile payments will rely on cross-industry cooperation among many parties, including banks, credit card companies, services providers, merchants, and the mobile telecommunications operators (telcos). All relevant parties have to agree on technological standards and security standards, as well as revenue-sharing schemes, such as how much money each party will get from mobile payment transactions. Many actors are fighting to establish a role that would allow them to influence the standardization of mobile payments. The battle is especially severe between the mobile operators and financial institutions. There are over 21,000 financial institutions and more than 500 mobile operators worldwide, many of which have interests in this developing field of business. Indeed, competition and fragmentation in the standardization process is hindering the development and deployment of mobile payment systems worldwide. Part of the reason for this is the complexity of the industry value chain: each actor in the value chain wants to have its own interests promoted and protected in the process of setting up industry standards. For example, an increasing number of mobile carriers in Europe are interested in developing their own payments systems for micro-payments, with the plan to let macro-payments go to the financial institutions. As a result of this competition many industry forums and consortia have emerged aimed at facilitating cross-industry cooperation (see Table 9.7). In addition there are many more consortia being created to promote region-based standards. Whether these industry consortia are organizations seeking commercial interests or whether they are non-profit driven; whether they are led by mobile operators, financial institutions, or mobile equipment manufacturers; whether they are located in the USA or in Europe, these industry alliances work on creating open and interoperable mobile payment standards to promote mobile commerce in general, and mobile payments in particular, on a worldwide scale. Some of these organizations have been created around existing protocols in order to support and promote the development of emerging standards, and to share experiences and influence the emerging standards in the common interest of the participants.

As of 2007, no dominant patterns had emerged in global standards for mobile payment technologies and in the business models within which the technologies are implemented and diffused. The lack of consistency in payment models and an absence of consensus on technology and security standards continually impede the mobile payment industry's growth. Financial institutions, telcos, handset manufacturers, and services providers continue to develop, in isolation, proprietary solutions to address specific requirements for individual market sectors, causing confusion among consumers and delaying diffusion. There is a need for a greater convergence between the mobile and the financial spheres to develop the mobile payments industry. It is an open question whether the effort to create de jure standardization is pushing the market to accept mobile payment technologies or whether strong individual businesses are determining de facto standards development for mobile payments.

Source: Zhang and Dodgson 2007.



**Table 9.7.** Some standards bodies in mobile payments

	Founding Members
<b>Mobile Payment Forum</b>	American Express, Visa, Mastercard, JCB Mobey Forum
<b>Pay Circle Consortium</b>	Visa, ABN Ambro, Bank of Ireland, HSBC, Barclays, Credit Suisse, Nordea, RBS, Deutsche Bank, Nokia.
<b>Mobile electronic Transaction (MeT)</b>	Siemens, HP, Sun, Oracle, Lucent
<b>Mobile Payments Services Association (MPSA)</b>	Ericsson, NEC, Nokia, Panasonic, Siemens, Sony Ericsson
<b>Infrared Data Association (IrDA)</b>	Orange, T-Mobile, Vodafone
	CrossCheck, C-Sam, Extended Systems, Avaro, Ingenico, In2M, Link Evolution, Novalog, NTT DoCoMo, Palm Computing, Toshiba, Verifone, Visa, Vivotech, ZiLOG

One of the most important strategic decisions firms need to make regarding standards is the choice of an open or closed policy. Firms that adopt an open policy are more likely to obtain an early installed base for their products. An open policy is also more likely to attract producers of complementary products and customers who may not want to become dependent on a single firm.

## Marketing technology products/downstream support

The primary means by which technology is commercialized is the production of products, components, and services, which are then sold in the marketplace. We have seen, however, that a high proportion of new products fail in the market. It is the marketing domain that has the task of reducing these high levels of failure, and some of the ways it does so have been discussed in Chapter 7. Marketing expertise would have made a significant difference to the biotechnology company described in Chapter 1. Whilst its technology was excellent, the company was unaware of how best to use it, and it originally targeted the wrong market.

Previous chapters have emphasized the importance of direct inputs from marketing into the broad range of firms’ technological activities. The high levels of internal and external organizational integration required by MTI include close links between marketing, R & D, and operations and production, and their further integration through innovation strategy. Marketing plays an important role in the use of stage-gate systems and QFD, where it disciplines the innovation process towards considerations of market needs. We have also seen how, in the case of the Post-It notes, marketing can make some serious miscalculations, occasionally preventing firms from realizing

opportunities. Poor integration of marketing and production input into the innovation process can lead to the sorts of difficulties DuPont experienced when it developed Kevlar. The original market for the product was to be tyre cord, a large market, but the company had not properly understood the costs of production, and the costs of alternatives. It took some time before the product was successfully used in other applications.

There are three major roles for marketing in the commercialization of technological investments through technology products and services. First, market definition, or posing the question: what should we make? The marketing function has an important role to play in defining what R & D to undertake, what new products and services to develop, and what sorts of operations are required. Littler (1994: 295) argues that:

[Marketing's functional] role is seen to be concerned with commissioning and/or undertaking market research and analysis, and with having an active part in the development of all aspects of the offering that include pricing, advertising, promotion, service support, distribution, packaging, sales, and design. Its prime purpose should be to ensure that the offering which emerges from the development process has significant appeal to the customer segments which it has identified as having the optimum potential for the business, whilst at the same time having a perceived differentiation from its competitors with regard to those values which its customers regard as important.

Customers, both industrial and individual consumers, can often be segmented into groups with specific requirements, and marketing can assist in articulating, defining, and measuring these requirements.

Second, and relatedly, marketing plays an important role in facilitating internal and external communications. According to Littler (1994: 294):

[T]he marketing function may also have a key part in gathering, analyzing, and disseminating throughout the organization intelligence on customer purchasing behaviour, satisfaction levels, attitudes towards the business and its competitors and such like, as well as contributing to the development of an overall corporate culture which not only acknowledges the central role of the existing and potential customers but also the manner in which the dynamics of the environment are continuously shaping demands, resulting in new customer priorities, with consequent implications for the development of new and existing products.

Littler argues that firms market not just a product, but rather a collection of values such as the ability to perform tasks, enhance appearance, and augment or reinforce perceived self-image. When it comes to technology products, where there is an increasing commodification of technical product features, it is the non-technical features, such as design, service quality, distribution, and technical support, which add the greatest value. He argues that there is a temptation for technology producing firms to concentrate too much on the features of the technology, and it is the role of marketing to ensure that new products satisfy the basic criterion of presenting the customers with something that they regard as having some differentiating benefits, such as ease of use.

Third, there is a well-established field of marketing that concentrates on relationships between firms and their management (Hakansson 1982). We have seen that close customer–supplier relationships are important in the development of new products, inasmuch as longer-term, more intimate relationships engender the trust required to exchange sensitive and valuable information. The loss of a major relationship with a customer in such circumstances can be very difficult, so it is important in such cases for the marketing department to be involved in the conduct of the relationship. It is also important to ensure that firms do not become too attached to particular clients, and have the capacity to diversify their sources of information about customer needs (Hakansson and Snehota 1995).

Box 9.13 provides an example of a company that benefits from matching its technological innovation with extensive marketing support.

#### **Box 9.13 Netafim: a case of successful international technology marketing**

Drip irrigation offers significant environmental benefits. Its efficient utilization can reduce the application of pesticides and fertilizers, inhibit erosion, save water and energy, and allow the use of recycled or waste water. Israel is world leader in the \$1 billion market for agricultural drip irrigation technology. Making optimal use of its scarce water, harsh land, high salinity, and extremely hot summers has led to a research focus on water-saving techniques with significant export potential. Netafim is an Israeli firm that is the largest low-volume irrigation company in the world. The company was set up in 1965 by agronomist farmers in a kibbutz, and its drip-irrigation product was developed to deal with problems kibbutz members faced in irrigating their own crops. For the fiftieth anniversary of Israel's independence, a team of experts chose Netafim's product as the most important Israeli invention since the state was founded.

Netafim has a range of products including drippers and dripper lines for varying topographies and climates; high-precision mini-sprinklers and sprinklers; computerized irrigation systems including wireless monitoring from sensors, tensiometers, and weather stations for real-time data analysis and control; and greenhouse technology, including turnkey systems. The company's strategy is to expand its business of providing total systems solutions. In 2005 it employed 2,000, its sales were \$359 million, and had 12 manufacturing facilities in 30 countries. Netafim's international marketing and service operations include a worldwide network of 30 subsidiaries and distributors in 110 countries. The company is reputed to have (indirect) sales in Iran.

Israel has a strong scientific base in agriculture (e.g., its milk cows are claimed to be the most productive in the world). Israeli agriculturists have pioneered agricultural biotechnology, hydroponics, soil solarization, and the sustained use of industrial wastewater for agriculture. There is a well-established extension service system, and researchers argue that Israeli companies receive significant support from government and academic research in new technology, products, and services that advance water conservation and management (Hirshfeld and Schmid 2005; see [www.mfa.gov.il](http://www.mfa.gov.il)).

The company invests over 5 per cent of annual sales in R & D, with a focus on improved system efficiency and broadened applications. New products are designed by the Product Research and Development Department in Tel Aviv, while production R & D is the responsibility of R & D departments at each production centre. Product development is updated via research undertaken by the Agronomic Research and Training Departments, and by feedback on product performance from local and export sales departments. Its production lines are fully computerized, and operate 24 hours a day. Its factories are capable of producing many billions of drippers each year. The production machinery and software were exclusively designed by the company (see <http://www.netafim.com>). The company actively cooperates with renowned agricultural research centres and it has created the Netafim Irrigation University (NIU), which it claims is gaining recognition as a principal source of advanced irrigation technology. NIU offers courses, seminars, and workshops and it has developed educational manuals and e-learning materials.

The effort and resources the company invests in technology are matched by its commitment to marketing. Its marketing network also sells the products and services of Netafim's affiliated companies. It provides comprehensive technical and agronomic support services to export customers, and to agricultural and landscape experts. Company agronomists, geologists, soil and plant experts, water engineers, and other support personnel are frequently sent out from Israel, and local agents participate in regular updating and training sessions. Each country is served by a desk of specialists that regularly visit customers and understand local conditions ([www.netafim.com](http://www.netafim.com)). The company operates Training Centres in Greece, Thailand, Brazil, and the Philippines, as well as Israel.

Netafim has built manufacturing bases in India and China, both large countries with enormous water problems and demand for efficient irrigation systems. It has embarked on a \$40 million agreement in China to build an irrigation systems plant, and to undertake various projects. One project will install advanced irrigation systems in high-tech greenhouses in a desert region of China, and will be overseen by China-based Netafim employees. The Israeli agency, MARSHAN, has worked with Netafim to establish a model farm near Beijing to demonstrate products and technologies (Hirshfeld and Schmid 2005).

Netafim provides an excellent example of a company whose growth has resulted from a combination of substantial investments in product and process innovations with extensive technological marketing and support activities.

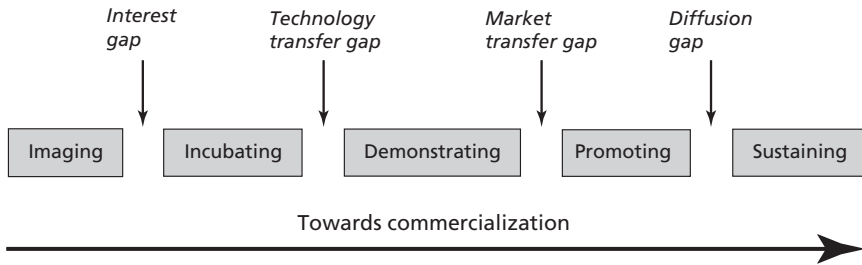
## Technology transfer

The commercialization process involves getting technology to where it can be used most profitably, and this often involves the transfer of technology. Technology transfer can be defined as the movement of technological capability—typically a package of artefacts, information, rights, and services—from supplier(s) to potential user(s). It is therefore a broader concept than the sale of IPR. These transfers can occur *internally* between two organizations under the same financial control, *quasi-internally* between joint venture and alliance partners, and *externally* between independent buyers and sellers. We have already discussed the processes of transferring technology within laboratories and between the various functions of the firm (Chapters 6–8). And we have examined the transfer of technology between collaborating partners (Chapter 5). Here we focus on a simple means by which firms and research organizations can analyze and manage the transfer of their technology and some methods by which firms can import technology from international sources.

## JOLLY'S COMMERCIALIZATION MAP

A large number of tools and techniques are used to assist firms and research organizations in analyzing and managing the process of technology transfer for commercialization.

Jolly's (1997) 'Commercialization Map' illustrates some important general principles, suggesting that there are five key stages in the commercialization of technologies—imagining, incubating, demonstrating, promoting, and sustaining. Each of these has a definable transfer gap—in interest, technology transfer, market, and diffusion—through



**Figure 9.4.** Jolly's commercialization map

Source: Jolly (1997).

which the technology must pass if it is to be commercialized (Fig. 9.4). The stages involve finding solutions to a variety of technological, production, or marketing problems, and the 'bridges' between the stages involve the mobilization of resources to deal with them:

- *Imaging.* Conceiving of the technology and linking it to a market need. A vision is created (with colleagues and partners), a concept is proved, and patent protection is sought. If there is sufficient interest in the idea, in developing it, funding it, and buying it, the technology progresses through the interest gap.
- *Incubating.* The idea is fully demonstrated, technically, and in a business sense, often with customer involvement. If the research originated in a public-sector institute, this stage usually represents the end of its involvement. If the process is complete, it moves to a product development process (described in Chapter 4), and it has progressed through the technology transfer gap.
- *Demonstrating.* The first commercial quantities are produced, and suppliers and customers involved in the development are integrated into supply lines and marketing channels. Once this occurs the product has moved through the market transfer gap.
- *Promoting.* This entails careful market positioning and targeting to ensure that the product quickly gains a profitable share of the market. If this is done successfully, the product has moved through the diffusion gap.
- *Sustaining.* Here the aim is to entrench the product as broadly as possible in the market so as to ensure continuing long-term income streams.

This approach reveals several important principles:

- Commercialization can fail at any one of the stages or gaps in the process. The process throughout is highly uncertain and risky.
- The commercialization process is continuing. It does not end when the product reaches the market. The product itself may be subsequently improved, and the market may change. Long-term income streams depend not only on careful market-entry strategies, but also on continuing market development activities.

- As we have seen throughout this book, the commercialization of technology requires high levels of organizational integration, in which human factors, such as teamwork, are critically important.
- Integration with external organizations is also important. Early feedback from customers and opinion-formers, sound links with suppliers and, if it is not self-funded, the procurement of suitable sources of external funds, are all required.

## ACCESSING INTERNATIONAL TECHNOLOGY

Apart from actual purchase or through FDI, firms can access international technology in a number of ways:

- *Reverse engineering* is a very common method of technology transfer, and was instrumental in the development of Japanese industry. It involves disassembling goods, learning about how they work and are made, and developing improved versions sold under the firm's own name.
- *Pirating*, where replicas are sold as originals, requires analytical and manufacturing competencies to be developed.
- *Original equipment manufacture* (OEM), which is very common in electronics and consumer goods. OEM involves a local firm producing a finished product to the specification of a foreign buyer (commonly a large Japanese or US consumer electronics firm). The foreign firm then markets the product under its own name. OEM sometimes involves the foreign firm in the selection of capital equipment and managerial and technical training, and can involve close, long-term technological relationships. It provides a valuable learning experience in design and manufacturing and has been instrumental in assisting the technological development of Korea, Taiwan, and Singapore. There are some disadvantages to OEM inasmuch as the junior partner is subordinate and dependent upon the technology, components, and market channels of the large multinational firm (which often imposes strict conditions). Furthermore, the local firm is denied access to large post-production value-added, and cannot develop brand image and international marketing expertise.
- *Turnkey* plants involve the transfer of usually complex production facilities, whereby the foreign firm takes responsibility for project management, the selection of overseas and domestic suppliers, and training of plant managers and technicians.

Personnel transfer is a key aspect of technology transfer, domestically or internationally. In the USA, high job mobility moves knowledge from firm to firm. In Japan, job rotation transfers knowledge within firms. This also occurs when employees are seconded from firms to collaborative research institutions. In Korea and Taiwan large numbers of professionals returning from the USA bring important knowledge with them. Many Asian

scientists and engineers have returned from the USA because of the ‘glass ceiling’ that can prevent movement from R & D into management positions, and this has considerably assisted the development of technology in these countries. The Indian software industry has also greatly benefited from this type of mobility of its highly qualified nationals.

## Summary and conclusions

The commercialization process is an essential element of MTI and the delivery of value. It is important to distinguish between social and private value from innovation, and achieving the balance between these is a continuing challenge for governments trying to maximize public good and maintain private incentives to innovate. Firms operate in different appropriability regimes, the nature of which—whether they are loose or tight—strongly influences the ways managers commercialize. Mobilizing or accessing complementary assets is key to the delivery of returns to innovation. When complementary assets are not owned in-house, there are significant challenges for firms needing to access them, especially if there is a power imbalance between small start-ups and incumbents. These difficulties are compounded by the paradox of disclosure—the knowledge you wish to buy is at the same time the knowledge needed to enable you to decide whether to buy.

Firms commercialize through the market for ideas and the market for products, each posing different tests for managers. IPRs are a means by which firms can appropriate value from their technological investments in the market for ideas. In the knowledge economy, where it is extensively traded, IPR provides the security underpinning firms’ transactions. Licensing is a particular way of selling IPR, but there are difficulties in managing the sale of licences for both the licensor and licensee, particularly in respect of technology pricing. The examples of BTG and OEC show that these difficulties can be managed. Technical standards can also play an important role in the commercialization process.

Continuing input from the marketing function is critical to commercialization in the market for products and services. Marketing informs firms about the commercial potential for technological innovations, and helps direct those innovations towards meeting commercial objectives. Technology transfer in the commercialization process can be managed through the application of various analytical tools; one such was described which helps and disciplines what is often a complicated and vexatious issue for private- and public-sector organizations.

# 10 Five Future Challenges

## Managing technology-based competition

Firms create customer value and competitive advantage when they bring to market new and improved products and services, or devise better processes. Businesses thrive and decline as a result of the way they manage technological change. The ability to manage technological innovation has become a core business process. The pace of technological change will continue to be rapid and its direction uncertain. It follows that there will continue to be an extended range of new business opportunities and risks associated with new technology. As we saw in Chapter 2, the fifth wave of broad historical technological change, or techno-economic paradigm, based on ICT, continues to have a profound impact on contemporary industrial organization and management. While each 'revolution' is in full swing, the next wave of technological change is in genesis. It has been speculated that the next historical wave of technological change will be based on life sciences, and environmental and space technologies (although we should remember the problems of predicting scientific and technological developments). Whatever the key factor industries of the future, the extent of the technological changes, and the concomitant broader changes in society and business, are unlikely to be less disruptive than in the past, creating continuing challenges for firms.

A common feature of technological innovation is the way it entails fusion or combinations of different technologies, knowledge-bases, disciplines, and business sectors. It frequently requires integration of new technologies with older vintages, and merger of the existing and new. Future 'open' innovation strategies, focused on the coordination and integration of the innovation efforts of multiple parties, will need to be balanced with effective mechanisms for protecting and trading the specialisms and IP of individual firms. Prospective technological innovations will not only be more dependent on basic research, making access to science more important, but will also involve combinations of fields of technology, such as photonics, micro-electronic mechanical systems, molecular biology, biosensors, and nanotechnologies, requiring firms to possess a level of competence in multiple technologies. In the future, continuing and extensive efforts will be required to seek synergies between business sectors and between products and services. As we saw in the case of the merger of financial services and mobile networks to create mobile payments in Chapter 9, this remains problematic. The challenge for management



will be to create the strategies and structures, resources and capabilities, and to effectively use the new technologies, to encourage this cross-disciplinary, cross-sectoral, and cross-technology synergy.

These changes in technology and in the possibilities for new combinations provide many challenges and opportunities for business. The capacities of IT and IvT to share and process information more quickly, and the growing extent of globalization, both features of the 'knowledge economy', will make the use of technological innovation an even more important source of competitive advantage in the future. Furthermore, the increasing knowledge content of value-creating activities will continue to blur the boundaries between manufacturing and services. So, for example, a key future development in biotechnology lies in robotics—machines for the manufacture of genetic materials; major competitive advantages in the auto industry will derive from the provision of advantageous financial and insurance services; and financial services firms are adopting the practices of manufacturing operations management. These developments will reduce the advantages in many areas of large-scale, entrenched positions, so that the opportunities for new entrants will increase. Given the rapid changes in technology, the ability of firms to strategically position themselves quickly, to learn fast, and have the capacity to reach the market first, will confer competitive advantages. Those firms most skilled at design, systems integration, and project organization will be best placed to offer flexible and speedy responses to new challenges.

The opportunities and benefits of being innovative are likely to increase so that remaining the same will not be an option. If a firm does not innovate, one of its competitors—in its domestic markets or from overseas—will. As individual innovations and the innovation process itself result more from the activities of multiple contributors they possess characteristic complex and emergent—that is, unpredictable—properties. The ability to manage this complexity will become a greater source of competitive advantage (see the discussion later). Somewhat paradoxically, the more difficult the innovation and innovation process, the greater will be the advantage to be derived. If innovation were easy, it would not provide any relative competitive advantage.

How will firms react to these opportunities and threats? They need to respond with internal changes, and external changes related to customers and suppliers and their communities and networks, including with governments and the science base. They need to explore new business models, unlocking the potential to create value from technological innovation.

Changes in internal organization will continue along the current development path with all components of the business (e.g., R & D, design, operations, and marketing) being ever more closely integrated. Importantly, this will bring a greater customer focus on innovation, driving manufacturing businesses towards more flexibility in design and

operations, and services firms towards more efficient production methods, experiential services, and niche and novel delivery strategies. Companies will be organized primarily by *process* rather than *function*, with the emphasis on building creative, learning organizations around the principles of small, cohesive groups, continually refreshed by new and challenging members, and focused on innovation as the most important process of all. These processes will need to carefully balance efforts to make them more efficient, with an emphasis on the elimination of wasted effort and resources ('lean thinking'), with concerns to provide 'slack' resources for experimentation and play. Firms will learn to better reconcile the tensions in organizations that are at once 'exploiters' of existing knowledge and 'explorers' of the new, with different management skills, structures, and incentives. They will adopt search strategies that enable them to pick up weak signals in the external environment about potential radical or disruptive innovations.

Changes in external links will continue along the current best practice trajectory. Companies' innovation activities will be more fully integrated with those of their suppliers and customers. Both customers and suppliers will be actively involved in defining R & D activities and innovating products, services, and processes, in real time, using new technologies, from the product's or service's conception to its commercialization. Lead users and individual consumers will be involved in the design and development of an increasing number of products and services, ranging from houses and cars, to pharmaceuticals and education. Relationships within these external links will be based on high degrees of mutual commitment and trust to improve information flows, share learning, and encourage innovation. In supply chains this integration will continue to extend globally, particularly in Asia and Latin America. The development of new forms of linkage such as 'global commodity chains', illustrates that even in industries dominated by large global firms there will be innovation opportunities for small and medium-sized companies to form cascading links.

Increasing R & D collaboration will occur amongst clubs of firms with common interests, and R & D service suppliers will be increasingly integrated into network activities. Such collaborative activity will extend deeply into the science base. This strategic integration will be driven by the increasing cost and scope of innovation, and by the importance of time, or speed to market. Technological collaboration will see the development of new ways of operating, particularly in the management of relationships in which firms simultaneously cooperate and compete. Firms will become much more adept at integrating the insights and realizing the opportunities provided by public-sector research organizations, and research organizations and intermediaries or brokers will become highly skilled at proactively articulating the innovation needs of firms and finding solutions to them. Firms will learn in communities and networks, becoming much more adept at using the creativity of their customers to help design new products

and services and encourage their diffusion. Effective networks will be those that can integrate the activities of numerous constituents to deal with the complexity of technological systems.

These developments in networks are sympathetic to the recent analytic work on systems of innovation, discussed in Chapter 2. In future, the strength of national, regional, or sectoral innovation systems, and the competitiveness of individual firms, will lie not only in the strengths of the constituent elements—firms, research institutions, sources of finance—but more than ever in the linkages between them and the quality of their relationships.

Firms will respond to the future challenges of technology-based competition by creating better innovation strategies. Innovation strategy on the one hand will improve the practice of MTI, and on the other will become the key means of identifying the broader corporate aims and activities of firms: innovation is the strategy. Innovation strategy will improve the efficiency of technological investments and thereby allow firms to gain greater returns from a budgetary area that has been, and will remain, under strain. Few companies can maintain levels of investment in R & D at over 10 per cent of sales for any length of time without very substantial returns. There will be increasing numbers of innovation directors and managers appointed. Their roles will become cemented into the core activities of the firm, and the more successful of them will ensure that the creation of their position does not abrogate the responsibilities of the Board of Directors, line managers, and the firm's entire staff for creating and delivering innovation. A key role of innovation directors and managers will be searching for, selecting, and developing technologies that satisfy and extend the needs of customers. Innovation strategy will be formulated on the basis of extensive market intelligence and wide comprehension of the developments at the technological frontiers, within internal and external research units, based on broad innovative capabilities and excellent technological and personnel resources. Innovation strategy will reflect comprehensive understanding of the regulatory environment, and the articulation of that strategy will be instrumental in advising the development of those regulations and policy supports from government.

The innovation director/manager will have the responsibility for providing stakeholders with an annual innovation audit outlining present and future activities, and his or her performance will be measured not only against financial criteria, but also by the expanded opportunity and options available to the firm. Innovation audits will be part of firms' annual assessments of intellectual capital and knowledge bases, and will focus on evaluating and assessing IP, the scientific and technological skills residing in staff, and the delivery of value to the firm through innovation.

The technologically innovative companies of the future will be innovative across the board, not just in technology. They will have the business models, organizational structures, sources of finance, and marketing channels to build on their technological

advances. The extent to which organizations are innovative will become the major factor in the 'war for talent' as creative and productive workers make decisions about who they will work for. Firms will find it commercially advantageous to take environmental issues seriously. In response to increasingly stringent regulatory requirements in areas such as emissions control, and to strong customer and investor demand, the environmental credentials of firms and their products will be an evermore important aspect of their competitiveness (see the discussion later).

Just as business firms will have to change in the future, so too will financial systems need to adjust. There will be a need for novel sources of funds (both domestic and international) to finance growth opportunities in emerging technologies, particularly for longer-term technological developments. Private equity funds might restrict or enhance opportunities for innovation: the jury is still out. Banks will increasingly lose their power as money brokers as the technology directly links buyers and sellers. The balance between equity and loan capital may change, as greater information availability through the Internet allows investors to make better decisions about the balance of investments in stocks or bonds. There will be less passive investment by venture capitalists, as seen in the European model, with the trend towards the interventionist style of US venture capital. The future will see growth in the numbers and quality of business angels. As a result of increased and more readily accessible information, managers and investors will be able to make more ethical decisions about technological investments. Whether the investment is in a production plant in a low-wage country with primitive regulations, or is funding research into genetically manipulated seeds, the decisions made by companies will be progressively open to scrutiny. Ethical issues will increasingly impinge upon the choices managers and investors make about technological investments.

New sources of 'exit'—where investors can realize their investments—will be needed for individual and institutional investors in start-ups to reduce risks (valuable lessons can be learned from current experiences in over-the-counter markets, the Third Market in the UK, and the technology-based markets, National Association of Securities Dealers Automated Quotations (NASDAQ) in the USA, and Japanese Association of Securities Dealers Automated Quotation (JASDAQ) in Japan). Increased calls for accountability of finance managers to their investors will lead to increasing investor involvement in decision-making. There will be a need for new accounting tools, particularly related to valuing innovation options and reporting environmental and ethical credentials, which will assist firms to take a longer-term perspective on their investments.

The management guru, Peter Drucker, has said that firms need to become learning and teaching organizations. In the knowledge economy, learning about innovation is the most important productive activity. As we have shown throughout this book, learning is a complicated, multifaceted activity (which has implications for simplistic notions of building 'learning organizations'). In the future, firms will need to understand, appreciate, and attempt to manage learning in the same way as, in the past, they attempted to

manage other productive activities. They will require recruitment and training policies that attract and retain staff dedicated to lifelong learning and innovation. All staff will need to recognize and support the notion that innovation is the only true source of sustainable competitive advantage.

## Managing the new innovation process

The innovation process will become ever more complex, involving larger numbers of actors and displaying more emergent and unpredictable properties. This complexity will occur for a number of reasons and will manifest itself in a number of forms. First, the business, technological, and regulatory contexts in which firms operate will become increasingly intricate. Change is rapid and unpredictable and, as the chapters in this volume show, often requires networking and collaboration within communities, and engagement with governments to gain some control over the pace and direction of technological change (essentially sharing control in order to retain it). The scale and scope of scientific advice will multiply, increasing the challenges for firms to be appropriately receptive. Second, the internal organizational structures and ways of engaging with external parties will become more multifaceted. The need to ensure effective communications and engagement between a broader range of technical and other specialists will require continuous network, project, and team configuration and reconfiguration, and constant experimentation with new organizational forms. This is especially the case where innovations have social or environmental implications and a wide range of interested bodies demand involvement. Third, complexity will manifest itself in the configuration of ‘products’, involving ever-closer integration of recent basic research, and combined and merged service features, and may take the form of ‘integrated solutions’.

One way of dealing with an increasingly complex and unpredictable innovation process is by encouraging the use of play. The innovation process will become a much more ‘playful’ series of activities. Michael Schrage’s (2000) excellent book *Serious Play* analyzes how ‘the world’s best companies’ simulate, and in particular use prototyping, to innovate. In fact, play has always been central to creativity, knowledge, and development. Plato said that life must be lived as play, and Charles Dickens said: ‘There can be no effective and satisfactory work without play...there can be no sound and wholesome thought without play’ (Fielding 1960: 272). The novelist Philip Pullman says:

It’s when we do this foolish, time-consuming, romantic, quixotic, childlike, thing called play that we are most practical, most useful, and most firmly grounded in reality, because the world itself is the most unlikely of places, and it works in the oddest of ways, and we won’t make any sense

of it by doing what everybody else has done before us. It's when we fool about with the stuff the world is made of that we make the most valuable discoveries, we create the most lasting beauty, we discover the most profound truths.<sup>1</sup>

So play is a serious business and it needs to be incorporated centrally into the innovation process. It needs to be combined with the creative thinking and formalized research that occurs inside and outside of companies (described in Chapters 4–7) and the operations and process capabilities that firms need to deliver value (described in Chapters 8 and 9). *Homo cogito*—man the thinker—and *homo faber*—man the maker—need to be complemented by *homo ludens*—man the player.

Technologies, especially simulation and prototyping, will play an important role in encouraging play and its integration with thinking and doing in the management of the new innovation process. These innovation technologies, which we call IvT—e-science, simulation and modelling, artificial intelligence, and rapid and virtual-reality prototyping—will increasingly become essential tools of the innovation process. Companies will utilize computer-integrated operations systems linking all elements of the design and delivery of new products and services. Firms will have real time access to information in those systems to help control the entire value chain. Local area networks will integrate activities within operations; electronic data interchange will link the activities of those sites with suppliers and customers; the Internet will assist the iterative and playful processes of information exchange between firms and across all the activities within a firm. In its most advanced form the capacity to simulate and model innovations prior to their production (to see if anyone will buy them) will be extended to the simulation and modelling of the operations used to deliver them (to see if they can be made), and the simulation and modelling of the business models used to maximize returns from them (to see which will be most profitable).

ICT and IvT may on the one hand assist in dealing with complexity through facilitating the exchange and integration of information, but on the other hand will add to the complexity by multiplying its potential sources (and placing greater technical demands on the security of commercially sensitive information), and raising new challenges around the skills and organization required to co-produce and co-utilize knowledge.

The use of ICT and IvT in the innovation process raises questions about whether knowledge that previously was tacit can be codified. If it can, there are implications for appropriability and the use of collaborations (codified knowledge is more easily protected, and can be transferred via markets or hierarchies rather than alliances). Whereas the new electronic tools can store, transfer, and process information, their ability to do this with knowledge is more limited. Firms will increasingly experiment with new organizational forms using technologies, including virtual worlds and

<sup>1</sup> Speech given at the book launch for *Think, Play, Do* (Dodgson, Gann, and Salter 2005), Imperial College London, 11 October 2005.

new forms of visualization and representation, that improve understanding between diverse groups and engage multiple parties in the design of new products, services, and processes. Diverse groups playing collaboratively around common technology platforms will become a key feature of the future innovation process. Firms will face the challenge of providing people with sufficient time away from everyday demands to play, and create physical working environments conducive to experimentation and learning.

Technology is only a tool. It has no value until it is used productively by people. Tacit knowledge will remain a major differentiating factor for a firm's competitiveness, with the implication that rewards derive from investments in people. Particularly important will be investments in staff, whose ability to generate and assimilate new knowledge—that is, to learn, as a result of investments in R & D and technology, will improve. As Chapter 8 showed, there are many examples of technology initially being used to deskill and limit the discretion of those using it. Creating the managerial strategies, organizational structures, skills, and incentives to encourage the innovative use of technology presents a continuing challenge for managers. There will be particular demands for skilled people able to use the new technologies to work across organizational, professional, and disciplinary boundaries. There will be pressure on education institutions to produce graduates with more broadly based skills to operate effectively with new innovation processes. Creative staff will need to be skilled at co-simulating and developing their ideas (playing with others); systems thinkers will need to be skilled at integrating complex systems involving many different parties. Every employee in the innovation space—which increasingly will include everyone in the organization—will need to be skilled at teamwork and communicating across boundaries.

Everyone will become an innovator not only in their own job, but also as consumers and citizens. As firms become more adept at catering to 'markets of one', informed individual engagement would become more important. It is one thing for us to have our running shoes individually designed and manufactured. It is quite another to be actively engaged in the design of bespoke pharmaceuticals based on our particular genetic requirements, and capable of being manufactured at home using rapid prototyping systems. High levels of knowledge are critical to the process of effective engagement with such innovation.

Similarly, for citizens, forceful, articulate, and informed engagement with business and government will be critical to their search for improved social accountability and responsibility. The technologies and strategies of 'democratizing' the innovation process will fail to deliver without an informed and demanding citizenry engaging through the innovation process.

As ecologists have discovered with biomass, healthy systems require diversity. There are many advantages for businesses in learning from diversity. As 3M's vice-president put it, 'having people in our technical community who have grown up in different cultures provides us with a greater chance of innovation and creativity'. This diversity, as we



saw in Chapter 5, also applies to choice of collaborating partners. Leading firms will seek a small number of tension-ridden alliances within or outside their networks, with sources of potentially disruptive technology to encourage learning and the development of radical innovations. Because of the technology collaboration paradox, in which there are advantages in collaborating with the sort of firm that is more difficult to work with, the incentives for learning from failing will become even greater. The principle of diversity also applies to the construction of innovation teams. Diversity in all its forms—cultural, professional, experiential—provides a distinctive stimulus to innovation.

## The role of government

Innovation is too important to be left to the private sector alone to decide on. Through their responsibilities for social welfare and economic development, governments have profoundly shaped the nature of innovation within and across countries. Governments, nationally and regionally, will continue to extend and expand their role of harnessing innovation for public goals. They will look to innovation in response to the great challenges of the age—in energy, health, and the environment.

Innovation remains at the heart of the social and economic well-being of nations and therefore of political power. Governments will attempt to alter the nature and location of innovation by any means at their disposal. The future policies used by governments will increasingly involve more open, international, and fluid measures, supporting the capacity to adapt and absorb technologies and ideas developed elsewhere.

Governments around the world have moved away from interventionist industrial policies, which usually included selecting and supporting particular firms, sectors, and technologies. Few governments continue to subsidize their ‘national champions’. The rise of the multinational (or meta-national) firm makes the question of ‘who is us’ less pertinent and relevant. Governments instead are focusing on the wealth creation and employment prospects brought by innovation. For some governments, this shift means leaving a legacy of heavy state intervention often associated with considerable social and policy failure (Katz 2001). For others, more successful in shaping economic activities within their countries, the desire to ‘govern the market’ is increasingly tempered by a willingness to open up previously closed societies and markets to international competition.

This is especially the case in the service sector, where there is still great potential for international trade, and where there are opportunities for developing countries to make major economic breakthroughs. For developing countries seeking to harness the power of the state to shape economic growth, investments in innovation are being complemented by a wide range of policies to support education, training, health, the environment, and inequality reduction. For these countries, innovation is becoming part



of the tool kit of development, with considerable resources being invested in adapting and reshaping existing technologies for local circumstances. This focus recognizes the need for developing countries to build up their capability to create value from new combinations of knowledge and technologies.

Governments will continue to be main funders of basic research in advanced countries, but they will increasingly seek international collaboration to support it. The cost of such research is often beyond the resources of individual countries and its focus is often problems that require global solutions (see discussion later). Publicly funded research systems, mainly based in universities, provide governments with the power to respond to social, technological, environmental, and economic problems. The Cold War, with its vast expenditures on military and space technology, provides lessons about the motivating power of great challenges for scientific and technological problem-solving. Putting a 'man on the moon' was the rallying cry of scientists and engineers in the 1960s and 1970s. Contemporary challenges, such as global warming, call for a whole new generation of research and research coordination within and across a range of disciplines, including energy, materials, chemistry, logistic systems, biology, and geology. This will lead another considerable expansion in the global pool of scientific and technical talent available for disciplined problem-solving. The scientific know-how and problem-solving skills in international research systems will be essential to the development of more sustainable economic systems. The research systems themselves are also likely to be more open to outside voices and concerns, allowing non-experts to shape and participate in the scientific and technological decisions that affect them, rather than leaving these decisions to 'experts' (Callon and Rabeharisoa 2004). The current challenges will call forth new generations of knowledgeable people from around the world with the desire and passion to find new solutions to sticky or intractable problems. Governments, through national education systems, can send important messages about the importance of scientific and technological knowledge for solving these problems, encouraging young people to take up careers and develop expertise in these areas.

Throughout the 1980s and 1990s, governments focused on trying to understand their innovation systems, often developing detailed plans to promote industrial clusters or connections between previously disparate actors. In this role, governments sought to become *animators*, stimulating interaction between individuals, firms, and institutions. Efforts to support interaction within innovation systems will likely expand, but will also probably become increasingly sophisticated and targeted. Governments are likely to become 'brokers', creating new mechanisms that help firms, research organizations, and individuals to find ways to build useful relationships with one another. Government's role will increasingly be seen as a 'creator of connections', capable of rapidly responding to new opportunities and bringing disparate actors together to achieve a common goal. Collaborative programmes, using the potential of IvT, create new opportunities for governments to take on this role.

Governments have become more and more aware of the need to innovate, both by themselves and in collaboration with the private sector. In most advanced countries, government expenditure accounts for between 30 and 50 per cent of total economic activity. Although government agencies and government employees may not in the past have been highly innovative—there are political costs to taking risks with public money—there is great latent potential for innovation in government. Indeed, changes in public-sector practices are becoming one of the most important managerial challenges in MTI. Public institutions, often bound by past routines, represent an enormous reservoir of information, talent, and experience which can be drawn on as they seek to improve their operations and offer new and improved services to citizens. Unlocking this potential will require changes in the nature of work in public institutes, creating space for individuals to experiment with new ideas, take risks, and create connections across different areas. These changes will be fraught with difficulty in organizations driven by public accountability, social responsibility, and long-term, settled working practices. However, there are reasons to be optimistic as politicians and the general public are becoming more aware of the need for change in the way that public services are delivered and operated. Areas such as e-government—more effectively engaging citizens in decisions and elections, and e-health and telemedicine—giving patients greater knowledge and choices, can help to liberate the ideas and skills of dedicated public servants.

The risks related to innovation have been described. These are particularly acute in the case of start-up firms. Because of their massive budgets, governments can afford to assume levels of risk unsupportable in small firms; these small start-ups can be supported by government purchasing goods and services from them. Governments around the world will increasingly support innovation through their procurement policies.

Chapter 9 showed that standards and regulations are often a key source of new ideas for innovation. In response to environmental challenges, for example, governments have increasingly been willing to use regulations and standards to shape the types of products and processes produced and used in society. In the future, it is likely that government will be even more active in creating regulations, not just to limit the negative consequences of the use of a technology, but also to create the incentives for developments to tackle a range of social and economic challenges. Prizes for the resolution of difficult problems could provide a mechanism to support and give momentum to new ideas. Promises of market access for new technologies could help stimulate private-sector interest and activity. Government regulatory authorities will increasingly focus on ensuring that markets are competitive by making sure they are open to innovation. They will encourage interoperability between technologies, ensure that platforms technologies are open to a range of different products and services, and seek to promote innovation by judicious use of IPR. They will stimulate innovation by providing open access to government information.

Modern society relies on new and old infrastructures. Sewerage systems were created in the twentieth century; trains were developed in the late eighteenth and early nineteenth century; air travel and electricity systems were introduced in the early twentieth century, the Internet went live in the 1970s. The maintenance, renewal, and expansion of these infrastructural resources remain a critical task for government—in collaboration with the private sector—as no modern society can function without them. Infrastructure projects, providing access to critical services, call for action from government as the one social actor capable of mobilizing and coordinating large amounts of economic resources to achieve significant social goals. Infrastructure investments in the digital space will continue to occupy governments as they seek to ensure citizens have access to affordable Internet access, and the new pipelines of terabit connections are created to enable scientists and others to share information and ideas in new ways. These investments may give rise to new networks, spanning the globe, and allowing individuals to be accessible at all times and in any format. They will place corresponding demands on governments to ensure access to this infrastructure is not denied by geographic location or socioeconomic status.

## The role of basic research

As Chapter 6 showed, governments and businesses spend considerable amounts of money on basic research. This investment is based on the idea that it provides knowledge that may conceivably be useful in the future. Basic research is experimental or theoretical work that is not directed towards any particular application or use at the time it is undertaken. Although the share of basic research funded by industry has increased, the majority is still paid for by public money. In the late 1990s and early 2000s, government expenditure on research increased significantly, especially in the USA, South Korea, and the UK. Governments look to their research systems to solve social and economic problems, and especially environmental challenges, such as global warming.

Despite large government and corporate funding, the research system remains a relatively autonomous sphere in society, in which the institutions of science continue to dominate, including peer review, peer recognition, and the establishment of priority through publication. Polanyi (1962) defended this independence, arguing that intellectual production must be divorced from the sphere of production. New ideas are developed through the insight, experience, and experimentation of individuals and teams working within the institutions of science—what Polanyi called the ‘Republic of Science’. For Polanyi, science needs to stand apart from society. ‘The soil of academic science must be extraterritorial in order to secure its control by scientific opinion’ (Polanyi 1962: 67). Along the same lines, Dasgupta and David (1994) argue that the fundamental difference

between scientists working in the sphere of basic research and industrial scientists is the incentive system in which they operate. Scientists working in the public sphere are motivated by establishing priority for their work and status among their peers. Priority is established through publication and therefore science remains a relatively open system. In contrast, scientists working in private organizations seek to capture value from their knowledge creating activities.

Although the institutions of science have been remarkably durable, and government investments in research have increased over time, the traditional contract between scientists and the general public has come under increasing strain. The public has become more aware of scientists' self-interested behaviour in seeking funds, status, and glory through less than honourable means. The experiences of South Korean scientist Hwang Woo-suk, with his fraudulent reports on cloning research, are telling about the pressures to pursue prestige in science. In popular science fiction novels and films the bad guys are often scientists, whose greedy behaviour leads to evil acts.

Despite the ideal of the republic of science, the science system is open to penetration and influence from non-scientists. Some, with noble personal agendas, are able to win funding for research and shape research agencies by bringing attention to neglected areas of research, such as the spinal cord research effort led by Christopher Reeve, an actor famous for his role in, and as, *Superman* in the 1980s and 1990s. Moreover, the thirty years since the mid-1970s has seen rise in the range of civic associations dedicated to the treatment of particular diseases, in the funding they have acquired, and the testing and treatment procedures that have developed. The most successful group in this area are the AIDS activists in the USA who were able to change the way potentially life-saving drugs were tested and released to patients (although some argue that the forcefulness of this lobby redirected funds away from equally worthy causes). Others—such as Craig Ventner and his efforts to map the human genome—use the science system for private ends. We can expect to see many more of these interventions in the science system, from individuals with a wide range of motivations, as the knowledge and skills of the science system engage with the problems or agendas of the rest of society.

The science system itself is becoming increasingly international and open. The co-authoring of scientific papers has been increasing over time as has the number of scientific journals that are published (from 700 to 165,000 in the twentieth century (Mabe and Amin 2001)) and these are likely to continue to expand with increasing numbers of e-journals. The share of internationally co-authored papers has increased from 6 per cent in the early 1980s to over 36 per cent in 2003 (NSB 2006). To make discoveries, scientists need to combine ideas from many different disciplines and researchers around the world. The British-led team of scientists that developed the first heart valves made from stem cells in 2007, for example, drew upon the skills and ideas of physicists, biologists, engineers, pharmacologists, cellular scientists, and clinicians from several different countries.

Major discoveries commonly require new combinations of knowledge, instruments, and ideas from diverse disciplines. In the future, scientific teams will become increasingly heterogeneous, including people from a range of backgrounds from inside and outside the natural, life, and physical sciences. These new teams will work across disciplines, each bringing a particular set of skills to bear on a large and complex problem.

Some research projects require large-scale efforts and can only be accomplished by big teams. The recording of the DNA code of the human genome was one such project, involving scientists from around the world. It was a project rife with dispute and conflict, including competition from the public and private sectors. These 'big science' projects command great public attention and combine the resources of many different research systems. However, 'small-scale science' can also be very productive and there is no reason to assume that the future belongs to 'big science'. The challenge for the research system is to create opportunities for researchers from around the world to work together on problems, but to avoid the high costs of management associated with large and complex teams. Institutions, such as CERN, provide examples of where national research capabilities and investments are pooled, and where individual scientists or teams of scientists work independently of one another.

Working with universities can provide significant advantages for industrial firms and there is considerable evidence that such links are becoming increasingly common. Gaining access to these scientific networks requires firms to invest time and resources, including funding of doctoral students, provision of consultancy, funding for professorial chairs, buildings, and student projects, building up goodwill among researchers working in areas adjacent to or related to the firm's own research activities. As firms increasingly make these investments the problems for universities in managing the balance between 'free' and 'directed' research will increase.

Science can be a highly conservative activity in which past experience determines future funding. Thus, it is necessary to ensure that the science system is open to adventurous research that steps outside the bounds of conventional disciplines or methods. Creating opportunities for such research activities to be conducted is a major challenge for research funders. There is a need to ensure that the research system is balanced between rigour, which implies a high degree of conservatism, and adventure, which tends to exploit methods far removed from convention and the current peer review standards.

Advances in research create unanticipated new challenges for society. The use of stem cells, reproductive technologies, and therapeutic cloning raises difficult ethical issues. Public attitudes towards these procedures often change as new circumstances present themselves. In the UK, it was forbidden for a woman to use sperm from her deceased husband for fertilization procedures. The case of a husband who was killed in horrible circumstances, however, shifted public opinion and the procedure was thereafter allowed. In the future, we can expect many more similar situations as scientific advances

produce previously unimagined ethical dilemmas. In such cases, the science and the decisions related to the science are too important to be left to scientists and politicians. Public debate and discussion involving many groups—ethicists, artists, social scientists, and political activists—will be necessary to craft workable and acceptable solutions to these dilemmas. We can expect these debates to become noisier and more contested in the future. The balance between what is knowable and may be useful, and what is publicly acceptable will become increasingly unclear. Many governments around the world are trying to create DNA databases, for example, to allow them to identify criminals. These databases are likely to be a highly valuable tool to fight crime, but they may impose an unacceptable level of government intrusion into personal privacy. Where should society draw the line between the desire to preserve individual freedom and ensure collective security? The price of the social contract of the future, where broad engagement in scientific research is essential, is increased investment in the scientific and technological education of all citizens.

Research in all its forms is becoming central to government strategies for economic development. Governments are increasingly measuring their universities' contributions to economic development by the number of spin-off companies, levels of industrial research funding, and formal IP activities. This focus on commercial activities has led to shifts in the nature of incentives in universities, leading some academics to increase their focus on transferring their work into practice. Public funding for research increasingly comes with responsibilities for knowledge transfer as a condition of funding. The mantra for academics has changed from 'publish or perish' to 'apply or die'. This emphasis on the relevance and usefulness of research has also led to universities becoming commercial actors in their own right, seeking to maximize returns to 'their' IP. The trend towards commercializing research will likely continue, with universities more pecuniary in their outlook. The implications of this commercial focus for research system are disputed. As Chapter 9 showed, some see the negative effects of an overemphasis on commercial activities drawing academics away from curiosity-driven research, publication, and teaching. For others, this movement is ensuring an alignment between research and society, guaranteeing that research is used in practice. It is to be hoped that at least some institutions will revert to the purely intellectually driven agendas of the past, pursuing knowledge for its own sake, and enjoying the unexpected and serendipitous discoveries that result.

## **Sustainable business**

Innovation has been defined by a corporate system that created value and wealth from knowledge to maximize returns. Schumpeter's description of innovation as 'creative

destruction' was borne out in the rise and fall of firms and the demise of industrial sectors as new technologies destroyed old. This generated economic development, creating new types of organizations and opportunities to expand international markets. It disrupted old forms of social cohesion and often resulted in local conflicts and upheaval as firms and industries passed out of existence.

In the past, economic growth and social well-being were based on the production of goods and services that were energy, material, and resource intensive. There was a belief in the unlimited expansion of global markets and a certainty that if business focused on its own best interests it would also serve a useful social purpose. This view was encapsulated by the economist Milton Friedman, who in 1970 declared that the responsibilities of firms were to: 'conduct business in accordance with their desires, which generally will be to make as much money as possible while conforming to the basic rules of society'.

Vannevar Bush's 'endless frontier of science' in the 1940s and Harold Wilson's 'white heat of technological revolution' in the 1960s reflected technology and supply-side approaches to government policy. Governments made major attempts to stoke the furnace of technological innovation to stimulate economic growth. As long as new technologies were continuously being developed and applied they were generally thought to be beneficial rather than harmful.

Climate change has been a rude awakening for many in business and government. Scientists have long been concerned about the consequences of unfettered exploitation of natural resources to fuel energy and resource-intensive economic growth. In the 1860s, the physicist John Tyndall was the first scientist to hypothesize about the earth's natural 'greenhouse effect' and that carbon dioxide concentration in the atmosphere could cause climate changes. In May 2006, former US vice-president Al Gore released his documentary film, *An Inconvenient Truth*. This presents scientific evidence to mass audiences, showing that global warming is the result of the energy-intensive form of industrial development that was the driver of economic growth for nearly two centuries. Carbon dioxide and other gases produced by burning fuels such as coal, gas, and oil, trap energy from the sun, warming the earth's surface. Evidence shows that glaciers are melting, plants and animals are being forced away from their natural habitats, or dying out completely, sea levels are rising, and there is a greater incidence of extreme weather events, such as hurricanes and droughts. Gore is part of the social movement that argues that climate change caused by industrial pollution is irreparably damaging the resources that we all depend upon for our future survival.

Some earlier technological and economic certainties are appearing increasingly fragile. Societies and the businesses that generate economic prosperity are searching for new 'sustainable' patterns of development. They face the challenge of overcoming the relentless creation and destruction of products, processes, and services irrespectively of the environmental cost. The restless world of Schumpeterian technological change



has been confronted by new requirements, described by Gro Brundtland, former Prime Minister of Norway, as ‘the ability to meet present needs without compromising those of future generations’.

Business is increasingly responding to the challenge of sustainability. In October 2006, the former World Bank chief economist, Sir Nicholas Stern, presented a Review of the economics of global warming (Stern 2006). It added to the growing number of calls for business and society to change the way in which goods and services are produced and consumed to reduce negative environmental, social, and economic impact. The Kyoto Protocol, statements from the IPCC (Intergovernmental Panel on Climate Change), and the World Economic Forum point in the same direction. These reports and policy recommendations are underpinning a transformation in business attitudes to what were previously thought to be ‘externalities’—costs and benefits external to their direct sphere of interests and control. Historically, the biggest incentive to change technologies to accommodate environmental concerns was driven by the need to mitigate risk and avoid damage to corporate reputation. The pressure driving environmental innovation was to minimize negative impacts on business success.

A succession of highly visible and publicly embarrassing corporate events changed the ways in which firms view their relationship with the external environment. Shell for example, suffered reputational damage in 1996 over the way it attempted to decommission the Brent Spa oil rig, by sinking it in deep water. This action could have resulted in serious pollution, a potential consequence that triggered widespread public protest. This, and similar incidents, such as the environmental catastrophe caused by the Exxon *Valdez* in Alaska, has increased the recognition that economic prosperity is intimately entwined with environmental and social sustainability. Issues that were previously assumed to be independent and outside of many businesses’ concerns have become central to their future survival. For example, energy shortages, income disparities, environmental degradation, and extreme weather patterns are disrupting business and causing social unrest and increased migration, threatening stability and expectations of future economic growth and profitability.

Developing new technologies that enable communities to prosper in a healthy and sustainable way, without depleting the natural environment, has become a prime driver of technological innovation. Issues that were previously treated as independent are now seen to be interdependent. Technologies are needed that support social and economic activity and growth without relying on the fossil energy- and resource-intensive systems of the past. The future requirement of MTI is to ‘touch the earth lightly’ replacing what is taken away. New technologies and processes are needed that reduce the environmental impact of the ways in which products and services are consumed. Innovation is necessary to create products that are resilient to climate change, particularly in industries and markets vulnerable to changing patterns of weather, or rising sea levels. Innovation is required in production processes for reducing, reusing, and recycling materials. Business



models need to change together with the ways in which people behave towards one another, and towards the natural environment.

Concerns over the degradation of the natural environment are not the only driver of innovation for creating a more sustainable economic system. Relationships between business, society, and governments have become more sophisticated in recent decades. As we showed earlier, many firms now need to understand and work with a far wider range of stakeholders than in the past. Many of these stakeholders will want to take an active interest in what business does and how it does it. Consumers want to know how and where products and services are produced. This has resulted in innovative responses. Marks and Spencer, for example, launched a 'look behind the label' campaign to inform customers of their ethical sourcing credentials. Individual citizens, employees, the media, government and non-governmental agencies, and pressure groups all have a role to play in questioning in whose interests business is working. The growth of the Internet has meant that many of these stakeholders can find information about how business works, and communicate their views about what it does. The corporation is under scrutiny in a way not experienced before. There are few hiding places for those not prepared to face the challenges and responsibilities of accounting for their actions.

How should business respond to these new innovation drivers? Some see them as threats to current practice, and respond by defending the ways in which they deploy and utilize resources and capabilities in a traditional manner. Others see a new business agenda focusing on sustainability as a major opportunity triggering new product, process, and service development and through which they can gain competitive advantage. They argue that sustainable business is good for business, creating charters for Corporate Social Responsibility (CSR), embracing environmental, social, ethical, and governance issues. These innovation drivers are created as much as a result of new incentives to make profit and foster emerging markets, as by an eagerness to obtain damage limitation and avoid penalties related to non-compliance with stringent regulation. Companies that innovate to improve their social and environmental performance, reducing their carbon footprint, stand to reap great benefits: they see the opportunities of 'doing well by doing good'. They look forward to enjoying a better reputation, creating an attractive workplace, which reinforces the prospects of recruiting and retaining talented employees who are increasingly demanding to work for environmentally responsible and active employers.

What does this mean in practice? At minimum, firms have to establish a new performance baseline from which they can demonstrate compliance with a wide range of standards and regulations across their areas of operation, such as health and safety, workforce and supplier diversity, ethics and governance, care for the natural environment, relationships and trust with local communities, and public reporting systems. Beyond this baseline, developing sustainable businesses can be a creative stimulus for the development of new technologies and processes which foster market diversity. Some

businesses have been operating in this new paradigm for several decades. Companies such as 3M, DuPont, and GE, for example, have made demonstrable improvements in business performance by focusing on sustainability.

The sustainability agenda has given rise to a new set of concepts that help to frame the space for innovation. Terms such as 'ecosystem', 'social and biological diversity', and 'sustainable communities' are appearing in the product and services marketing literature. For some firms, 'less is more' and small may now be beautiful and profitable. New concepts give rise to new methods and practices, such as life-cycle analysis, the use of real options rather than discounted cash flow in investment decisions, allowing different trade-offs to be made. These in turn give birth to new ways of measuring performance. Metrics for understanding 'carbon-footprints', 'food miles', 'Fairtrade' and sustainability indices, embodied energy measurement, and measures of life quality are becoming as important as traditional quantitative output measures. Some companies such as GE have set new targets to motivate their business divisions to capitalize on the opportunities presented by sustainable business: GE plans to double its revenue from products that provide measured environmental benefits between 2005 and 2010.

New models for delivering a more sustainable approach to business are emerging. The ability to manage systems integration to provide sustainable solutions has become a central feature of most approaches. Technological innovation focuses on targets such as biodegradable, energy saving, or reusable materials, and new processes such as carbon sequestration. Provision of power using renewable energy sources and development of clean technology is opening new markets. Health care, genetics, stem cell research, and regenerative medicine are challenging more orthodox approaches to therapeutics. Markets that were hitherto unknown are beginning to grow. The creation of a market for carbon, enabling businesses to trade carbon in an effort to reduce pollution, is indicative of the continual search for market solutions to environmental challenges. Whilst many governments and firms are attempting to develop sustainable approaches, others remain to be convinced or are wilfully ignoring the evidence. There is a need for continuing efforts to tackle this problem. But the sustainability agenda cannot be left to institutions and market forces; it has to become part of a personal journey in which individuals make choices and employ trade-offs. Managers of technological innovation, as the designers of a sustainable technological future, have a central role to play in this corporate and personal passage.

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