RON BASU

GOWER

Managing Projects in Research and Development

Managing Projects in Research and Development

Ron Basu never disappoints. His books show how to make things happen. In this book he draws on his many years as a project manager and on his teaching experience as an MBA lecturer to provide an easy to read strategy for taking a R&D project from inception through to fruition. His how to do it approach is supported by well researched case studies. Highly recommended.

Nevan Wright JP, Auckland Institute of Studies, New Zealand

Dr Ron Basu has delivered a highly recommended and much-needed treatise on R&D initiatives. This excellent resource is both authoritative and comprehensive offering a tried and tested approach for delivering successful R&D projects.

Darren Dalcher, Director, National Centre for Project Management, UK

For those needing a thorough introduction to R&D Project Management, Ron Basu provides a wealth of materials for those seeking to understand how project management is being successfully applied in R&D in larger, traditional businesses.

Michael Cross, Chair and Co-founder, Rezatec Limited, UK

The economic advantage of developed countries is closely tied with their ability to add value through innovation. R&D is the engine of innovation and inevitably R&D is project based. In this book Dr Basu offers a tour de force of R&D projects. The book addresses the key issues such as managing risks, managing R&D portfolios, and success criteria clearly and concisely. The case studies help to bring to life key concepts. This is an excellent book addressing a key managerial issue and I highly recommend it.

Abby Ghobadian, co-editor of *Journal of Strategy and Management* and
Past President of British Academy of Management (BAM)

Few books are able to grasp the critical elements of the complex R&D process, especially in the corporate context, and it is very pleasing to see Ron Basu's book tackling this subject with rigour and precision. The chapters are well organised and they cover the essential practicalities of the project management and the R&D process, enabling an understanding of the latter to be firmly embedded in the realities of project management. This book addresses key issues directly, illustrating the arguments with some interesting examples of corporate activity in this sphere. The book will be very useful for project managers and senior executives designing meaningful strategies for corporate projects, as well as government agencies looking at new ways to facilitate local and global projects. I also see this book as being particularly valuable for graduate students of management in general and project management in particular.

Jay Mitra, University of Essex, UK

Project Management in R&D is an area that is not well written about, needing tools different from traditional project management. Ron Basu's approach is easy to follow, and provides an excellent approach. The book is welcome.

Rodney Turner, Professor of Project Management,
SKEMA Business School, France, and
Editor-in-Chief, *International Journal of Project Management*

Without the tools and skills of project management there is no way to lead and finish complex projects starting from the construction of buildings, building infrastructure and production plant or introduction of products to the market. … In a situation when R&D has a role to bring products to the market, or in a situation when basic research needs to be led through limited time and resources, the skills and methodology of project management and risk assessment play a significant role. If one needs to lead complex activities from any aspect of R&D, this book by Ron Basu needs to be treated the same way as any scientific paper from a field of particular research.

Ernest Mestrovic, Senior Director, TEVA TAPI R&D

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Director, Performance Excellence Limited and
Visiting Fellow, Henley Business School

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To the memory of Sonada and Kuida

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Every effort has been made to credit the authors, publishers and websites of material used in this book. I apologise if inadvertently any sources remain unacknowledged and if known I shall be pleased to credit them in the next edition.

My sincere thanks go to the staff of my publishers, especially to Liz Barlow (now at Palgrave McMillan) and Jonathan Norman (Gower Publishing) for getting this project off the ground.

Finally, the project could not have been completed without the encouragement and help of my family, especially my wife Moira, sister-in-law Reena, daughter Bonnie and son Robi.

This book is a product of teamwork and that is why I have used the word ‘we’ in the text.

Ron Basu

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About the Author

Ron Basu is Director of Performance Excellence Limited and a Visiting Fellow at Henley Business School, England. He is also a Visiting Professor at SKEMA Business School, France. He specialises in operational excellence and supply chain management, and has research interests in performance management and project management.

Previously he held senior management roles in blue-chip companies like GSK, GlaxoWellcome and Unilever, and led global initiatives and projects in Six Sigma, ERP/MRP II, supply chain re-engineering and Total Productive Maintenance. Prior to this he worked as a management consultant with A.T. Kearney.

He is the co-author of *Total Manufacturing Solutions*, *Quality Beyond Six Sigma*, *Total Operations Solutions* and *Total Supply Chain Management*, and the author of *Measuring e-Business Performance*, *Implementing Quality*, *Implementing Six Sigma and Lean*, *FIT SIGMA*, *Managing Project Supply Chains* and *Managing Quality in Projects*. He has authored a number of papers in the operational excellence and project management fields. He is a regular presenter of papers in global seminars on project management, Six Sigma and manufacturing and supply chain topics.

After graduating in Manufacturing Engineering from UMIST, Manchester, Ron obtained an MSc in Operational Research from Strathclyde University, Glasgow. He has also completed a PhD at Reading University. He is a Fellow of the Institution of Mechanical Engineers, the Institute of Business Consultancy, the Association for Project Management and the Chartered Quality Institute. He has also won an APM Project Management Award.

Ron lives with his wife Moira in Gerrards Cross, England and has two children, Bonnie and Robi.

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About this Book

The extant R&D and project management literature identifies and supports the need for an improved understanding and application of appropriate project management processes, tools and success factors to R&D initiatives. There are many publications in the fields of both R&D and project management, but publications combining these two fields are very limited. This book aims to bridge this gap. The topics in this book cover primarily the application of the rigour and tools of project management in R&D initiatives.

This book is aimed at a broad cross section of readership, including project managers and leaders who aspire to make a difference in R&D and innovations. Also:

- Research scientists, product managers, stakeholders and practitioners in R&D, government departments and universities will find that this book will provide them with a comprehensive insight into the definition and effective application of project management in the success of R&D initiatives.
- Members of the Association for Project Management, Major Projects Association, Institute of Mechanical Engineers and Institute of Civil Engineers will find in this book a total approach to managing projects in R&D. These professional bodies will be encouraged to convene more conferences and seminars on this (viz. managing projects in R&D) topic which could be underpinned by this book.
- Senior executives in both government and infrastructure projects will find that this book will give them a better understanding of basic concepts of project management and help them to support an R&D initiative and sustain a strong competitive position.
- Professional management and training consultants will find the comprehensive approach of project management in R&D an essential handbook for R&D-related assignments and seminars.
- Management schools, academies and research associations will find this book valuable to fill the visible gap in the basics of project management and R&D.

The readership will be global and particularly cover the UK, North America, continental Europe, Australia and Asia Pacific countries. The book is intended for both niche and volume markets.

Application

The book allows for maximum flexibility for readers and users to apply it depending on their requirements and interests. The application areas of the book are described below.

IMPLEMENTING R&D INITIATIVES

Organisations, whether services or manufacturing, private or public sector, large, medium or small, should particularly benefit from the methodology of implementation in Chapter 11. Programme members and task groups should acquire a copy of the book and gain a common understanding of the tools and techniques described.

UNIVERSITY AND COLLEGE COURSES

The book can be as a text book or a reference book for advanced programmes in managing projects in R&D in universities and business schools. The case studies with questions in Chapter 10 should help students to practise and assess their level of understanding achieved from the relevant chapters. Tutors will have the opportunity of applying these case studies as part of their lecture materials and course contents. A recommended course structure is included as an appendix.

ENHANCING KNOWLEDGE

The book contains both the strategic approach to managing R&D projects and detailed coverage of the tools and techniques which underpin the programme. The reader, whether a CEO, employee or student, should find the book helpful in enhancing their knowledge and understanding of the challenge of R&D projects.

The evidential data presented in this book offers a strong argument for R&D investment. It suggests that there is a need for continual investment in R&D to create sustainable employment,a firm knowledge base and growth in the national economy. Furthermore, the rigour and tools of project management in R&D allow longer term benefits. They ensure successfully delivering new products, innovative concepts and intellectual properties at the start of the value chain.

I hope you find this book as stimulating and exciting as I have found writing it, and really useful in your journey of exploring R&D projects.

Ron Basu
Gerrards Cross, England

Preface

Background

I hear from entrepreneurs that most innovations, inventions and businesses were started serendipitously. This may be so, but serendipity requires a keen and sharp mind to recognise it when it presents itself. Winston Churchill once observed, 'Men occasionally stumble over the truth, but most of them pick themselves up and hurry on as if nothing had happened'. Therefore we need a structured process to make it happen. Louis Pasteur encapsulated this observation when he said 'chance favours only the prepared mind'. The rigour of project management tools and processes is meant to help the 'prepared mind' and provide a structured process to make it happen. Such a belief in the role of project management on the success of R&D initiatives was growing on me when I worked, in manufacturing and supply, alongside R&D leaders both in Unilever and GlaxoWellcome/GSK.

Since my research on my first book, *Total Manufacturing Solution*s, I have been exalting the theme that a strong manufacturing-based economy – rather than a fragile service-based economy – can ensure economic growth, and the sustainability of that growth can only be guaranteed by a continuous supply of innovative products. Those innovative products come from successful R&D initiatives. When the success of R&D is helped by project management, why not write a book to contribute to this quest for success?

There is another reason for me to think about this book. It appears that I have been writing books in the form of trilogies. My first three books were operations management and supply change management (viz. *Total Manufacturing Solutions*, *Total Operations Solutions* and *Total Supply Chain Management*). Then I wrote three books on quality and Six Sigma/FIT SIGMA (viz. *Quality Beyond Six Sigma*, *Implementing Six Sigma and Lean* and *FIT SIGMA*). Having recently completed two books on project management (viz. *Managing Project Supply Chains* and *Managing Quality in Projects*) I thought that another book on project management should complete a trilogy. It could be related to R&D, I thought. Sounds corny, but it is an honest statement.

Then I was contacted by Liz Barlow of Kogan Page (now at Palgrave Macmillan) to see if I would be interested in writing a book on a project management topic. It seemed serendipitous, but I had a 'prepared mind'. The project started well but when it was showing signs of waning it was rescued by Jonathan Norman of Gower Publishing.

In the experience of the author in industry, major projects and management courses, the details of the various tools and techniques of project management relevant to R&D initiatives had to be acquired from different books, publications and training manuals. It is time now to produce a comprehensive, user-friendly and hands-on book which could be a single-source reference for project management tools and processes appropriate for R&D for all researchers, practitioners and students of R&D projects.

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Why Project Management is Essential in Research and Development

Introduction

Before I address why project management is essential for research and development we need to establish the significance of some key terms (viz. 'project management' and 'research and development') in the context of this book and also why research and development is so important for the sustainable growth of both businesses and the national economies contributing to human well-being. In recent years both project management and in particular research and development have witnessed major changes in the way organisations manage their technological resources. Project management is known to offer formal planning processes and the use of these formal processes in research and development may be viewed as an impediment to creativity and innovation. Hence it should be helpful to explain these key terms before analysing their roles and interdependence.

Project Management and Research and Development

The PMI (Project Management Institute 2008) has defined a project as 'a temporary endeavour undertaken to create a unique product or service'. This concept of a project being a temporary and one-time undertaking is perceived as different from operations which comprise permanent or semi-permanent ongoing functional activities. The management of these two disciplines is often very different and requires varying technical skills and philosophies, hence the need for the development of the discipline of project management.

Project management is the discipline of organising and managing resources in such a way that these resources deliver all the work required to complete a project within defined scope, time and cost constraints. Meredith and Mantel (2003, p. 1) describe project management as a social science and comment, 'Project Management has emerged because the characteristics of our contemporary society demand the development of new methods of management.' *The Body of Knowledge* from the Association for Project Management (APM 2006) also defines project management as 'the most efficient way of introducing unique change'. Bodies of knowledge have been compiled by professional organisations such as the APM and the PMI.

The term 'research and development' (also R&D) refers to a specific group of activities within an organisation, whether it is a profit-driven business or a national government initiative. The activities that are classified as R&D differ from organisation to organisation, but there are two primary models. In one model, usually adopted by a profit-driven business, the primary function of an R&D group is to develop new products. In the other model, the primary function is to discover and create new knowledge about scientific and technological topics for the purpose of both the advancement of knowledge and enabling development of valuable new products, processes and services. The first model of R&D is often staffed by product designers or engineers while the second model may be resourced by industrial scientists. R&D activities are carried out by corporate (businesses) or governmental entities. R&D may carry different meanings or objectives for different groups. To academics the term 'research' may mean the systematic approach to the search for and discovery of new knowledge. However, in industry the term 'research' may mean both new knowledge and the application of old science to develop new products, Although the border of research and development is not always clear-cut it is more rational to view industrial R&D as a combination of knowledge at one end and physical products and marketable concepts or services at the other end.

Another term often used in the context of R&D is 'innovation'. Innovation is the application of new solutions that meet new requirements, previously unarticulated needs or existing market needs. This is accomplished through more effective products, processes, concepts or services that are readily available to markets. One usually associates it with new phenomena that are important in some way. Innovation differs from invention in that innovation refers to the use of a better and/or novel idea or method, whereas invention refers more directly to the creation of the idea or method itself. Sometimes an improvement is described as innovation when this is not appropriate, because innovation refers to the notion of doing something different rather than doing the same thing better through an improvement.

History of Research and Development

The first organised attempt to harness scientific skill to communal needs took place in the 1790s, when the young revolutionary government in France was defending itself against most of the rest of Europe. The concept of research is as old as science, while the concept of the close relationship between research and development was not recognised until the 20th century.

Thomas Edison once remarked, 'I find out what the world needs, then I proceed to invent it.' Arguably the first case of industrial research started when Edison set up the Edison Electric Laboratory at Menlo Park, New Jersey in 1875 with a staff of about 20 people. In the same decade Germany started the physical standards laboratory which provided scientific cooperation between Krupp, Siemens, Zeiss and other companies. The US National Bureau of Standards was established in 1901 and during the early part of the 20th century large US companies including General Electric, Du Pont, Westinghouse, Eastman Kodak and Standard Oil set up research laboratories for the first time.

In the United Kingdom, the National Physical Laboratory was founded in Teddington, England, in 1900 to develop and maintain physical measurement standards. Many British firms were actively engaged in research well before the First World War. During the Second World War R&D expenditure in industry increased much faster with the employment of qualified research staff. During the 1940s the major part of R&D expenditure was supported by development contracts from the state. In the private sector, according to Edgerton and Horrocks (1994), the top five UK companies in the R&D league table were ICI, Rolls-Royce, De Havilland, Napier and AV Roe. GEC (General Electric Company) was largely turned over to government-funded wartime production.

Following the Second World War, in spite of the devastation in Europe and Japan, the achievements of the scientists who produced radar, the atomic bomb, the V-2 rocket and penicillin created an awareness of the potential value of R&D that ensured a major place in post-war research plans. The US initiatives stressed further research on aircraft, defence and space. President Eisenhower established the National Aeronautics and Space Administration (NASA) in 1958 with a distinctly civilian orientation encouraging peaceful applications in space science. In his address to the US Congress in 1961, President Kennedy spoke of 'putting a man on the moon before the decade is over'; many believed anything was possible through research and technological achievement. Although few figures are available for the USSR, the high quality of Soviet research on space exploration was evident when Sputnik 1 was launched in 1957.

At the turn of the 21st century the industrial landscape and economic power of emerging markets are rapidly changing. These changes are also reflected in the R&D initiatives and expenditure by business enterprises. The R&D dominance of aircraft and automobile companies (e.g. Toyota, VW, GM, Honda, Daimler, Boeing and EADS) has now shifted to pharmaceutical companies (e.g. Roche, Pfizer, GSK, Novartis, Sanofi-Aventis, Johnson & Johnson and Merck) and information and communication technology (ICT) companies (e.g. Microsoft, Nokia, Samsung, Siemens, Intel, IBM, Panasonic and Apple).

In recent times, during the last two decades in particular, there have been step changes in the management of research and development. There are many factors contributing to these major transformations, including:

- Shorter R&D cycle: The R&D cycle involves the stages of scientific, technological and design developments prior to the traditional product life cycle (e.g. Launch, Growth, Maturity and Decline). For example, the R&D cycle of a new chemical entity (or a molecule) in the pharmaceutical industry has been reduced from 15 years in the 1970s to about 6 years in 2010 (Barnhart 2013).
- Technology revolution: There are two aspects to the recent technology revolution – knowledge explosion and ICT revolution. Rothwell and Zegveld (1985) estimate that 90% of our technical knowledge has been gained since the 1930s. The advancement of ICT, including data sharing, data mining and the power of the Internet, has transformed the speed and nature of R&D processes.
- Globalisation: The emerging markets, especially the Pacific Rim countries, have offered both the ability and capacity to transform research outputs into marketable new products. This has resulted in the growth of outsourcing R&D, strategic alliances and 'open innovation'.
- Project and programme management: The enhancement of project and programme management tools and processes and their selective application in new product development has accelerated the translation of ideas into new product development (Barkley 2007). It is a good beginning but it has a long way to go, especially in the area of research and development.

Types of Research and Development

Research and development activities can be classified based on the facilities (or laboratories) and resources deployed and also based on the objectives or outcomes of research and development.

There are four main types of research laboratory:

- government
- university
- industry
- independent

GOVERNMENT LABORATORIES

The pattern of government laboratories followed by different countries varies widely. The US government usually encourages research and development contracts based on competitive bidding to private companies. The US government also supports departmental laboratories including the National Bureau of Standards, the Atomic Energy Commission and NASA. The detailed research and development work is contracted to a private company whereas the overall control, especially related to national security, is directly handled by central departments. The UK government supports a chain of government laboratories (e.g. the Royal Radar Establishment, the Atomic Energy Research Establishment) meeting the requirements of the armed forces to deliver new weapons and military techniques. In addition to these military laboratories the UK government also supports a number of civilian laboratories including the National Physical Laboratory and the Royal Research Laboratory. Germany, Japan, France and other developed countries support similar laboratories in both defence research and civilian research. In spite of differences in organisation, the general conduct of government funded research and development in all countries has much in common in dispensing contracts and keeping in contact with the technical community. In some countries it is done under direct government control and in others through private agencies.

It is not surprising that there is a long list of famous cases illustrating both successes and failures of government sponsored research and development projects. Case Example 1.1 is a story of one such project. The objectives of the International Space Station are not commercial. The strategic objectives of scientific advancement and space exploration are only feasible in government laboratories.

CASE EXAMPLE 1.1: NASA INTERNATIONAL SPACE STATION (1993–PRESENT)

The International Space Station (ISS) project is a good example of a multi-government global project of fundamental space research.

The International Space Station (ISS) started in 1993 as a multi-government project comprising NASA's Space Station Freedom project, the Russian Mir-2 station, the European Columbus station and the Japanese Kilbo laboratory module. In the 1980s NASA originally planned to develop Space Station Freedom alone, but US budget constraints led to the merger of these projects into a single multinational programme in 1993. NASA is retained as the controlling project manager.

There are naturally many major components of the station. These include pressurised modules, external trusses, solar arrays and other components. Many of these components have been launched by Russian rockets, and the US Space Shuttles. It is currently being assembled in low Earth orbit. The on-orbit assembly began in space in 1998 and completion is expected by 2016. The ownership and use of the space station is established in intergovernmental treaties and agreements which divide the station into two areas. One area allows Russia to retain full ownership of the Russian Orbital Segment. The other area of the US Orbital Segment is allocated between the other international partners.

Long duration missions to the ISS are referred to as ISS Expeditions. Expedition crew members typically spend approximately six months on the ISS. The initial expedition crew size was three but it temporarily decreased to two following the Columbia disaster. Since May 2009, expedition crew size has been increased to six crew members. Once the Commercial Crew Program becomes operational the crew size is expected to be increased further to seven. The ISS has been continually occupied in space for nearly the past 15 years, having exceeded the previous record held by Mir-1. It has been visited by astronauts and cosmonauts from 15 different nations. The station can be seen from the Earth with the naked eye, and is still the largest artificial satellite in Earth orbit with a mass and volume greater than that of any previous space station. The spacecraft delivers crew members, stays docked for long missions for six months and then returns them home. In addition, since 2009 several uncrewed cargo spacecraft services have been accomplished. The Space Shuttle, before its retirement, was also used for cargo transfer and would often switch out expedition crew members, although it did not have the capability to remain docked for the duration of their stay. Until another US manned spacecraft is ready, crew members will travel to and from the ISS exclusively aboard the Russian-built space craft Soyuz.

Although on-orbit assembly is scheduled to be complete in 2016, the ISS program is expected to continue until at least 2020 but may be extended until 2028 or possibly beyond that.

Source: www.wikipedia.org.

UNIVERSITY LABORATORIES

University laboratories or research centres are independent, in principle, and free to investigate basic and applied research. However, in practice, universities also aim to collaborate with industry to obtain funding and focus on specific industrial and business problems. There is a dilemma between managing scientific freedom of research and keeping abreast of the industry and consumer market where the outcomes of research could be applied while also generating funding for research. A popular university R&D model is the sponsorship of research by industry, where funding is focused on practical problems and university staff also enjoy the opportunity of acting as consultants for industry. The major part of funding for university laboratories comes from government grants and students' tuition fees.

Research reports from university laboratories are published on their merit in a large number of peer-reviewed journals and proceedings of academic conferences. There is no problem with the quantity of reports although their quality, in spite of reviews by competent referees, is not always conducive to the contribution to knowledge. Case Example 1.2 is a good illustration of basic research carried out in a university on an important debate regarding climate change.

CASE EXAMPLE 1.2: PREDICTING CLIMATE CHANGE AT UK UNIVERSITIES

Predicting the likely effect of climate change is a good example of basic research carried out in UK universities.

In spite of doubts and debates about causes and effects of climate change, predicting the effect of climate change on our environment and ecosystems is becoming ever more important. It is anticipated by numerous research studies that a small rise in the average global temperature may lead to melting glaciers, a subsequent rise in sea level, and consequently large areas of land becoming uninhabitable. If we cannot find effective ways of predicting and modelling these kinds of changes to our environment, we face an even more uncertain future. Therefore more research is vital in helping us map out how our world might look in 20, 50, even 100 years time.

Sometimes we have to look back in history to see the future. For example, at the University of Birmingham, UK, researchers have made use of available commercial three-dimensional seismic datasets to map out the unique historic coastal landscapes of the North Sea. Following the last Ice Age, rising sea levels resulted in vast swathes of inhabited prehistoric land becoming the North Sea. A team of archaeologists and geomorphologists has now mapped nearly 55,000 square kilometres of this lost world. This has allowed unprecedented access to landscapes which could provide vital clues to how climate change might affect us. This project is a timely reminder that modern humankind has endured catastrophic change in the past and that this resulted in the permanent loss of immense areas of habitable land.

Back in the present, researchers at the University of Reading are working with the Australian government to improve predictions of the impact of climate change in Queensland. Much of Queensland experiences considerable fluctuations in its rainfall. Recent climate models have predicted that by 2050 Queensland could be somewhere between 30% wetter and 30% drier than today. This uncertainty makes it very difficult for governments and industries to take measures to adapt to climate change. By combining historical rainfall data with the latest, high-resolution models of the Earth's climate, far more accurate predictions can be made, providing essential information for planning suitable climate mitigation. The research is ongoing.

Making good use of available data is central to improving environmental modelling techniques. Researchers at Imperial College, London are developing a 'virtual observatory' which aims to integrate the huge range of software and data used in environmental simulation, scenario analysis and decision-making. Much of this data is currently held in unconnected systems in incompatible formats, so the 'virtual observatory' will bring it together in one place. This is expected to facilitate fast communication of data and to create tailored, interactive simulations of the impact of environmental decision-making.

Source: communications@rcuk.ac.uk

INDUSTRY LABORATORIES

Industry laboratories are organised as an integrated R&D laboratory or in three distinct categories: research laboratories, development laboratories and test laboratories. Integrated R&D laboratories are favoured by FMCG (fast-moving consumer goods) companies such as Unilever, Nestlé and Procter & Gamble, whereas distinct laboratories are deployed by companies interested in both fundamental and applied research (e.g. pharmaceutical, ICT). In these research-driven companies the laboratory may be located a considerable distance from other parts of company operations. Bell Telephone Laboratory, where the transistor and coaxial cables were developed, is a good example. The installation of development and test laboratories is usually preferred near a manufacturing plant with easy access to engineering and operational staff. These laboratories may be part of a manufacturing organisation but most companies give them an independent status.

The primary objective of industry laboratories is to carry out applied research to develop new products for the business. There are also examples of basic research leading to new knowledge and discoveries supported by pharmaceutical industry laboratories. Case Example 1.3, the search for a cure for Alzheimer's disease by Pfizer illustrates this point. This is also an example of collaborative research where many research activities are shared, and 'open source' innovation where ideas and services are solicited from contributions from a large group of people.

CASE EXAMPLE 1.3: PFIZER SEEKING NEW TOOLS TO HELP IMPROVE ALZHEIMER'S CARE

Pfizer is one of the world's premier innovative pharmaceutical companies with a turnover of $27.8 billion and R&D expenditure of $3.2 billion (11.5% of turnover) in 2012.

Pfizer introduced the 'Alzheimer's Challenge 2012' at the Care Innovations Summit in Washington, DC. Pfizer also collaborates with Janssen Alzheimer Immunotherapy and the Geoffrey Beene Gives Back Alzheimer's Initiative in the Alzheimer's Immunotherapy Programme (AIP). The Alzheimer's Challenge 2012 calls for inventive concepts to help improve the diagnostic identification and tracking of Alzheimer's disease. As an incentive to this initiative Pfizer will also provide cash prizes for the best submissions.

The Challenge seeks specifically the development of simple, cost-effective, consistent tools that could be easily applied to assess memory, mood, thinking and activity level over time in order to improve the diagnosis and monitoring of people with Alzheimer's disease. Alzheimer's disease is a big challenge today. At the moment it remains an unmet need to find easy to use, reliable, objective and cost-efficient methods to track and monitor the disease. The Alzheimer's Challenge 2012 supports the US Department of Health and Human Services (HHS) call to 'harness new thinking to deliver better care and better health at lower cost'. It also provides an entrepreneurial springboard to harness new thinking and approaches to improve Alzheimer's care. 'Each person diagnosed with Alzheimer's disease experiences its devastating impact differently', said Michael Williams, Vice President, Pfizer Primary Care Business Unit, on behalf of the Alzheimer's Immunotherapy Program. This could be a huge step to advance the global fight against Alzheimer's and other dementias.

The Challenge provides awards totalling $300,000, including $25,000 to five finalists and a $175,000 grand prize to one winner. 'The organizations presenting challenges here today are pushing the best minds in the country to create a better health care system. They represent exciting solutions to help address some of the Nation's most urgent health needs', said CMS Acting Administrator Marilyn Tavenner.

'We believe someone out there has the answer and shares our sense of urgency. The Alzheimer's Challenge 2012 is open to problem-solvers and we encourage anyone and everyone who thinks they have a creative solution to step up, submit an entry, and be recognized', said Meryl Comer, president of

The Geoffrey Beene Foundation Alzheimer's Initiative. Chairman of the Initiative, George Vradenburg, also representing US Against Alzheimer's on the National Alzheimer's Project Act (NAPA), adds, 'We are pleased to partner with the AIP in making this Challenge and are grateful for the continuing leadership of HHS Secretary Sebelius in focusing a broad-based national effort to address Alzheimer's.'

Following the March 16, 2012 submission deadline, five finalists were selected and announced by April 16, 2012. Each finalist was awarded $25,000. Team Ginger.io, of Cambridge, Massachusetts, was announced as the winner of the Alzheimer's Challenge 2012 at the end of June 2012 and awarded the $175,000 prize. Judges were drawn from experts in the Alzheimer's community and other related fields.

Source: www.pfizer.com (accessed 14 August 2013).

INDEPENDENT LABORATORIES

In addition to well-structured laboratories exclusively supported by governments, universities and companies there are other forms of laboratories or research centres such as independent laboratories, research associations and research consortia.

The concept of independent laboratories originated with the Mellon Institute in Pittsburgh, USA, before the First World War. These independent laboratories, more prevalent in the USA, undertake studies within their competence for fees agreed with clients. They are usually regarded as self supporting although some independent research arms of large consulting firms (e.g. Arthur D. Little, PA Consulting and IBM Consulting) also run on strictly commercial lines. Most of their clients are companies that lack adequate research resources of their own in particular areas of interest.

A major part of the industry research and development effort in Western Europe and Japan is provided by industry-based research associations. Examples are the Machine Tool Industry Research Association and the British Glass Manufacturers' Confederation in the UK and the Textile Research Institute in Yokohama. It is estimated that there are about 150 such associations in Europe alone. In the UK costs are shared by government and industry and controlled by a council with representatives from companies within the industry. These research associations are also referred as R&D consortia, particularly in the Far East. In Japan, *keiretsus* (societies of businesses) are supported by 20 to 50 companies serving the total supply chain of the industry. In South Korea, *chaebols* are similar to *keiretsus* and they are financed by multinational conglomerates. The concept of a consortium is also applied in the USA, for example in SEMTECH, a consortium of 14 US semiconductor manufacturers.

The types of research can also be classified by the purpose and outcomes of research initiatives. These classifications comprise three categories:

- basic research: to discover new areas of knowledge and new technologies;
- applied research: to improve the understanding and application of existing knowledge and technologies;
- development: to develop new products, processes and concepts for the market and business growth.

The above classification also leads to the view of R&D as two sides of the same coin – on one side the basic and applied research and on the other side the development of new products and processes.

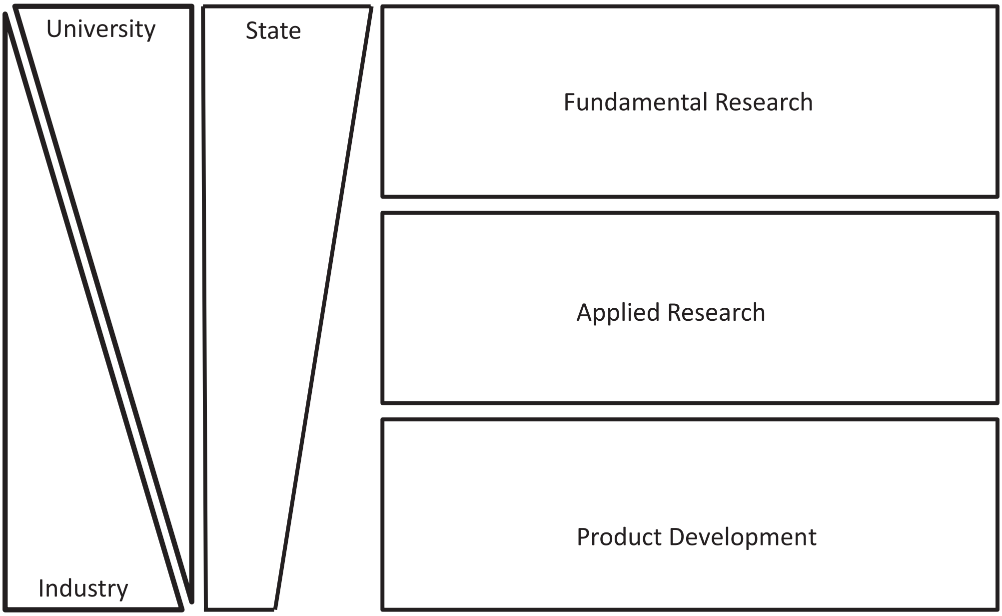

Figure 1.1 Areas of emphasis by different R&D laboratories

In a pure-play model universities and government-funded basic research laboratories are concerned with basic and applied research, while industry R&D centres focus on applied research and development. There are exceptions to this model when government-funded laboratories produce military products and some industry (e.g. pharmaceutical) is also engaged in the basic research of discovering new opportunities. Nationalised industries, controlled centrally by government, are also engaged in new product development. Figure 1.1 shows the primary objectives and areas of emphasis, not the exceptions, in the types of R&D activities as shared by different R&D laboratories.

Challenges of Research and Development

There is no doubt that research and development have significantly improved the quality of life, especially during the last 50 years. The tremendous achievements in transport and communication, healthcare, information technology and the environment result from research and development activities carried out in all types of laboratories and research centres. However, there are many challenges in starting and managing a research and development initiative. Pavitt (1990) observed (about an R&D initiative), 'in many areas it is not clear before the event who is in the innovation race, where the starting and finishing lines are, and what the race is all about'. There are many publications emphasising different aspects of the challenges for specific R&D initiatives. For example, von Zedtwitz et al. (2004) identified 10 challenges for managing innovation. A recent report by UNESCO (2010) aimed to pinpoint and measure R&D challenges specifically for developing countries. The following section briefly addresses some of the generic challenges of R&D, and in the subsequent chapters some of these challenges will be addressed in more detail.

CHALLENGE OF FUNDING R&D EXPENDITURE

A major challenge in initiating a research and development activity, especially if it relates to basic research, is to find the money to start, because it is very difficult to develop a business case. In the case of developing a new product from the current product portfolio it may be relatively easy to prepare a preliminary cost–benefit analysis based on previous experience. The sources of funding are from governments, industries, individual companies, trust funds (e.g. Wellcome Trust) and risk-taking investors such as venture capitalists. President Kennedy pledged the Apollo project at ‘whatever it costs’ but it was a unique situation without the usual economic forces in play. R&D expenditure is also affected by the health of national economies. A recent report by Battelle (2013) states:

> *Plagued by massive debts and weak overall economies, the combined government and industrial R&D organizations of the U.S. and Europe will both fail to even match their projected inflation rates of 1.9% and 1.5%, respectively, in 2013. And while China’s economy is starting to heat up with a projected inflation of 3.6% in 2013, its expected GDP growth of 8.2% and R&D growth of 11.6% will continue to move it toward a leadership role in both areas in the near future.*

There is a slight increase to the 2013 global R&D forecast (Battelle 2012) over the past year, totalling $1.5 trillion, but the share of expenditure by both Americas and Europe fell, as shown in Table 1.1.

Table 1.1 Share of global R&D spending

	2011	**2013**
Americas	34.80%	33.80%
Asia	34.90%	37.10%
Europe	24.60%	23.40%
Rest of world	5.70%	5.70%
TOTAL	100.00%	100.00%

Source: Battelle (2013).

There are some success stories of research and development by trust funds. One such example of outstanding success is The Sanger Institute, Cambridge, UK, funded by Wellcome Trust, as Case Example 1.4 clearly illustrates.

CASE EXAMPLE 1.4: SANGER INSTITUTE CATALOGUES MUTATIONAL SIGNATURES IN 30 CANCER TYPES

In 2004, at the Wellcome Trust Sanger Institute a large international team has published a new study outlining a ‘somatic’ mutational catalogue. This reflects the processes at play in dozens of the most common cancer causes.

The researchers brought together data for more than 7,000 cancer genomes as part of an effort to discover the mutation processes behind them for 30 top cancer types. The research led to at least 20 mutational signatures. These are most likely to be found in distinct combinations in tumours depending on a patient’s age, cancer type, past exposures to DNA mutating agents, and so on.

The study authors noted, ‘More research is needed to understand the various DNA replication glitches, repair problems, modifications, and mutagens that can produce this suite of mutational signatures and prompt the onset of various cancers’. However, they hope that by documenting these patterns, it would encourage future studies into the nature of those mutational processes as well.

The researchers identified almost 5 million somatic substitutions, small insertions, and small deletions in tumours from 30 common cancer types. This was achieved by applying a similar computational method to exhume sequence data for 6,535 cancer cases as well as 507 whole cancer genomes. With the aid of that information, the team also tracked down and verified 21 mutational signatures. The combinations of these signatures tended to vary in ways that coincided with factors such as a patient’s past exposure to mutagenic compounds, his or her age at the time of cancer diagnosis, and the type of cancer involved. On the basis of their findings so far, researchers predict that at least two types of mutational signature are at play in most cancer types. Even so, they noted that some of the signatures seem to be specific to a narrow swath of cancers, while others are far more common.

The processes proposed in the past can also partially explain some of the mutational signatures documented in the study. For example, several of the breast, ovarian, or pancreatic cancer genomes carried the type of mutational patterns that occur in the presence of inactivating changes to BRCA1 or BRCA2 genes. The research data are made available in the public domain at the Wellcome Trust Sanger Institute COSMIC (Catalogue of Somatic Mutations in Cancer) database and website.

Source: GenomeWeb Daily News, 14 August 2013.

CHALLENGE OF MANAGING SCIENTIFIC FREEDOM

There is a deep-rooted cultural challenge amongst R&D scientists and managers that a scientist’s ‘spirit of innovation’ should be given freedom of exercise and the idea of applying formal control (e.g. cost control and project planning) is viewed as an impediment to free thinking. On the other hand R&D departments do not have unlimited funds or cycle times. This cultural challenge may also result in separating research and development into two distinct departments. There is also a view that research is for scientists and development is for engineers. This demarcation, unless it is genuinely based on knowledge and experience, is not helpful. Fortunately R&D managers are also realistic in recognising the need for R&D successes in a competitive market. It is generally accepted that a certain amount of time should be allowed for scientific enquiries.

A primary aim of this book is to address this challenge to enhance the success of R&D initiatives by applying project management tools and processes and at the same time ensuring the spirit of innovation and the need for sufficient time for the research to yield results.

CHALLENGE OF MANAGING RISKS

Research and development are by definition exploring new opportunities, often in uncharted territories, and thus carry many risks. The main and obvious risks are related to uncertainties – uncertain cost, uncertain timescale and uncertain outcomes. There are also some less obvious risks. One such risk, according to Trott (2008), is 'appropriability risk', reflecting the ease with which competitors may imitate a newly developed product. However, this is a risk regarding the management of intellectual property, which is relatively well protected through patents, trademark and copyright protection. The product portfolios where intellectual property protection is more open to risks (such as fast-moving consumer goods innovations) tend to focus more on cumulative technologies and line extensions.

There is also a risk in integrating the research, development and delivery culture. The essence of risk management is the way the R&D organisation treats risks in time, cost and quality as a team from the viewpoints of the scientist, the designer, the engineer, the accountant and the product manager. R&D risk cannot be disassociated from the overall risks faced by the business. There is an inextricable link between the threats, opportunities and risks that a business, or even a national economy, faces in the marketplace and those encountered by the R&D team.

CHALLENGE OF ATTRACTING TALENT

The challenges of attracting appropriate skills and talents in R&D organisations are twofold. First, R&D tasks require specialists in particular areas and it is not surprising that research laboratories deploy more PhDs than other departments. Companies also need to identify creative talents in their hiring policy to have the best chance of generating new product ideas. It is also important to engage high-potential project leaders to manage the multiple stages of an R&D programme cycle. It is relatively easy to recruit qualified scientists and specialists but it is difficult to attract creative talents and high fliers to the R&D environment. The second risk is 'competence destruction' (Trott 2008). When technological uncertainty is high the companies attempting to develop highly radical or untried innovations (e.g. 'dot.com bubble' companies) need to attract expert staff, but unpredictable outcomes may involve redundancy.

CHALLENGE OF GLOBALISATION

Globalisation is an overarching 'megatrend' which will increasingly shape the world during the next decades. Globalisation offers both opportunities and challenges for research and development. After more than a decade of widespread global R&D expansion, multinational companies expected their international research and product development functions to deliver results. However, recent studies (CREST Working Group 2007; Boston Consulting Group 2010) have identified challenges for global R&D programmes, including problems interfering against the driving motivations, insecure intellectual property regimes, unbalanced knowledge circulation flows and the relocation of FDI (foreign direct investment) in R&D from Europe and USA to other regions (notably Asia). Companies like General Electric responded to these challenges of globalisation by what is also known as 'reverse innovation' where local product designs are made in emerging markets for emerging markets.

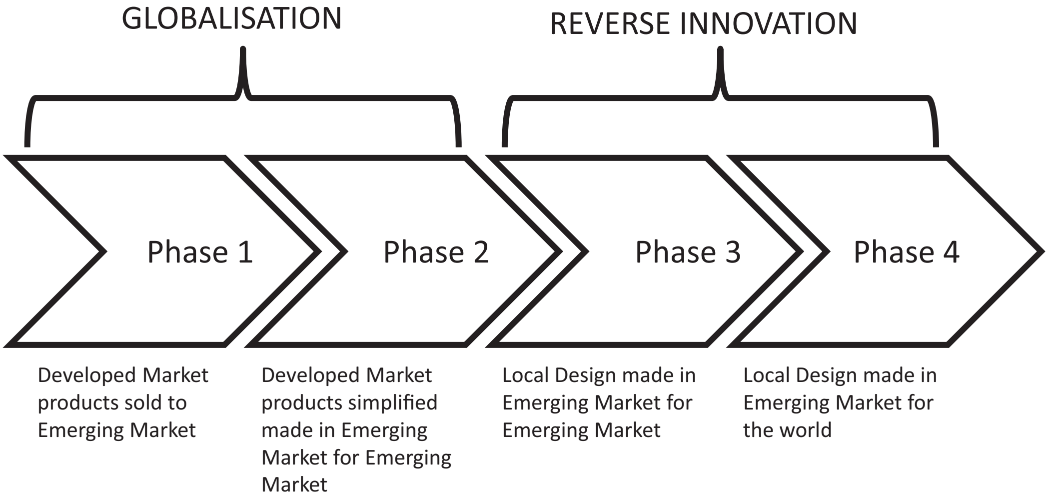

Figure 1.2 **Transition of R&D focus**

Reverse innovation refers broadly to the process whereby goods developed as inexpensive models to meet the needs of developing nations, such as battery-operated medical instruments in countries with limited infrastructure, are then repackaged as low-cost innovative goods for buyers in developed countries. A proven cycle of reverse innovation is:

1. Hear the voice of customers in the emerging market.
2. Develop technology, product and business model in the emerging market.
3. Meet the needs of the emerging market.
4. Adapt the product and business model for the developed market.

GE have established technology centres in Bangalore and Shanghai to successfully promote the strategy of reverse innovation. Figure 1.2 shows GE's transition of R&D focus from globalisation to reverse innovation.

THE CHALLENGE OF FUNCTIONAL TENSIONS

One of the greatest challenges involved in delivering a typical R&D project on time and within the allocated funding is the inherent tension between two contrasting elements. On the one hand there exists the softer, creative R&D culture; on the other, the far more driven ethos behind project management. The project manager has the mandate which covers mediation between representatives of different cultures, the nature of which is driven by very opposing forces. A businessman is motivated by financial benefit, while a researcher is inspired by personal curiosity and creativity.

There is also empirical evidence to support this tension. Von Zedtwitz et al. (2004) interviewed managers from 18 multinational companies in the late 1990s and identified as many as 10 challenges creating tensions between R&D and business managers. One fundamental difficulty was the management of knowledge and human resources. R&D managers supervised highly creative knowledge-based resources. By contrast, researchers had more loyalty to their science than the rigour of project management processes. There were also creative tensions and goal conflicts between local effectiveness and global programme objectives, as well as between R&D hierarchy and project management processes. A third area of friction was found to exist between creativity and discipline.

Interestingly, the authors argued that these challenges and tensions were not negative per se. Their recommendations included one effective approach to managing these tensions – the application of integrated project and programme management in R&D.

It can be asserted that the above tensions as observed during the late 1990s are still prevalent and that the recommendation of enhancing project management knowledge and application in R&D is equally appropriate today. A recent study (Alik 2008) has revealed that there is a demand for a project manager who could act as a mediator between R&D staff and the external non-academic world in order to address any functional tensions.

The challenge of such functional tensions is a difficult area to resolve. Here we are trying to manage human emotions, the drive for results and intellectual pride. Yes, as the above empirical studies indicate, one approach is to increase the knowledge and understanding of project management processes amongst R&D managers. It is also important that project managers are exposed to the complexity and additional risks endured by R&D managers. When the R&D leadership brings together R&D managers and project managers using a shared office and facilities there is a better chance of building up a harmonious accord.

CASE EXAMPLE 1.5: UNILEVER INTEGRATED R&D AND ENGINEERING AT PORT SUNLIGHT

In 1994 Unilever tried to launch Omo Power in the Netherlands, Persil Power in the United Kingdom and Skip Power in France. 'Power' was the biggest advance in fabric detergents in 15 years, and initially met with great success. As an innovative new product, its sales were leaping ahead in the three European countries where it had been unveiled. However, the initiative worried Procter and Gamble (P&G), and not just because their arch-rivals were doing so well. 'Power' contained a manganese catalyst, known as the 'accelerator', the revolutionary element that eliminated soiled marks from clothing. P&G had previously tried to bring a similar product to market using manganese, and had failed for the same reason that the market rejected Power. In fact, the Power products were flawed, because the manganese attacked not only stains, but the fabrics themselves.

Clothing was left tattered and Power products were eventually withdrawn from all markets. There were painful lessons to be learnt by Unilever management. Not least, the company had to try harder to fulfil their core aim – to develop new products that satisfy changing customer needs profitably. However, the essential part of this process was to harness the collaborative efforts of both the R&D and project teams and achieve greater synergy between them to avoid a similar humiliation with product content in the future.

The newly appointed director of R&D, among other strategic changes, implemented two action points. First, it was vital for R&D managers to enhance their understanding of project management processes, and structured workshops were used to achieve this. Another major change was to bring engineering and research elements closer together physically. This meant relocating Unilever Engineering to the Unilever Research Centre at Port Sunlight.

It may not be because of these changes alone, but in 1998 Unilever did beat rivals P&G to the launch of revolutionary Persil tablets.

Source: The author.

The Delivery and Impact of Research and Development

Research and development and innovations derived from R&D have been argued to be the engine of economic growth for hundreds of years. Karl Marx started the debate in the 19th century by suggesting that innovations could be associated with waves of economic growth. Innovations are the outcomes of R&D and not inventions from serendipity. Perhaps Schumpeter (1934) and Kondratieff (1935) were the early modern economists to emphasise the importance of 'new products'. They argued that the impact of new products is more important than the incremental changes and prices in new products.

The importance and impact of R&D and new products continued to be supported by studies and publications after the Second World War, when in particular military R&D delivered significant technological advances such as radar and advanced aircraft. Some authors (Abernathy and Utterback 1978; Freeman 1982) argued the criticality of innovation and life cycles of research and development.

Robert Solow, the 1987 Nobel Laureate in economics, formulated a theory of economic growth that emphasised the importance of technology. He argued that technology – broadly defined as the application of new knowledge to the production process derived from R&D – is the main factor responsible for growing an economy over the long term (Garfield 1988).

A large empirical study in the UK (Griffith 2000) found the social rates of return of R&D to be substantially above private rates of return. The social rate of return is generally obtained by estimating the impact on growth in one firm of R&D undertaken in other firms. The private rate of return can be estimated by looking at the impact of a firm's own R&D on the firm's output. These rates of return both inform us of how important R&D is for growth and provide one of the main justifications for government subsidies of R&D. Firms' decisions to undertake R&D are based on their private return from R&D. We believe that because this is lower than the social rate of return, there is underinvestment in R&D. Griffith (2000) suggested that in order to achieve the optimal level of R&D investment, government policy should aim to bring private incentives in line with the social rate of return. However, a question remains: does an increase in R&D expenditure lead to increases in the knowledge stock, or does it simply lead to higher wages for R&D scientists, as has been suggested by recent work in the US (Griliches 1994)?

The Organisation for Economic Co-operation and Development (OECD 2010), in their recently published *Innovation Strategy*, highlight that innovation will become an ever more important driver of growth in recognition of the structural landscape of many developed Western economies. Economic growth theory (Kurz and Salvadori 1998) asserts that innovation is a primary source of productivity growth. Since the recognition of the relationship between technological progress, innovation and economic performance, investment in research and development (R&D) has grown rapidly, along with a widening of innovation activity across many sectors of the economy.

There are many R&D-based endogenous growth models. Two such models, one by Diego Comin (2004) and the other by Argentino Pessoa (2010), evaluate the impact of R&D on the economic growth of post-war USA and OECD countries respectively, with each model revealing similarly interesting insights. There is no doubt concerning the positive impact of R&D on the macroeconomic growth of both national economies and industries. However, the debate is on between (a) where the best return of R&D expenditure is, and (b) whether state or industry is more effective in the transformation of human and environmental well-being through R&D investment and activities.

Table 1.2 R&D Expenditure in G20 Countries in 2009

G20 countries	GDP (US $ billion) Year 2009	R&D as % GDP Year 2009	R&D (US $ billion)
United States	12,949	2.90	376
Japan	4.467	3.36	150
China	3,335	1.70	57
Germany	2,833	2.82	80
United Kingdom	2,320	1.86	43
France	2,203	2.26	50
Italy	1,732	1.26	22
Canada	1,171	1.92	22
India	1,065	0.80	9
Brazil	1,011	1.17	12
Korea	945	3.56	34
Russia	869	1.25	11
Mexico	866	0.40	3
Australia	787	2.75	22
Turkey	509	0.85	4
Indonesia	354	0.08	0.3
Saudi Arabia	348	0.08	0.3
South Africa	271	0.93	2.5
Argentina	223	0.60	1.3

Note: Total R&D Expenditure 2009 = US $900 billion (2.35% of GDP).
Source: World Bank.

It is relevant to observe that knowledge-based high-tech economies of the G20 group (viz. USA, Japan, South Korea, Germany, UK, France, Canada and Australia) are investing between 1.86% and 3.36% of GDP in R&D (see Table 1.2). This is indicative of the experience of these countries delivering a positive impact on their economic growth through relatively higher R&D investments compared to emerging economies. This finding is also supported by a recent empirical study by Wang et al. (2013) that has concluded that R&D investment is positively related to economic growth for the high-tech industries. Empirical evidence has shown that the impacts of R&D expenditures in the high-tech sector have a strong positive effect on GDP per capita at the highest quartile of the distribution. However, all sectors' R&D spending relative to GDP is subject to significant negative returns only when considering the middle income countries. A study for the International Monetary Fund (IMF) prepared by Ulku (2004) suggests a positive relationship between per capita GDP and innovation in 20 OECD countries and 10 non-OECD countries, while the effect of R&D stock on innovation is significant only in the OECD countries with large markets. These results provide support for endogenous growth models; they do not necessarily suggest that innovation leads to permanent increases in economic growth.

Therefore, the apparent conclusions on R&D investment are:

- R&D investment has a positive impact on economic growth;
- growth is more visible in developed high-tech countries;
- a permanent increase in economic growth is not guaranteed.

It is good to spend on R&D but the questions still remain as to what the right amount is and where the best area of investment is. The strategy of R&D expenditure is comparable to the famous pronouncement of Lord Lever, the founder of Unilever, on advertising: 'Half the money I spend on advertising is wasted, and the problem is I do not know which half.' Research to understand 'which half' is not wasted is still ongoing (Childs and Triantis 1999; Schwartz and Moon 2000) and the jury is still out. Can a project management approach provide some pointers? We will explore this in later chapters of this book.

R&D Roles of State and Industry

Another big issue of R&D investment is whether state or industry should play a big role and who is more effective. A traditional view (Trott 2008) is that more recent innovations and scientific developments are associated with industry rather than state (e.g. polythene by ICI, ballpoint pen by Reynolds Pen, Zantac by Glaxo, photocopying by Xerox, Windows operating system by Microsoft, iPhone by Apple and so on). The large companies have specialised in particular areas and aim to provide scientific leadership through a large amount of R&D investment. Conventional wisdom insists that the answer to innovations lies with private entrepreneurship.

However, this 'myth' is challenged in a recent publication by Mazzucato (2013) who argues that the entity that takes the boldest risks and achieves the biggest breakthroughs is not the private sector, it is the much-maligned state. Mazzucato notes that '75 per cent of the new molecular entities approved by the FDA trace their research … to publicly funded National Institutes of Health (NIH) labs in the US'. Such discoveries are then handed cheaply to private companies that reap huge profits. The US National Science Foundation funded the algorithm that drove Google's search engine. Early funding for Apple came from the US government's Small Business Investment Company. Apple put this together, brilliantly, but it was based on seven decades of state-supported innovation. In any case, the private sector could not have created the Internet or GPS. Only the US military and NASA had the resources to do so. Mazzucato also suggests that policy makers increasingly believe the myth that the state is only an obstacle to innovation. Indeed, the scorn heaped on government also deprives it of the will and capacity to take entrepreneurial risks.

The thesis of Mazzucato (2013) may be controversial. However, it is rational that the failure to recognise the role of the government in driving innovation may well be the greatest threat to rising prosperity. It is also important to explore whether the state or industry is bearing the largest share of R&D investment.

The *2010 R&D Scoreboard* (BIS 2010) shows that the 1,000 companies most active in R&D spent about £344 billion, out of which the top 25 companies (see Table 1.3) accounted for 37% of the share. Furthermore, 78% of global R&D expenditure occurs in five countries: USA, Japan, Germany, UK and France. Global R&D intensity (R&D expenditure as a proportion of sales) stood at 3.6%. Among the 1,000 leading companies in the UK, R&D intensity stood at only 1.7%. The top five R&D ranked companies in the UK (viz. GSK, AstraZeneca, BT, Unilever and Royal Dutch Shell) accounted for 35% of the total R&D investment of £25 billion by the top 1,000 UK companies.

Table 1.3 Top 25 global companies by R&D expenditure in 2010

Rank	Company	Sector	Country	R&D (£m)
1	Toyota Motor	Automobiles and parts	Japan	6,014
2	Roche	Pharmaceuticals	Switzerland	5,688
3	Microsoft	ICT services	USA	5,396
4	Volkswagen	Automobiles and parts	Germany	5,144
5	Pfizer	Pharmaceuticals	USA	4,802
6	Novartis	Pharmaceuticals	Switzerland	4,581
7	Nokia	ICT services	Finland	4,440
8	Johnson & Johnson	Pharmaceuticals	USA	4,326
9	Sanofi-Aventis	Pharmaceuticals	France	4,060
10	Samsung	ICT services	South Korea	4,007
11	Siemens	ICT services	Germany	3,805
12	General Motors	Automobiles and parts	USA	3,758
13	Honda Motor	Automobiles and parts	Japan	3,746
14	Daimler	Automobiles and parts	Germany	3,700
15	GlaxoSmithKline	Pharmaceuticals	UK	3,629
16	Merck	Pharmaceuticals	USA	3,619
17	Intel	ICT services	USA	3,501
18	Panasonic	Electronics	Japan	3,445
19	Sony	Electronics	Japan	3,308
20	Cisco	ICT services	USA	3,225
21	Bosch	Automobiles and parts	Germany	3,179
22	IBM	ICT services	USA	3,061
23	Ford Motor	Automobiles and parts	USA	3,034
24	Nissan Motor	Automobiles and parts	Japan	3,030
25	Takeda	Pharmaceuticals	Japan	3,014

Source: BIS (2010).

It is evident from Table 1.3 that the global investment in industrial R&D is led by companies from the USA, Japan and Germany, followed by enterprises in Switzerland, France, UK and South Korea. These are the knowledge-based developed and high-tech economies. In countries in the emerging markets (e.g. China, India and Brazil) and also the resource-dependent economies like Saudi Arabia both the total R&D investment and more significantly the R&D intensity are well behind those of the knowledge-based high-tech economies.

When we consider the R&D intensity (R&D as % of GDP) of 2011 alone, then the top three countries are Israel (4.4%), Finland (3.8%) and Sweden (3.4%), followed by Denmark (3.1%). However, the OECD engine of R&D is provided by the top five R&D investment countries (see Table 1.4) and these countries carried between them a total R&D expenditure of £478 billion in 2011, three times the GDP of Israel.

Table 1.4 Top five R&D investment countries (£ billion) in 2011

	Business	Government	Higher Education	Total
USA	182	32	40	254
Japan	78	9	13	100
Germany	42	9	11	62
France	24	5	6	35
UK	17	3	7	27

Source: OECD R&D statistics.

It is difficult to accept or reject the argument of more outcomes of fundamental innovation by the state as compared to businesses (Mazzucato 2013) because it is very difficult, if not impossible, to measure the benefits of all the research patents resulting from state-funded and business-funded research programmes. However, if there is any correlation between R&D investment and outcomes then approximately 7 out of 10 outcomes come from business (see Table 1.5). This crude analysis does not prove the possible dominance of either player but provides evidence of the power of investment in each camp.

Table 1.5 Top five R&D investment countries (% share) in 2011

	Business	Government	Higher Education	Total
USA	72	13	13	100
Japan	78	9	13	100
Germany	68	14	18	100
France	68	15	17	100
UK	63	11	26	100

Source: OECD R&D Statistics.

It is also arguable that the focus of business R&D is more on business-related new products and processes whereas the emphasis of state-funded research is more on fundamental research providing fundamental outcomes, where the state can take the boldest risks to obtain breakthrough results. Therefore Mazzucato (2013) may have a point that fundamental outcomes, when supported by the state, are winners in the longer run.

The Importance of Project Management in Research and Development

Having discussed why research and development are so important for the sustainable growth of both businesses and national economies and also the inherent challenges, we can explore the importance of project management in R&D. A simple argument is that R&D work is, by definition, hard to predict but the formal disciplines of project management can provide a means of helping to plan, organise and control multidisciplinary projects without stifling innovation. This argument appears to be too simplistic but it merits further development.

We have established that R&D must operate strategically in the organisation and also in the global economy, becoming a key driver of success. However, there are many examples of major R&D schemes that have failed to deliver the expectations of stakeholders. Ries (2011) argues that resistance to having structured processes is often the cause of R&D failures and most R&D initiatives avoid all forms of project management process and discipline. Former Rolls-Royce Chief Engineer Darrell Mann (2013) explains why 98% of R&D projects end in failure and has come up with an approach called 'systematic innovation'. 'If you studied the 2 per cent you will realise that they followed a certain path and rules and if you understand those rules you have a far higher likelihood of success', says Mann. The core principles of Mann's 'systematic innovation' are rooted in the fundamentals and rigour of project management.

The study by Cowley (2005) analyses company survey results (based on 60 successful and unsuccessful projects of Canadian firms) to develop eight major factors to help distinguish between successful and unsuccessful R&D projects. These factors relate very closely to project management principles. Cowley also suggests a decision model where the R&D process is broken down into five stages entailing four decision points. The five project stages are: 1) initial screening, 2) commercial evaluation, 3) development, 4) manufacturing/marketing launch, and 5) initial commercialisation. The four decision points are between the stages. These stages are comparable to the 'stage-gate process', first published by Cooper (2001). The concept of these stages is based on the principles of 'manageable chunks' and progressive risk control embedded in the discipline and rigour of project management.

A white paper by EFCOG (2010) identified that the success of most projects under the management of the US Department of Energy in the R&D environment supports following universally accepted project management principles:

- line management accountability
- sound, disciplined, up-front planning
- development and implementation of sound acquisition strategies
- well-defined and managed performance baselines
- effective project management systems (e.g., quality assurance, risk management, change control, and performance management)
- implementation of an integrated safety management system
- effective communication among all project stakeholders.

This white paper explores the merits and limitations of traditionally 'projectising' R&D and draws attention to the need for a more appropriate and tailored application of project management techniques.

Turner and Cochrane (1993) described in their 'goals and methods' matrix (see Figure 1.3) four types of projects based upon whether the goals and methods of a project are well defined or not. For example, projects with well-defined goals and well-defined methods are Type 1 projects, typified by engineering projects. Those with well-defined goals but not well-defined methods are Type 2 projects, typified by product development projects. Type 3 projects are typically information systems projects where methods are well defined, but the goals are ill defined. Type 4 projects have both poorly defined goals and methods, and typically research and organizational change projects are in this category.

According to this model both Type 2 and Type 4 could relate to innovation and new product development initiatives where methods are not well defined. In other words these initiatives in general lack the rigour of project management methodology. Turner and Cochrane (1993) also argue that the success rate of a project will increase when both the goals and methods are well defined. Thus, arguably we have established well-defined goals and methods as two key success factors of a project, including an initiative on innovation and product development which should be treated as a project.

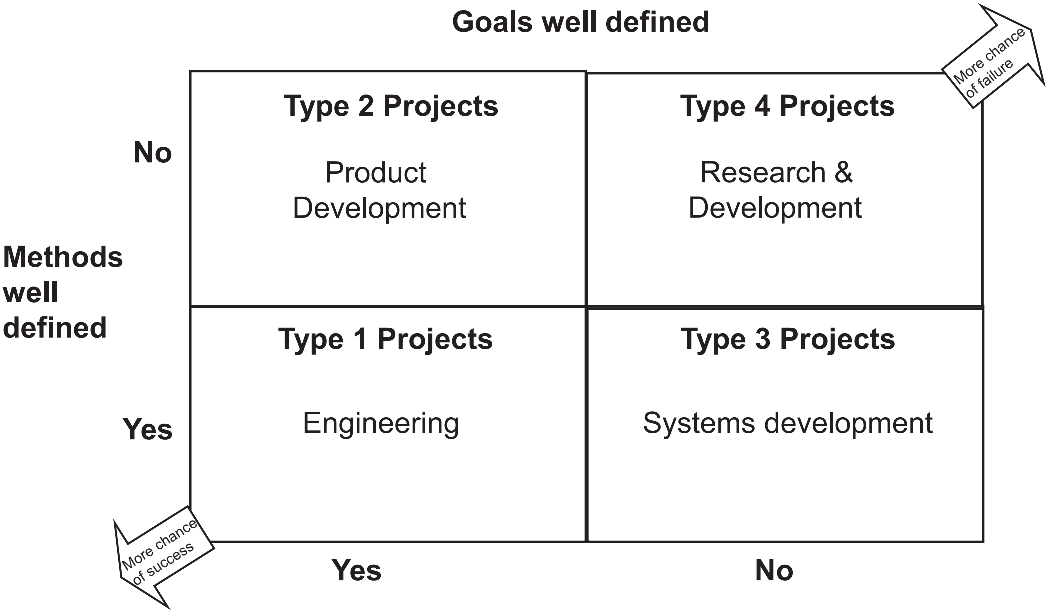

Figure 1.3 The ‘goals and methods’ matrix
Source: Turner and Cochrane (1993).

Shimizu (2012) argues that the outcomes of research, like a business strategy, need a programme of governance as a bridge between research and development activities to convert research ideas and outcomes to deliverable products, The governance of a programme is underpinned by a number of well-defined projects. A company’s survival, according to Shimizu, depends on its efforts to create new customer value in the form of a new business, new product, new technology or a new process. The creation of new values is an outcome of R&D and their successful delivery is carried out by projects.

Trott (2008) and Barkley (2007) are proponents of the application of project management in innovation and new product development. Trott (2008) emphasises the need to view innovation as a project management process and also the need to provide scientific freedom. Barkley (2007) demonstrates with detailed case studies how to efficiently manage the translation of new ideas into new products and services using advanced project management tools and techniques.

There is more published evidence supporting the application of project management tools and techniques to enhance the successful delivery of R&D initiatives. These will be addressed later in the book.

Summary and Learning Points

This book addresses four key questions:

1. What are the core concepts, challenges and opportunities related to research and development initiatives in business organisations and national economies?
2. What are the main process, tools and success factors of project management relevant to the success of R&D initiatives?

3. How can a project manager enhance and focus the capabilities of R&D resources to operate and deliver successful R&D projects?
4. What is the way forward to apply these processes, tools and success factors of project management more effectively to the success of R&D initiatives?

We aim to explore the above questions in the following chapters of this book and hope to find some answers. Perhaps the biggest challenge to R&D delivery is the functional tension that exists between project management and the R&D environment. However, in this chapter the analysis of published evidence has clearly set pointers to the role of R&D in sustainable economic growth and the role of project management in the successful delivery of the outcomes of R&D. It is worth reiterating the key findings emerging from this chapter:

- R&D investment has a positive impact on the economic growth.
- Growth from R&D is more visible in developed high-tech countries.
- A permanent increase in economic growth is helped by R&D but not guaranteed.
- Industry plays a bigger role in R&D investment although the outcomes of state-funded fundamentals are often far-reaching.
- The rigour and processes of project management show clear evidence of improving the success of R&D initiatives.

The application of the rigour and processes of project management will be addressed in later chapters. However, the following key characteristics of project management have been identified as appropriate for the success of R&D initiatives:

1. evaluation of technology readiness
2. project governance to transfer outcomes of research to development
3. investment appraisal and risk assessment
4. progressive scope definition
5. stage-gate process and life cycle of 'manageable chunk'
6. measurement of R&D success criteria
7. implementation of a tailored approach.