K.B. Akhilesh

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ISBN 978-81-322-1945-3 ISBN 978-81-322-1946-0 (eBook)
DOI 10.1007/978-81-322-1946-0
Springer New Delhi Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014946080

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Foreword

The author of this book, Prof. Dr. K. B. Akhilesh, is a Professor of Human Resource Management, Organizational Behavior and Technology Management at the Department of Management Studies, Indian Institute of Science, Bangalore. His research and academic interests lie in the development of IT, manufacturing and HR skills. He has lectured at many universities and organizations all around the globe and has guided global giants like Daimler-Chrysler, Airbus Industries, World Bank, BSNL, DRDO, Siemens, ABB, HMT, BEL, HAL, and WIPRO as a consultant and trainer. He has helped senior managers hone their managerial skills through more than 1,000 management development programs. He has authored 7 books and published over 100 papers in refereed journals internationally.

This book provides information about context, structure and process involved in R&D, strategic aspects of R&D management, importance of project planning and budgeting for an R&D project, process of technology roadmapping and the factors that influence roadmapping, importance of project selection and evaluation, human resource management and creativity in R&D and the role of R&D in driving Indian economy.

For corporates, this book provides the guidance to understand the function and involvement of R&D management in growth and performance of an organization. It helps students by bringing to their attention the role of human resource management, concepts, tools and techniques like human resource planning, inventories, performance appraisal, staffing plan and career planning in R&D function. The book can also be used for technology and R&D studies conducted by organizations.

This book will contribute towards building competitiveness of the organization through promoting technology development, adoption and adaptation supported by innovation of new products and processes.

I have known Dr. Akhilesh for many years now and have had the pleasure of working with him on multiple occasions. This book will be great addition to his earlier books on human resources management and technology management published over the last few years. I am sure management students, practitioners, teachers, R&D scientists, engineers and managers will find this book practical and useful in their pursuit of knowledge and goals.

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June 2014

Dr. Prahlada

Preface

Research and development (R&D) is an important functional area of management discipline. Competitive advantage of the nation as well as the organization is largely dependent on innovation and development of new technologies. Research and Development activities contribute significantly to the overall organizational performance and growth. In the era of achieving comparative advantage, efficient management of research and development activities is not only critical but is also a part of a survival strategy. Demystifying research, development, engineering and technology helps in planning, coordinating various activities of research and development function. Understanding the roles and responsibilities, structuring and functioning helps in scoping of the activities and relate to other functions of management within an organization. This book gives an insight for global R&D platform. It is intended to help engineers to understand the roles and contributions of R&D functions and enable them to plan their careers in R&D activities. This book will contribute toward building competitiveness of the organization through promoting technology development, adoption, adaptation and innovation of new products and processes.

The book gives an introduction to functions of R&D, developmental activities and developmental phases of R&D management in organizational context. Organizational changes are perceived as reactionary and revolutionary responses to overcome the challenges faced during developmental phase of an organization. The different phases of R&D generations have encountered wide range of technological, organizational, and structural challenges. This book briefs about how R&D activities in India drive the major economic developments and provide detailed evaluation of challenges faced in carrying out these activities and how to transform these ideas into financial returns. It explains the role of corporate strategy and planning in enhancing R&D in organizations. This book also emphasizes on project planning and the need for effective budgeting system and reviews process in R&D functions. It also elaborates on the qualitative and quantitative analytical methods and the advantages and disadvantages of each of these methods provide essential tool or technique for an R&D manager. It explains the importance of Project Evaluation combined with quantitative measures and expert judgments to assess and evaluate R&D projects.

This book elaborates on human resource management, concepts, tools and techniques like human resource planning, inventories, demands, performance appraisal, staffing plan, and career planning in R&D function. The need for talent management in order to undertake a strategic analysis of the HR processes in R&D organizations has been highlighted. It elucidates the role of creativity in organizations and factors influencing the organizational creativity. It also introduces the role of interdisciplinary teams and cross-functional teams in R&D setup and describes how to implement R&D innovation management in an organizational structure. This book gives a brief introduction, objective, scope, and different methods of portfolio management. It also briefs about the accounts of theoretical understanding of NPD (new product development), framework of NPD, and models to explain the execution of NPD.

This book has been basically prepared for students who would like to pursue a career in R&D Management. It can also be used as an introductory text book for the orientation programs for trainees in the engineering and manufacturing areas. However, it can also be employed for technology and R&D studies conducted by organizations. This book is a result of a number of years of teaching and continuous interactions with developers and scientists. I am grateful to late Professor A.K.N. Reddy and late Professor B.G. Raghavendra for partnering with me in coming up with the syllabus in the initial stages of teaching this course in the Department of Management Studies, Indian Institute of Science, Bangalore. I wish to thank project assistants Ms. Sowmya. V, Ms. Anusha M.V., Ms. Raksha. A.S. and PhD students Dr. Madhurima Das, Ms. Sindhuja C.V., Ms. Aparna Shankar, Ms. Swetha V. and Mr. Shaym for their consistent contributions to the contents of the books, figures, in identifying case studies and for proof reading. I would also like to thank the authorities of IISc, Bangalore, for their support. I extend my hearty gratitude to Springer for providing constant help and inspiration in bringing out this book.

Bangalore, India K.B. Akhilesh
May 2014

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About the Author

K.B. Akhilesh is a Professor of Human Resource Management, Organizational Behavior and Technology Management at the Indian Institute of Science since 1982. Prior to this, he was the Chairman of the Department of Management Studies at the institute from 1993 to 1998. His research and teaching interests lie in the development of human resource skills in information technology and manufacturing sectors. He has published over 100 papers in Indian and international journals and authored seven books. Professor Akhilesh has guided over 20 doctoral students, served as an external PhD examiner in India, South Africa and USA. He has been a visiting lecturer at many universities and organizations, worldwide, including USA, Germany, France, Japan, Canada, Belgium and Sweden. He was invited as a visiting researcher by the Japan Institute of Labor, Tokyo. He is also Adjunct Professor at George Mason University (Fairfax, VA) and Visiting Professor at the School of Information, University of Hamburg (Germany). He has taught in Pforzheim University and University of Lemgo (Germany). As a consultant, speaker and a trainer he has interacted with companies like DaimlerChrysler, Airbus Industries, Pratt and Whitney USA, Lapp India, International Labor Organization, Volkswagen, Vee Tech, Honeywell, BSNL, 5th Central Pay Commission, Central Silk Board, DRDL (DRDO), LRDE, CPRI, among others. As a corporate management trainer and facilitator, he has participated in over 1,000 Management Development Programs. He is a member of many major professional organizations, including Academy of Management, New York, USA. Professor Akhilesh was honored for his life time contribution to HR Management by National Institute of Personnel Management (NIPM), Mumbai, India. His latest book is *Emerging Dimensions of Technology Management* published by Springer in 2013.

Chapter 1
Introduction to R&D Function

Abstract This chapter gives a brief introduction to R&D. The comprehensive role of research, development, science, engineering, and technology is based on the type of research activities undertaken in different organizations of India. This chapter also attempts to provide R&D categorizations in India under a global context. Further, we have discussed the functions of R&D, developmental activities, and its role in management. Finally, the chapter offers a wide range of operational definitions of R&D and developmental phases of R&D management in an organizational context.

Learning Objectives: To understand the role of R&D; to differentiate terms such as research, development, science, technology, and engineering; to understand the terms from the perspective of organizational context and application situation; to categorize R&D to view India in a global context.

Keywords R&D functions • R&D initiatives • Elaboration • Research • Development • Science • Technology • Definitions of R&D • Categorization of R&D • Scope of R&D

1.1 Introduction

The pursuit of knowledge has been a part of the global ethos for centuries. From time immemorial, we have seen developments in science and technology and also the growth of knowledge and the pursuit of innovation. The advent of industrialization, the change in industrial policies, and the growing focus on research and development have always been evident in various ways. Every society is in pursuit of knowledge, technology, and innovations, which defines a desired path, where science was denoted as a precursor to economic growth. As science was to be reformed, so was technology also to be affected. This reformation resulted in an organizational reset in the technology front, which led to the creation of the term Research & Development (R&D).

This chapter attempts to trace R&D function as it has evolved over a period of time. Further, the scope of the function is also elaborated in different contexts such as manufacturing and services and in different technology sectors, which include pharmaceuticals, drug development, cements, sugar, space, and so on. Essentially, R&D functions attempt to meet the competitiveness of organizations that are

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_1

striving at their best to rise up to the standards in the technology era by following innovation, value-added services, and cost-competing platforms. Organizations need to understand and apply the industry standards as well as analyze and adopt the various available technologies to achieve better quality and productivity. This defines the functional scope of R&D activities in any organization. As a strategic function, compared to other similar functions such as human resource management (HRM), manufacturing, finance, and marketing, R&D activities contribute toward the growth and survival of any technology-intensive organization. R&D function is also responsible for enhancing the quality of life by providing improved products and features and functionality for the organizational goods and services. It is also the custodian of the intellectual wealth of the organization. It has to promote and sustain the creative efforts of engineers, experts, and scientists. R&D function is not restricted only to the organizational level. Its activity is also planned and supported at the state and national levels. Suitable policies and programs are required to encourage a scientific temperament in the country and build appropriate levels in talent transformation. Governments have to play a key role in developing universities and national laboratories, enhancing collaborations, creating machine-driven systems, and also providing budgeting support. R&D activity is generally undertaken by the government through its various departments of science and technology, the industry and organizations in both public and private sectors, and also the academia, which is increasingly focusing on building an environment of research. Initially, while most organizations developed their research capabilities in-house, today the focus is on collaboration, sharing of knowledge, and cost-effective investment, and with it, the role of licensing has become important. This was to be done by establishing universities, altering education systems, developing new laboratories, and building academia and industry collaborations.

Research & development has grown in most of the nations that are recognizing the growing need for innovation. The focus of most of the nations has been on R&D as a national strategy. Although currently, nations such as the United States, China, and Japan are leaders in innovation, this is a phenomenon that is no more geographically bound. R&D indicators are a matter of serious concern and are the focus of countries such as India, China, Russia, and Brazil along with other European nations.

Research & development activities in India have grown over a period of time through four distinct initiatives. The first was in the form of science education and the establishment of universities: Banaras Hindu University, Mysore University, Calcutta University, and Indian Institute of Science, which was patronized by the then Maharajas and princely states, gave the initial push for the scientific temperament in India.

The second initiative can be seen from individual scientists such as Jagadish Chandra Bose, CV Raman, and Ramanujam to name a few who set in the spirit of scientific achievement and aspirations in the country. The third root can be seen in the establishment of the many national laboratories by Jawaharlal Nehru, the first Prime Minister of India.

The fourth important initiative came in the form of the establishment of mission-driven organizations such as Indian Space Research Organization, Atomic Energy

Organization, as well as Defense Research and Development Organization. One cannot ignore the significance of the four initiatives while understanding R&D function in the Indian context.

Indian public sector organizations such as Bharat Heavy Electrical Limited, Oil and Natural Gas Commission, Bharat Electronics Limited, Hindustan Aeronautics Limited, and many others pushed in the frontiers of R&D function from the 1960s to the 1990s. The period after 1991 will be described as the post-liberalization era, when the Indian government, public sector organizations, and business houses of India such as Tata, Birla, Kirloskar, and Reliance, through their inspired economic activities, showed the benefits of economic activities through the application of innovation. Technology-led growth not only created employment opportunities but also demanded more contribution from technical manpower.

Research & development has emerged as an important department in organizations with a clear view of providing a competitive edge at the strategic level, managing ideas and talent toward the development of new and improved products and services at the operational level. Similarly, at the national level, R&D is contributing toward the security of its citizens through the development of defense technologies and atomic energy applications on the one hand, whereas on the other, it is driving the economy by creating self-sufficiency with new innovations and products. Developing capability toward technical competence in a globally competitive era has been the main challenge faced by the country. Once the capabilities are developed, the other challenge lies in creating appropriate organizational and institutional form toward a climate of innovation and the development of new technologies.

The next challenge is to prioritize the allocation of resources for the smooth functioning of the organization by creating infrastructure, equipments, and facilities as well as implementing appropriate reward and incentive systems. Furthermore, the challenge is also to disseminate and transfer technologies, applications, and methods to the end users to realize the benefit of applications of R&D and to solve problems.

The next important challenge is to protect knowledge and technology through appropriate policies and practices. It is in this context that one needs to understand the scope and activities of R&D function at the organizational and at the national level.

1.2 R&D Categorization

R&D centers are categorized based on the types of research activity that is undertaken, which are classified as follows:

1. R&D within an organization (colocated).
2. R&D activities are contracted, collaborated, and located in university systems.
3. Independent R&D laboratories not colocated.
4. Captive R&D, which are contracted or outsourced within or outside the country (dedicated lab).

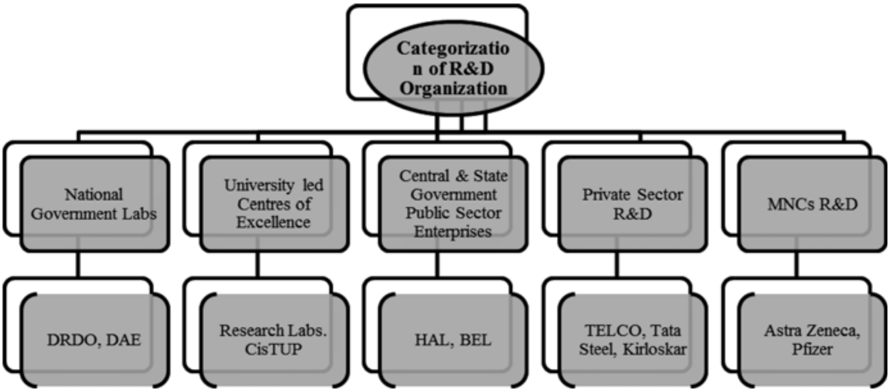

Fig. 1.1 R&D categorization

The categorization of R&D can also be classified based on the ownership of the organization. Figure 1.1 provides such a classification as well as lists some examples of organizations. It can be seen from Fig. 1.1 that there are national government laboratories focusing on defense research or atomic emery–related activities. Second, a group of R&D would be in the form of a university-led center of excellence or centers of advanced research, design, and development. The third category is basically government-owned manufacturing organizations. Government policies do influence their R&D activities, and it includes both central and federal or state governments. Some of the examples of government-owned organizations are Hindustan Aeronautics Limited and Bharat Electronics Limited. The next category of R&D is basically driven by private-sector organizations. They could be large, medium, small enterprises. The last illustrative category could be the form of multinational corporations. Hence, it can be seen that R&D function can take different forms and deal with different complexities depending on the ownership and nature of the organization.

1.3 R&D Function: Related Concepts

R&D function requires initial elaboration and clarification related to some of the commonly used terms and concepts. They include research, development, science, technology, and also engineering. Science is more concerned about why inputs, engineering is more concerned with why not, and technology should merely work and shouldn't raise question graphs. Research is defined as a continuous process of inquiry or examination in which a detailed examination, especially analysis or experimentation aimed at the discovery of facts, review of conventional theories, or application of these theories, is conducted (Merriam Webster Dictionary, online dictionary). It is a three-step process used to collect and analyze information to understand a topic in depth. The three steps include posing a question, gathering data, and presenting an answer to the question (Creswell, online dictionary). Research is basic and applied in nature. Basic research is an experimental and theoretical process by which to acquire new knowledge without looking for longevity benefits other than the progression of knowledge.

Deloitte defines research as "An original and planned inquiry undertaken with the outlook of gaining new scientific or technical knowledge and understanding" (Deloitte 2011).

The Business Dictionary has defined development in various ways, which are listed as follows:

- "Development is a methodological use of science and technology knowledge to meet certain goals or requirements."
- It is an extension of theoretical or practical aspects of a concept, design, discovery, or invention (Business Dictionary, Online dictionary).

Development aims at providing solutions to the problems faced. Development makes corrections according to the feedback provided in the research platform, which is more useful for end use. Hence, development is defined as "A process prior to commercial production wherein research findings are applied to design new qualitatively improved outcomes in any organizational platform" (Deloitte 2011).

Developmental activities conducted by organizations at various levels are stated as "It is the design, construction and testing of pre-production or pre-use prototypes and models. It is the design of tools, jigs, molds and dies involving new technology. It is the design, construction and operation of a pilot plant that is not of a scale economically feasible for commercial production. It is the design, construction and testing of a chosen alternative for new or improved materials, devices, products, processes, systems or services" (Deloitte 2011).

Science is a basic platform for knowledge. It comprises more of the fundamentals, laws, theses, and proved experiments. It is a set of theories, which are more basic in nature. Science is more concerned with how and why things happen.

Science can also be defined as "A system of acquiring knowledge. This system uses observation and experimentation to describe and explain natural phenomena. The term science also refers to the organized body of knowledge people have gained using that system."

Fourth, *Technology* is defined as a market application, which is dependent on science. It is defined as an "Application of knowledge to bring in practical change in human environment. This is done by using materials, tools, techniques and sources of power." Technology focuses on making things happen. The word *technology* can also be referred to as a collection of techniques. In fact, it is the combination of resources to produce desired outputs or solve problems, which includes raw materials and tools, technical methods, skills, and processes (Wikipedia 2012).

Finally, the one which gives shape to these definitions is "engineering." Engineering is mainly a combination of measurements and execution of methods. It is the manufacturing platform to increase the scalability of a product. It is defined as the "Professional art of applying science to the optimum conversion of the resources of nature to the uses of humankind" (Wikipedia 2012).

1.3.1 R&D Management

R&D management is defined as a combination of the tasks of innovation management (i.e., creating and commercializing inventions) and the tasks of technology management (i.e., external and internal creation and retention of technological know-how). It includes various activities such as basic research, fundamental research, technology development, advanced development, concept development, new product development, process development, prototyping, R&D portfolio management, technology transfer, and so on. But certain independent activities such as technology licensing, innovation management, IP management, corporate venturing, incubation, and the like are not included in R&D management.

R&D functional aspects include a kind of functional orientation like production, human resource, marketing, and finance. These functions are basically necessary to attract, develop, and retain scientific manpower.

1.3.2 Technology Management

Technology management is the strategic aspect of making or buying technology. It mainly constitutes tech roadmapping, positioning of products to market conditions, and strategizing time to market.

In a company that has a nonassertive patent strategy, improvement initiatives in technology management will face problems if no balance is maintained between product and process innovation. Technology management has been explained more precisely in the subsequent chapters.

R&D management and technology management are on the same continuum and work together for the progress of technology and innovation in an organization.

1.4 Scope of R&D Management

Organizations can effectively manage their R&D operations as indicated in Fig. 1.2.

The scope of R&D function can be explained in different ways. The first step is to understand the business needs of the organizations. These could be to enter and expand new markets, provide better services, and integrate and deliver new features. R&D function essentially has to link technology and available innovation to the identified needs of the business. Furthermore, it has to determine the gaps in terms of "know-how" and "know-why." Identification of these gaps will leave R&D to decide on the technology in-house and acquire new technology from other organizations. While determining the nature of the technologies to be acquired or developed within the organization, R&D must have a futuristic view of how products and

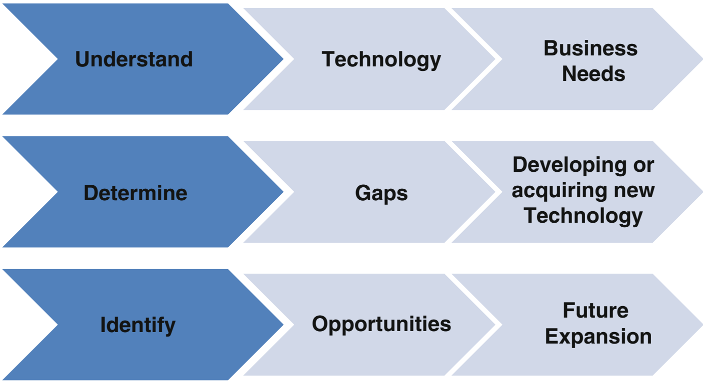

Fig. 1.2 R&D operations in organizations

services will provide new opportunities and scope of expansion for the organization. While conducting these basic activities of understanding, determining, and identifying, R&D function has to acquire the sources, create infrastructure, and develop talent to effectively execute the specific projects.

Questions

1. Define R&D management.
2. Explain the developmental phases of R&D management in India.
3. Briefly explain the scope of R&D management.

Exercise

1. Visit R&D labs, and discuss with R&D managers their experience postliberalization.

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Chapter 2
R&D—Reactive and Passive Partner to Responsive Collaborator

Abstract Organizational changes are perceived as reactionary and revolutionary responses to overcome the challenges faced during developmental phases of an organization. In the present chapter, we look at how different phases of R &D generations have encountered a wide range of technological, organizational, and structural challenges. The next section of this chapter accentuates the role of understanding context, structure, and process in R&D organizations. Contextual factors are ownership, location, pace of technology change, and organizational environment. Structural factors are formalized and standardized representations of hierarchy, authority, delegation, and coordination. Finally, the process emphasizes the end actions of organization through transformational leadership, goal setting, and timely decisions. We conclude this chapter with the new emerging dimension and future of R& D organizations of being ambidextrous. Ambidextrous organizations are an agenda to understand its own capability to keep their vision, goal, and strategies at par with market needs and technology development.

Learning Objectives: To explore the movement of R&D from being a reactive to a responsive partner in the organization; to understand the context, structure, and process of the R&D organization or R&D functioning; to analyze the evolution of five generations of R&D; to explore the challenges encountered in the changing face of R&D and the future in the context of ambidextrous organizations.

Keywords Reactive & passive partners • R&D generations • Evolution • Framework • Configuration • Methodology • Structures • The future of R&D

2.1 Introduction

R&D in an organization has changed the manner of functioning over the years. The layers of complexity have increased and with it the challenges it brings. In this chapter, we explore the evolution of R&D from being a reactive partner to a responsive collaborator in the organization. We also explore the changes over generations and the forces at play, the structure and process changes, the challenges involved, and the future in the context of ambidextrous organizations.

In the initial years, R&D had a slumberous existence. There was not much done until a problem was referred. With very little business pressures and methodology being standardized, the rate of change of any process was also low. At this point,

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R&D was in peaceful coexistence with other departments. Over time, as other functions came under pressure and performance became an important criterion, problems were shared, and people looked for solutions. The R&D department then assumed the role of a solution finder, and it thus became a reactive partner.

In an organization, when relationships are built and competencies are recognized, we have the process in place that makes work comfortable. Many a time, relationships may be strained, and there may be problems. In such cases, there is a tendency to either work for solutions or push the problems into the background. Effective problem solving involves several steps—accepting the problem, exploring available resources and generating alternatives, and identifying a specific course of action to solve a problem. At this level, R&D function gets its role and relevance defined around the problems experienced by the organization.

The next level involves whether R&D function is more proactive or not. Proactiveness involves listening, analyzing, and exploring of the problems of others by the R&D team. This enables establishing the identity of R&D function. In this situation, while establishing the R&D identity, they look for support from others and communicate with others so that they can solve and create common perceptions about problems and alternatives and thereby move on to the third level.

At this level, R&D establishes high levels of interdependencies, creating benchmarks and standards and accepting deviations as R&D problems that need to be addressed. The function then becomes more data based and data centric, and manufacturing and customer details are analyzed to obtain new patterns. The matrix of R&D is not only the degree of newness achieved through various activities but also the commercialization of products and services. R&D is then pushed toward generating resources, moving away as a cost center, and getting linked with other functions of the organization. As the function moves on to the fifth level, we see that R&D is now in the responsive mode. Here, the basic concern is the customer and the business model of the organization. The emphasis is now on analyzing the business trends, the competition and the competitor, and benchmarking. Through some of these, it defines the leadership of the organization through appropriate R&D activities.

2.2 The Five Generations of R&D

R&D growth over the years has been classified into five generations by some of the authors (Rothwell, Rogers). These authors have perceived that the scope, role, and responsibility of R&D function has experienced significant changes. Such changes at times are seen as reactionary or revolutionary to overcome the challenges faced by organizations. The five generations are described in the following paragraph. It is essential to understand that every generation brings with it various challenges, and organizations have to work to update their strategic vision, improve their innovation process, and look toward newer markets.

2.2.1 First-Generation R&D: Technology Push

According to Rothwell (2005), R&D growth and activities can be categorized into five generations based on research during each decade; according to him, the 1950s and 1960s can be seen as the era of technology push. This phase assumed that R&D would operate from an ivory tower and decide what technologies are required unilaterally. Independent researchers worked in an isolated fashion, and R&D produced solutions with the attitude of "take it" or "leave it." Rothwell also recognizes this generation of R&D as having almost no interactions and one that kept delivering from a position of isolation. New industries emerged from the innovation derived from laboratories and breakthroughs.

2.2.2 Second-Generation R&D: Market Pull

The second-generation R&D was more categorized by the market pull. This part of R&D forced organizations to examine the needs of the business. They had to work with other business functions such as operations, manufacturing, and marketing. R&D intentionally developed communication channels to appreciate the needs of the customer. Organization structures are evolved to scientific research outputs and delivery requirements of the organizations. Effective integration was essential for the success of the R&D efforts.

2.2.3 Third-Generation R&D: R&D and Marketing Work Hand in Hand

According to Rothwell, the third generation really evolved in the 1970s and 1980s. Organizations had to decide among different projects to succeed in the marketplace. Markets were perceived as dynamic and changing. R&D function had to be more goal directed. Essentially, their activities had to be tuned with market opportunities. Markets took on R&D to be more competitive. They not only emphasized innovation but also cost competitiveness. R&D management broadened their perspective, became inclusive, and appreciated the scientific and engineering challenges internally and also the significant changes in the marketplace externally.

2.2.4 Fourth-Generation R&D: The Integrated Business Processes

The fourth-generation R&D, which happened in the early 1980s to the mid-1990s, provided the scope of functioning through effective understanding of the value creation process. Value is what the customer pays for and recognizes the products and services in the dynamic marketplace. Customer centricity demands that R&D be continuously learning about changes in the environment and differentiating the customer needs and expectations. Satisfaction of the customer and exceeding the expectations of the customer were considered as the main business value, hence R&D had to be much more creative and knowledge intensive to come up with appropriate products and services. High priority on cost considerations and the need to be continuously delivering new products, new features, and processors made R&D an integral part of the business. R&D managers had to know the details not only of the business and customers but also of quality and finance requirements. Business intelligence, budgeting, forecasting, and roadmapping became part of the major function of R&D.

2.2.5 *Fifth-Generation R&D: System Integration and Networking*

This generation of R&D according to Rothwell began from the 1990s. The dynamic and changing context, uncertain environment, severe resource constraints, high degree of configuration, and the demanding customers pushed R&D to work continuously to be watchful of the future as well as current complexities. Flexibility was demanded internally to respond to the various demands of the customers as quickly as possible. Speed became the essential element of R&D functioning. R&D had to work in a network fashion with suppliers, partners, and internal and external customers to create new intellectual assets. Knowledge management was considered essential to deliver value propositions. In other words, continuous innovation and delivery of new products and services was part of R&D function. R&D had to create a new future for the organization in a discontinuous business situation. Collaborating internally and externally to acquire new ideas and networking for innovation was more of a necessity than a luxury (Table 2.1).

The different generations of R&D that have been described above are highly influenced by the R&D context, organizational structure, and organizational process. It is important to see how this context, structure, and process have evolved over a period of time, and it is essential to identify their advantages and disadvantages in the R&D context.

2.3 R&D Context, Structure, and Process

The generations in R&D came with a different focus. It is essential to understand the context, structure, and process of the R&D organization or its functioning. Important contextual factors influencing the scope of R&D are ownership, location, pace of technology change, and organization environment.

Table 2.1 The five R&D generations

	First	Second	Third	Fourth	Fifth
	Technology as the asset	Project as the asset	Enterprise as the asset	Customer as the asset	Knowledge as the asset
Core strategy	R&D in isolation	Link to business	Technology/business integration	Integration with customer R&D	Collaborative innovation system
Change factors	Unpredictable serendipity	Inter-dependence	Systematic R&D management	Accelerated Discontinuous global change	Kaleidoscopic Dynamics
Performance	R&D as overhead	Cost-sharing	Balancing risk/reward	Productivity paradox	Intellectual capacity/ impact
Structure	Hierarchical; functionally driven	Matrix	Distributed coordination	Multidimensional communities of practice	Symbiotic networks
People	We/they competition	Proactive cooperation	Structured collaboration	Focus on values and capacity	Self-managing knowledge workers
Process	Minimal communication	Project to project basis	Purposeful R&D/portfolio	Feedback loops and information persistence	Cross-boundary learning and knowledge flow
Technology	Embryonic	Data-based	Information-based	IT as a competitive weapon	Intelligent knowledge processors

Source: The Challenge of Fifth Generation R&D by Rogers (1996)

Table 2.2 Distinctive features of mechanistic and organic management systems

Mechanistic systems	Organic systems
1. High emphasis is placed on subdivision of task and differentiation	1. Low emphasis is placed on specialization or standardization except they realistically contribute to overall tasks and goals
2. Functional specialists are concerned with improving technical means of their tasks	2. Emphasis is placed on special knowledge and experience and their contribution to overall tasks and goals
3. Supervisors at each hierarchical level seek to integrate and reconcile performance of functions reporting to them	3. Individual task activities are continuously redefined through interaction with others
4. Rights, obligation, and technical methods of each functional position are precisely defined and assigned	4. Responsibility and obligation are loosely defined; problems cannot be passed up, down, or laterally
5. Authority, control, and communication are legitimate and hierarchical in nature	5. Authority, control, and communication are derived from common interests and needs and are not based strictly on contractual obligations
6. It is assumed that the necessary knowledge for ultimate reconciliation of functions is at the top of the hierarchy	6. Knowledge and competence are equally distributed throughout the hierarchy. Exact location is contingent on the nature of problem
7. High levels of vertical interaction patterns exist between superior and subordinate	7. High levels of lateral interaction patterns exist between participants: consultation instead of advice
8. Communication content emphasizes directions and orders	8. Communication content emphasizes information and advice
9. Loyalty to the organization and obedience to superiors is a condition of employment	9. Commitment to goals is more important than loyalty and obedience
10. Prestige is attached to achievement of position in the organization (local)	10. Prestige is attached to external technical and professional alleviations (Cosmopolitan)

Source: Burns and Stalker (1961)

Several researchers are interested in identifying a suitable structure for R&D. This emphasis was toward developing organizations, which would promote innovative work. They have examined the characteristics of innovativeness and innovative organization and have prescribed the conditions favorable for creative innovative work. One of the classic studies conducted in this respect is that of Burns and Stalker (1961).

Burns and Stalker (1961), as provided in Table 2.2, refer to bureaucratic structures when they speak of mechanistic organizations where authority, information requirements, technical activities, and competence of any given position are precisely defined. No position occupant may operate outside the limits of his or her position. The main goal of this structure is to maintain stable production. However, such structures tend to be rigid, and this rigidity can backfire to more critics. Some organizations are trying to loosen their structure. Flexibility is characteristic of the organic structure. In organic organizations, individuals define their jobs and then continue to redefine them as circumstances demand. In such a structure, we can however lose predictability and consistency. People are unclear as to exactly what their jobs are; nevertheless, organic structures can be effective under the right circumstances.

The basic prerequisite in organizational design is an effective situational analysis to decide which structural form is to be used. Burns and Stalker (1961) suggest on the basis of their research that the mechanistic systems are best suited for routine problems and stable environments, whereas organic systems are more appropriate for situations involving frequent change and no routine problems (Burns and Stalker 1961).

2.3.1 Context of R&D

The scope, breadth, and depth of R&D activities are influenced by various contexts such as socioeconomic and developmental. Building the defense strength of a country is paramount as it ensures that a country is safeguarded. Security of the citizens also determines their well-being. In this context, there is a growing demand for defense technology. The efforts should be focused and need to be driven with a mission to thwart all security threats. Along with defense, food production is an important aspect in a large economy, and technological developments in the area are imperative. We thus see a need to understand R&D activities in a holistic view.

Important contextual factors influencing the scope of R&D are

- Ownership
  Ownership plays an important role in the manner in which R&D is managed and developed by an organization. Over the years, we have seen national policies primarily focusing on public organizations. With time, private organizations also began focusing on R&D, and now multinational companies are focusing on technology, R&D, and innovation with renewed vigor.
- Location
  Location of R&D is very important as the needs of the customers are better perceived by the scientists. Colocation and continuous interaction will always help idea generation activities and enable innovation efforts of scientists. Centralized R&D and the "ivory tower" approach may not be very conducive to promote ideas, new products, and inventions. Location also influences in terms of the organization being closer to other competitors. Clusters of similar industries help compare best practices and exert pressure on continuous improvement.
- Pace of technology change
  The pace of technology change is an important criterion in R&D; certain industries have lived with the same technologies for ages. The static standardized procedure may result in inefficient processes over a period of time. It is well understood that the sectors which are less capital intensive are more flexible in deriving the benefits

Table 2.3 Environment

	Homogeneous	Heterogeneous
Static	Rigid procedures	Rigid procedures
	Standardization	Standardization
	Few divisions	More divisions
Dynamic	Flexible procedures	Flexible procedures
	Few divisions	More divisions

of fast-changing technologies. Capital-intensive organizations have to access the available technologies and make a better choice. Any investment in outdated technologies can affect the survival of an organization.

- Organizational environment
  This comprises several aspects at both product and organization levels. The number of elements dealing with products and geographic supply changes are cited below. The R&D system is also structured considering external factors. Such factors are relevant depending on whether R&D in an environment is dynamic or static. The model below illustrates the effect of these external factors (see Table 2.3).

2.3.2 Structure of R&D

The structure of an organization is a kind of representation of activities performed in any system. "The organizational structure informs both members and outsiders as to how the organization is inbuilt: particularly pertaining to the relationships which its planners believe its necessity to exist. In a more precise sense, structure is a map of how organizational activities and processes are arranged and linked to one another" (Gerloff 1985). Child (1972) defines structures as "The formal allocation of work roles and the administrative mechanisms to control and integrate work activities including those which cross formal organizational boundaries" (Child 1972).

The most common representation of the organizational structure is the authority pattern in the organizational chart. This chart especially depicts the reporting relationship.

- *Centralization* and *decentralization* are about the authority that is exerted in an organization by specific individuals and the manner in which responsibilities are delegated to them. Centralization in an organization relies on a single individual or small select group to make decisions. An organization is said to be more centralized when the lower-ranking employees are given more authority to make decisions than the senior supervisors. The opposite of centralization is decentralization or shared decision-making.
- *Standardization* defines the rules of the game and the procedures. It is also reflected as the degree of procedurization. In other words, for every given activity, there exists a guideline or return set of instructions or step-by-step instructions on

omissions and commissions. It clearly specifies the dos and don’ts to be followed in order to create, conduct, complete, and close any given activity. Standardization is an extent to which an organization is more bureaucratic in nature and works on standard operating procedures as well as extensive rules.

- *Formalization* is the degree to which an organization relies on and enforces formal written rules, policies, standards, and procedures. This definition consists of two important elements: The first is codification, which is the extent for organization to implement formal written documents that codify its policies. The second is enforcement, in which the degree of organization enforces its policies.
- *Horizontal differentiation (specialization)* in the context of specialization is a more detailed grouping of activities in contrast to generalization.

Differentiation by specialization is often referred to as departmentalization. This brings together people who have similar abilities and who are working together on some specialized tasks. Environment is also a determinant of differentiation. There are five major forms of departmentalization:

1. *Function*: This is when in an organization, various departments are set up based on the function that is being carried out, for example, manufacturing, finance, marketing, and so on.
2. *Process*: In this, the people and jobs are grouped together that meet the required need and help to implement a certain process for example, departments with specific machines or data-processing units.
3. *Location*: This is the “segregation by territories, regions, districts, or countries.” This works and bends the location barrier.
4. *Product or service*: This is the differentiation where the product is the primary concern and jobs are accordingly grouped.
5. *Client*: In this case, the activities and positions are grouped together in such a way that it is compatible with the unique needs of specific clients.

- *Vertical differentiation* is defined as the number of designations we have from top to bottom. It focuses on the hierarchical nature of an organization and command structure, including its segmentation, concentration, and height. Organizations with elaborate chains of command are more vertically differentiated than those with “flatter” command structures. Segmentation is the number of command levels in an organization, concentration is the percentage of personnel located at various levels, and height is the social distance between the lowest- and highest-ranking employees.
- Activities it carries out: standardization
  - Specialization
  - Formalization
- Concentration of authority: The extent to which authority has been passed down to the lower levels (decentralization) or has been retained at the top of the reorganization (centralization).

- Line-and-staff control of workflow.
- Line of supportive components like percentage of clerks and non-R&D personnel.
- Departmentalization.

The above considerations are internal to any R&D system where the structuring is done more with internal consideration. The organizational structure, which is a hierarchy of people and its functions, reveals the character of the organization and its values. Organizations adopt different management structures such as the bureaucratic structure, the functional structure, the divisional structure, and the matrix structure. There are cases when the departments and teams follow a different organization structure compared to the entire organization, whereas some organizations may follow a combination of structures.

2.3.2.1 Bureaucratic Structures

These structures maintain strict hierarchies for people management and are of three types:

- *Prebureaucratic structures:* This is seen in start-up organizations and small-scale organizations. They lack the standards, the structure is centralized, and there is one main decision-maker in the organization. The communication is on a one-to-one basis, and the founder has complete control over the decisions and the operations in the organization.
- *Bureaucratic structures:* This is seen when the organizations grow complex and large and the structure is systematic. This is suitable for all organizations.
- *Postbureaucratic structures:* Organizations adopting this structure adopt the strict hierarchies but are open to modern ideas and ideologies. They follow techniques such as total quality management (TQM), culture management, and so on.

2.3.2.1.1 Advantages

Top-level managers implement a great deal of control over the organizational strategy decisions. This ensures that the strategic decision-making time can be shorter in a tall organizational structure since the individuals involved in the process are less. This also ensures that work is consistently completed efficiently and effectively.

2.3.2.1.2 Disadvantages

This structure can discourage creativity and innovation throughout the organization. Ideas have to be brainstormed and worked out by multiple minds and interdisciplinary groups. Dissatisfaction from rigid work rules could impact turnover rates in the organization. There may be difficulties to adapt to changing conditions in the marketplace, industry, or legal environment.

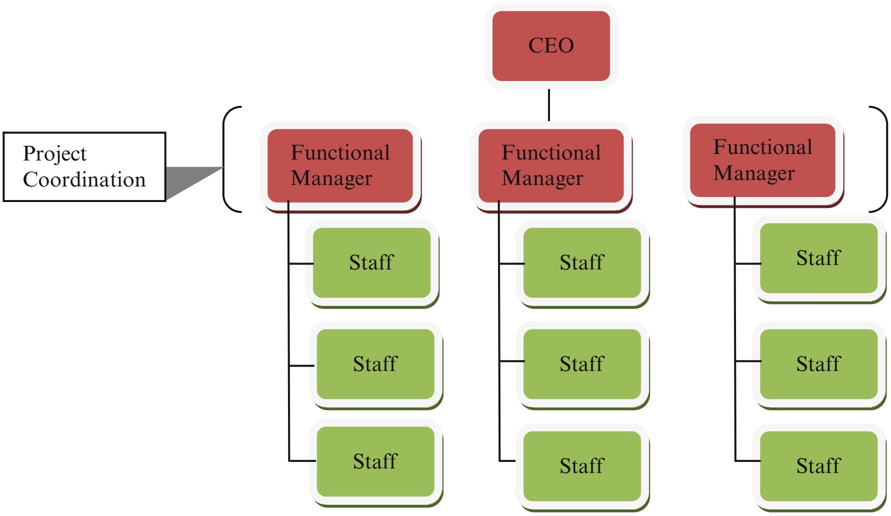

Fig. 2.1 Functional structure

2.3.2.2 Functional Structures

Based on the functions involved, the organization is divided into segments. This in turn enhances the efficiencies of the functional groups. This structure is successful in a large organization that produces high volumes of products at low costs, which is achieved due to the functional group efficiency. However, the disadvantage could emerge in the form of ineffective communication. Figure 2.1 highlights this structure.

The functional structure offers various potential advantages as well as disadvantages:

2.3.2.2.1 Advantages

Specialization

This structure provides a high level of specialization in which each unit is a self-contained miniorganization, and employees in such a structure develop specialized knowledge over time and become experts in a particular functional area. This is advantageous to both the unit and the organization in the long run.

Efficiency and Productivity

When an employee becomes an expert in his functional area, he can perform the tasks with a high level of speed and efficiency, which in turn enhances his work productivity. This also means an increase in the confidence of the employees and lesser mistakes at work.

2.3.2.2.2 Disadvantages

Lack of Teamwork

Functional structure allows different functional units to work efficiently and independently. However, these arrangements are functional independents and may create complexity and difficulty in working with each other. Personal agendas may take precedence, and the resulting infighting may cause projects to fall behind schedule.

Difficult Management Control

As the organization expands, the top management may find it difficult to maintain control. As functional areas increase and the management needs to delegate more decision-making responsibilities to each functional area, the degree of autonomy may also increase, thus making the coordination and control of activities more difficult. Geographic expansions pose greater challenges.

2.3.2.3 Divisional Structures

In these organizations, the functional areas of the organization are divided into divisions. Each division is self-sufficient and equipped with its own resources in order to function independently. The divisions could be based on various considerations such as geographic, products/services, or any other measurement. Thus, we see that each division can be considered as a microcompany with the main organization. Figure 2.2 highlights this structure.

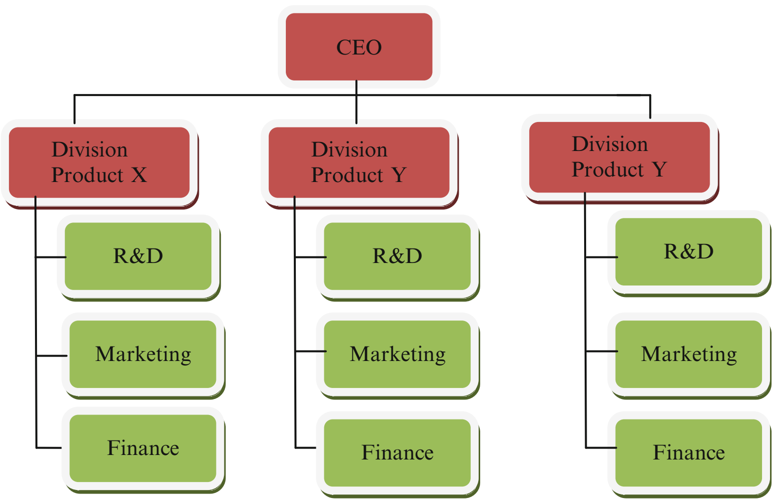

Fig. 2.2 Divisional structure

2.3.2.3.1 Advantages

Divisions work well because they allow a single team to focus on a single product or service with a leadership structure that supports the stated objectives. Each division with its top management focusing on that division is more likely to receive the resources it needs from the organization. There is also a sense of shared culture and *esprit de corps* that ensures higher morale and a better knowledge of the division's portfolio.

2.3.2.3.2 Disadvantages

Allocation of organizational resources may be a challenge with competing divisions engaging in petty politics. Also, divisions can bring compartmentalization that can lead to incompatibilities. For example, “Microsoft's business-software division developed the Social Connector in Microsoft Office Outlook 2010. They were unable to integrate Microsoft SharePoint and Windows Live until months after Social Connector could interface with MySpace and LinkedIn. Some experts suggested that Microsoft's divisional structure contributed to a situation where its own products were incompatible across internal business units” (Gillikin 2013).

2.3.2.4 Matrix Structures

In a matrix-structured organization, the employees are placed based on the function and the product. The matrix structure is thus a combination of functional and divisional structures. Teams become important and focus on task completion. They are based on the functions they belong to and the products they develop. An organization like this comprises several teams working on individual projects. The strengths of the matrix structure include accessibility of specialists, flexible team resources, and better intrateam communication. However, this also requires greater perseverance to handle multiple authorities and function cohesively. Figure 2.3 highlights this structure.

2.3.2.4.1 Advantages

Efficient use of resources means both individuals as well as equipment can be shared across projects. Project integration is present as there is a clear and workable mechanism for coordinating work across functional lines. Improved information flow and communication is enhanced both laterally and vertically. Flexibility in communication helps in decision-making and optimum use of resources. Discipline retention is ensured as functional experts are retained even as projects change. Improved motivation and commitment is there as the members are highly involved.

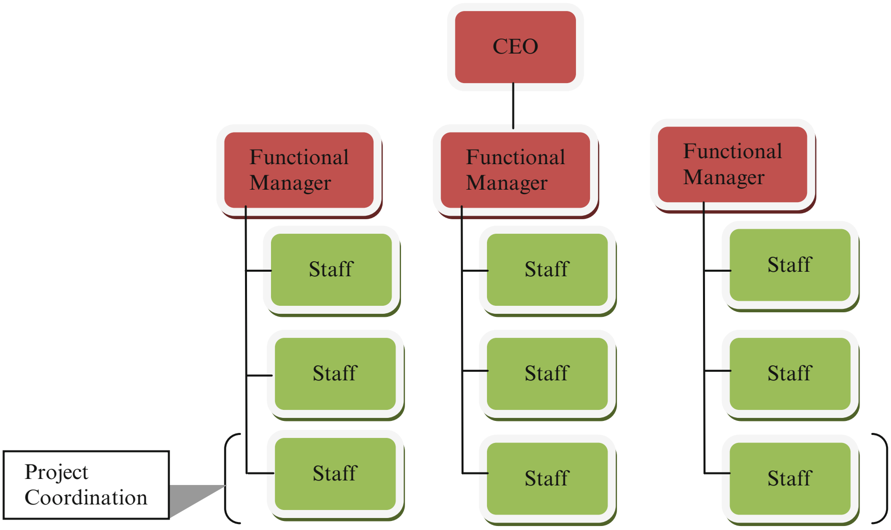

Fig. 2.3 Matrix structure

2.3.2.4.2 Disadvantages

Issues of power struggle and conflicts occur because the boundaries of authority and responsibility overlap. At times, competing over scarce resources, especially valuable personnel, creates heightened conflict. Slow reaction time is a reality as the organization lays emphasis on consultative and shared decision-making. Difficulties are in monitoring and controlling as there is the involvement of multiple disciplines, and evaluating responsibilities becomes difficult. An excessive overhead occurs as there is double management. Due to the dual reporting relations, there is authority ambiguity and role conflict, causing stress for the employees.

2.3.2.5 Networked Organizations

A network-based organizational model is a type of matrix structure that uses digital technology and specialized employees to complete assignments without the need of traditional work spaces. While this model allows employees and managers to function on more even ground, network-based organizational structure can also lead to conflicts due to a lack of formal hierarchy.

A network organization is characterized by independent teams, departments which share common values, projects which support each other, and multiple links between projects. The information and communications technology is used to connect the projects, and the chief executive plays the role of the main coordinator in works to construct the teams and manage the interrelationship of projects. Networks can be both internal and external and have specific characteristics.

2.3.2.5.1 Internal Networks

Internal or intraorganizational networks consist of members of an organization who stand to each other in intensive relations, both horizontal and vertical. Internal networks are particularly characterized by collegial relations and partnership cooperation between equal standing specialists. They are based primarily on personal contacts. Such networks supplement or overlay the existing organizational structure and are therefore the secondary organization to be assigned.

2.3.2.5.2 External Networks

"External or interorganizational networks, on the other side, consist of *several* legally and economically independent enterprises. The subject of such cooperation can be the entire process of the development, the production and marketing of products and services. Cooperation can refer however to only a few functions, so that the cooperating enterprises stand further to each other concerning other functional areas in the competition. Thus synergies or competition advantages are to be achieved, which would not be possible without cooperation due to missing resources. They can be divided according to the place of the activity or according to the cooperation direction" (Network Organization 2011).

2.3.2.5.3 Advantages

Communication and interdependencies are well managed in the network structure contributing to increased efficiency and flexibility. Network structure also tends to be nonhierarchical and promotes egalitarian work culture. People tend to feel more responsible and accountable as they have direct contact with different nodes or people of importance to seek information and solve problems.

2.3.2.5.4 Disadvantages

The dependence on clear lines of communication to deliver project assignments and due dates to employees could often pose problems and delays if computers crash or network traffic errors occur. Too many supervisors could also create confusions, especially if the employees have multiple managers communicating work orders at the same time. Sharing skilled workers is a mandatory aspect, and this could overload the skilled workers. Increased work stress is seen as managers may feel unable to supervise with customary authority, and employees feel as though they are working without any guidance or feedback. Project development and assignment completion can quickly break down in this environment that is not bound by space and time.

2.4 Organizational Process in R&D

The organizational processes include the following dimensions:

- *Goal setting*: Whether the organization follows a participative type of goal setting, where the goals are set by members too (system 4, Likert 1961), or whether it is totally centralized and the management alone has the autonomy of setting goals
- *Decision-making*: Whether the organization is centralized or decentralized in their decision-making, whether or not members are directly involved with it
- *Leadership*: The kind of functions performed by the leader. Whether it is a supportive or a punitive climate and what opportunities are provided by the leader for a leader for the improvement of individuals
- *Motivation*: The type of individuals who exist in the organization, whether they intrinsically dislike work and attempt to avoid it; whether they should be subjected to control, direction, and threat, with a view to mobilizing their efforts toward the attainment of organizational goals; whether they avoid responsibility and possess relatively little ambition; or whether work is a source of satisfaction for the individual, they are self-directed and controlled; and whether they are committed to the goals, keeping in view the rewards related to their achievement. Furthermore, the motivational methods are used in the organization, whether the reward system makes use of positive rewards or negative rewards and so on
- *Communication*: The type of communication patterns that exist in the organization, whether it is upward or downward, whether the information and messages are received by all concerned without distortion, and so on

In the Likert (1961) model, organizational processes can be based on one of the four systems. He found that management styles of an organization can be depicted on a continuum from system 1 through system 4. He suggests that the ideal system toward which an organization can work is system 4, where a highly participative, supportive, interactive climate prevails. Such a structure would facilitate innovativeness in an R&D department (Likert 1961).

Based on studies of schools and other organizations, Likert identified four systems describing management styles in the 1950s. He outlined four systems of management to describe the relationship, involvement, and roles of managers and subordinates in industrial settings.

The four management systems are exploitative authoritative, benevolent authoritative, consultative system, and participative system.

- System 1: Management is seen as having no trust in subordinates.
- System 2: Management has condescending confidence and trust in subordinates.
- System 3: Management is seen as having substantial but not complete trust in subordinates.
- System 4: Subordinates make specific decisions at lower levels.

Litwin and Stringer (1968) have looked at these process aspects in terms of organizational climate.

The suggestions are

- Organic systems are more suited for R&D organizations.
- The structuring can be done based on internal as well as external considerations; however, it is important to balance both internal and external factors.
- Organizational processes and climate have a major influence on the performance and satisfaction of scientists and engineers. It is suggested that a periodic review of these should help the management to promote a better organizational climate in R&D organizations.

2.5 The Future: Ambidextrous Organizations

The changing organizations and the changing R&D structures, processes, and challenges call for innovative ideas. It is essential to understand whether "ambidextrous" organizations are the answer. "Ambidextrous organization designs create distinct units that have their own unique processes, structures and cultures that are specifically intended to support early-stage innovation. These units often comprised of one or more innovation teams, reside within the larger parent organization but have been set up to support the unique approaches, activities and behaviours required when launching a new business." Figure 2.4 depicts the features of an ambidextrous organization, which could translate to how most future R&D organizations will appear.

Ambidextrous organizations establish independent units of which each has its own process, structures, and cultures but is integrated into the existing management hierarchy.

The future R&D as elaborated is an ambidextrous organization, sixth-generation R&D, the integrator, the orchestrator, and the licensor approaches, and supportive organizational processes. All these will move toward R&D becoming a responsive partner.

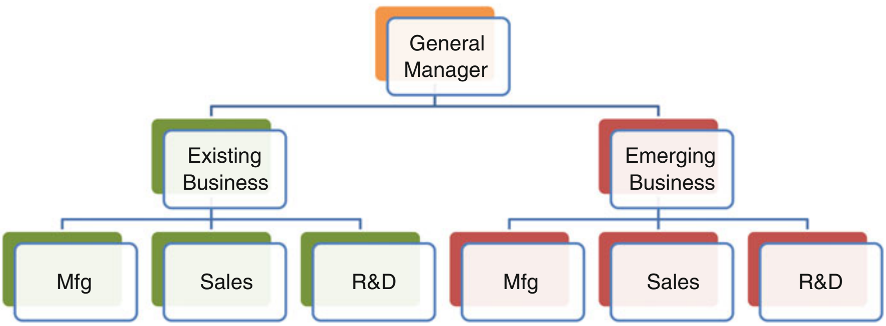

Fig. 2.4 Features of ambidextrous organizations (*Source*: O'Reilly and Tushman 2004)

Questions

1. Discuss the different generations in R&D with the core focus of each generation in prominence.
2. Explain the various important contextual factors influencing the scope of R&D.
3. Compare and contrast various structures of R&D.
4. Briefly explain the features of an ambidextrous organization.

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Chapter 3
Driving the Economy Through R&D Activities

Abstract The major drivers of economic developments are R &D activities. At the introduction, we have emphasized how different R&D activities can drive the economy. R&D activities include resource mobilization and allocation, networking and collaboration, creativity and talent management, and innovation. The present chapter gives a detailed evaluation of challenges faced in R&D activities and how to turn the ideas into financial returns.

Learning Objectives: To understand the role of organizations toward growth of economy through R&D activities; to identify the processes of resource allocation in R&D activities; the choices of approaches toward commercialization of R&D activities toward driving the economic growth.

Keywords Economy growth • Allocation of resource • Resource mobilization • Gap analysis • Product life cycle • Challenges in R&D • Commercialization • Management frameworks

3.1 Introduction

Research & development activities are the major driving force of the economy. It is critical that all sectors of economy build systems and procedures that support new technologies, promote innovation, and build a culture of realizing wealth and improving quality of life through new applications. Transfer of technology through appropriate R&D activities to various sectors of the economy is critical and essential. Researchers, engineers, manufacturers, and customers need to interact and support each other to drive the economy through the application of knowledge and developed solutions. In other words, knowledge-driven solutions have to become the growth engine and promote trade, exchange goods, increase employment, and generate wealth.

The challenge, however, lies in converting the orientation of R&D from the laboratory to the concerns of the industry and society at large. According to industry leaders as mentioned by Battelle, FICCI, and ISB (2011), in management, challenge can be seen as "Lack of an appropriate mindset, Insufficient Resource base, Lack of commercialization capabilities, Lack of intellectual property infrastructure, Lack of incentives, and Absence of collaboration across companies and the Absence of regulatory framework for academia-industry collaboration" (Battelle, FICCI and ISB and Academia Linkages, India R&D 2011, Industry). These challenges

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_3

can be addressed through a collaborative academia–industry environment by setting up incubation centers in educational institutions, providing better access to resources, establishing knowledge networks, and ensuring technology transfer centers. These arrangements will provide incentives to scientists, managers, institutions, and organizations that are involved in R&D function.

On the basis of the abovementioned factors, it is also necessary to understand how technologies relevant to market activities need to be defined. Technologies should deliver a value as perceived by the end customers; in other words, customers should be ready to pay for the utility of a given technology. Market defines the expectations of the customers, hence technology should attract customers as well as other intermediaries in the marketplace through the benefits it can deliver to the end customers. Such an approach would involve applications to satisfy the end customers, develop new products, convert inefficient processes into effective methods, and improve the scalability of developed technologies to reach masses. These activities demand sustaining creative activities, effective talent management, better resource management, and effective transfer of technologies.

R&D activities to drive the economy comprise of the following at the organizational level. Some of the activities include resource mobilization and allocation, make-or-buy decisions, networking and collaboration, creativity and talent management, innovation, IPRM, institutional funding, and efficient management practices.

3.2 Resource Mobilization and Allocation

Resource mobilization and allocation essentially means the effort of the R&D function to make appropriate proposals which have strategic importance. Strategic importance is derived from the regional authority or appropriate government or the top management of the organization. Resource mobilization can be expressed as a percentage of the revenue turnover of the organization or GDP of the nation. Conceptualization of resource allocation has to be in relation to long-term and short-time objectives of the nation or the organization. Some of the sectors like defence and space are influenced by the national objective. Manufacturing service sectors are more likely to be influenced by the organizational objectives. Resource allocation is largely influenced by the demands for the delivery and products and services. Long-term needs may be compromised for short-term requirements. Allocation of resources hence is a balancing act between different priorities.

3.2.1 Resource Allocation to R&D

Investment funds are invariably limited, and these limited funds have to be distributed between short- and long-term returns. R&D has to compete for these funds with production, advertising, and other activities. In this competition, the real problem is that R&D expenditures are not easy to justify on a cost–benefit basis. It is rarely possible to correlate R&D expenditures with profitability because quite apart from R&D, there are several other factors that contribute to profitability such as pricing, marketing successes, tax changes, economic conditions, and so on.

The amount of money to be spent on R&D is one of the most difficult problems that top management faces; hence, this is usually decided through a judgment based on the value system of corporate leadership and through negotiation between the director of R&D and the top management. What is evident is that a "zero" R&D budget is against the interest of the organization because even if R&D only serves the purpose of forecasting the likely technological changes in the areas of concern to management or enhances the capability to choose technologies for import, it justifies a nonzero expenditure.

In the case of absence of an accepted basis for the allocation of a budget to the R&D unit, there are several approaches to address the problem. These include allocation on the basis of interfirm comparisons, fixed percentage of turnover, fixed percentage of profits, reference to previous expenditure levels, and casting of an agreed program.

It would be expected that competitors would spend roughly similar amounts to stay in business and therefore a rough guide on how much expenditure to be incurred on R&D is the competitor's expenditure, R&D manpower, recruitment policies, and so on. But there are several problems with this approach. Different companies compute their R&D expenditure differently; their product mixes may not be the same.

A constant percentage of turnovers is the most frequently used method. Its shortcoming is that the present turnover is the result of past investments, but R&D expenditure must be correlated with future turnover.

Linking R&D expenditure to profits carries the unfortunate implication that R&D activity is a luxury that should be indulged in only when the company is making profits. In fact, present profits may well be the result of less R&D expenditures in the past. Furthermore, the building up of R&D capability is associated with long lead times, and therefore once an R&D team is destroyed, it cannot be rebuilt easily and quickly. For all these reasons, few companies link R&D expenditures to profits although during hard times, the axe often falls first on the R&D budget.

The absence of acceptable criteria makes it even easier to use as a starting point the previous allocation plus a margin to cover inflation, expansion, new equipment, and so on. Finally, it is possible to agree on an R&D program and then frame an R&D budget to suit the agreed program.

Since no single method provides a satisfactory basis, judgment and negotiation will inevitably play an important part in the allocation of an R&D budget. Consideration should however be given to the following expenditure by competitors, adequacy of previous allocations in relation to the needs of R&D strategy, long-term growth objectives, the need for stability and smooth change to avoid violent fluctuations in the R&D budget, which would cause painful contractions or difficult expansions, and distortions due to large projects.

3.2.2 Resource Allocation Within the R&D Unit Between Projects

- *Gap Analysis:* The corporate long-range plan will specify company objectives in terms of a quantitative parameter such as profit over a number of years. This profit is the result of the contributions of a number of products. But most products have a limited life, and the profit contributions from products at the beginning of the planning period will diminish and even disappear in the course of time. Hence, there will be a "gap," which will have to be filled by the introduction of new products. "Gap analysis" thus shows the magnitude of the task facing R&D, which is responsible for ensuring that the required new products are available when required and are the kinds that will make adequate profits. In addition, gap analysis provides a more rational basis for estimating the funds required by R&D.
- *Product Life Cycles:* After an initial period of unprofitable trading when there is low volume and losses, the profit life cycle rises and falls ahead of the volume life cycle because of high margins during the innovation phase and increasing competition during the mature phase. The product life cycle indicates a number of considerations to be borne in mind in making allocations within R&D:

  (a) The different behavior of the profit and volume life cycles.
  (b) While the initial profit growth following breakeven is attractive in the case of successful products, the risk of failure is also high.
  (c) Initial success relies heavily on the ability to develop innovative products, but continued profit ability depends more on manufacturing and marketing to maintain sales volume with low production costs.

- *Single-Product Companies:* Although gap analysis is necessary for understanding needs in a multiproduct company, the pattern of product life cycles shows the problems of a single-product company. Even a single product can go through a succession of changes sufficiently important for each to be regarded as a separate product in its own right, for example, various materials (cotton, rayon, nylon, polyester, and glass) used as tire cords. The tire cord life cycles show the typical form, but in addition, they show that the life span of a tire cord material is about 35 years and a new tire textile is introduced every 10–15 years. Thus, it is important to anticipate the introduction of new technologies, which may threaten established products, estimate the rate at which new products are likely to appear, estimate the rate at which new products will capture the market, and decide when to enter the market with a competitive new product. Timing is essential for these crucial strategic decisions.

The requirement for profit growth can now be combined with the contributions obtainable from each of a family of successive products. But the shapes of the individual profit curves are the result of R&D decisions. They are made to happen, and the shapes of the individual curves are determined by the allocation of resources to individual R&D projects.

There are ways in which R&D decisions (and the allocation of resources to individual R&D projects) influence the shapes of the profit curves of individual products and as a result the shape of the corporate profit curve. R&D investments can influence the following short-term development of an existing product, extension of product life, and early introduction of a new product.

- Late entry with a new product.
- Long-term development of third-generation products.

Short-term development of an existing product may be the response to the threat of pressure from competitors on price and improvements. It may involve R&D effort devoted to product improvement and reduced manufacturing costs.

Extension of product life through R&D is a highly desirable policy because manufacturing facilities for the existing product are a "sunk" cost. But this extension must be undertaken as part of a deliberate policy which ensures that adequate provision is made for the new product, which will eventually replace the existing product.

The early introduction of a new product as an "offensive strategy" is a high-risk strategy with opportunities for a high financial payoff. Late entry with a new product to allow a competitor to pioneer the market is a low-risk/low-payoff defensive strategy. Because it is less demanding to be a follower than an innovator, R&D investment is likely to be lower both with respect to the cost of developing the new product and the involvement of high-caliber technologies. Long-term projects are to safeguard against a future when even the second-generation product becomes obsolete and will need to be replaced. Such projects involve several choices of R&D investment, particularly when it is not clear what form the third-generation product will take. The choices range from initiation of a major R&D program to "wait and see." The alternative actions include

1. Technological forecasting and monitoring to identify and interpret significant developments
2. A minimum "foot in the door" investment in R&D capability to facilitate rapid response to future technological threats
3. A major R&D program to wrest the initiative if funds were unlimited

In practice, a choice has to be made, and it may be necessary to sacrifice short-term interests for long-term gains. Hence, priorities must be developed.

- *Analysis of Resource Allocations:* The reasoning applied to a single-product company is equally applicable to multiproduct concerns, but it is necessary to analyze the spending opportunities under general headings such as short-, medium-, and long-term work, existing and new products, and existing and new technologies. Other possible classifications are between product and process development or between product areas. The analysis of current allocations along these lines is also useful because it can reveal imbalances and indicate the changes that are necessary.

3.3 Challenges of R&D

Challenges of R&D can be classified as being internal or external. Internal factors influencing R&D can be further categorized into resource mobilization, competency development, allocation of resources and prioritization, effective execution of the project, and speedy conversion of ideas into production services. R&D has to face challenges in each of the above areas and deal with it appropriately.

External challenges include policies of the government, regulators and regulating agencies such as enforcement (directorate solution control board), and various other agencies. Public concern about environment, use of scarce or protected resources, and sustainability are some of the other external challenges. R&D needs to consider these external aspects in product design research and development. Apart from the above internal or external aspects, R&D managers also have to face challenges in making effective decisions on buying or developing new technologies, set short- and long-term priorities, and attract and retain top talent.

3.4 The Changing Face of Commercialization of R&D—Choice of Approaches

There are various reasons why R&D has to change with time to meet the needs of customers. Literature has explored the "lost customer," termed the "defectors." The various types of defectors are (1) price defectors—who switch to a low-priced competitor; (2) product defectors—who defect to a superior product offered by a competitor; (3) service defectors—who leave due to poor service; (4) market defectors—who are lost but not to any other business, that is, they may go out of business or to another market; (5) technological defectors—who switch to products offered by companies outside the industry; and (6) organizational defectors—who switch due to internal or external politics.

- *Price defectors:* These customers shift to a competitor who is offering a cheaper price. In most cases, these customers are compulsive "bargain hunters," and one may be better-off by not having them. But in some cases, customers do not see value in patronizing their existing service provider as a competitor is offering similar or better service at cheaper rates.
- *Product defectors:* Product defectors are former customers who are not satisfied with the existing products offered by the firm. This may be due to a bad experience with the product performance or availability of better products from competitors.
- *Service defectors:* Service defectors are former customers who are dissatisfied with the service. The impact of service dissatisfaction is normally very high. At the same time, customers give sufficient opportunity for organizations to retain them. Customers not only expect and demand more, but they are also more articulate in saying so.
- *Market defectors:* In almost every market in every developed country in the world, competition has increased dramatically during the last 10 years. Globalization and

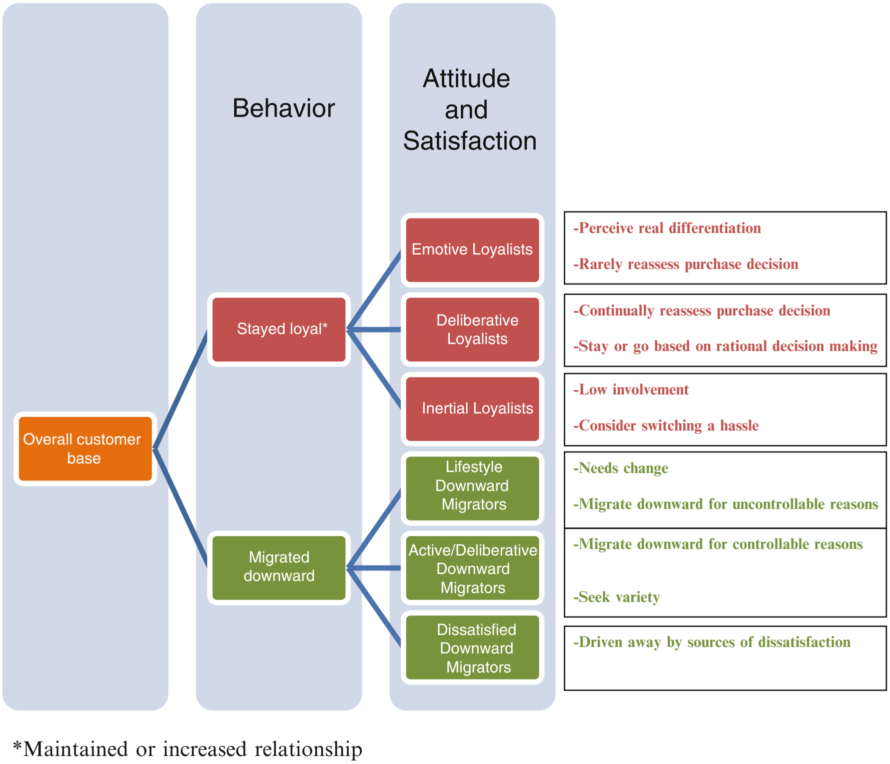

Fig. 3.1 Combining behavior, attitude, and satisfaction provides a new view of customer loyalty (*Source*: McKinsey & Company 2001)

advanced manufacturing technology have resulted in businesses becoming faster and improving product quality. Market defectors have stopped patronizing their former service providers as they have moved away.

- *Technology defectors:* These customers would have shifted to another, normally superior technology, for example, which include customers shifting from a typewriter to a word processor, from a digital diary to a personal digital assistant (PDA), from a line printer to an inkjet printer, from fax to e-mail, and so on.
- *Organizational defectors:* If the customer wishes, buying the simplest product or service can be a very complex decision-making process. Individual users who belong to a group (organization, club, association, etc.) may shift to an alternate supplier because the group has switched. If the company can divide the customer base into several profitable customer segments, it can refine its marketing message to these “segments of several” rather than to “segments of one.”

It has been observed that understanding behavior, attitude, and satisfaction could provide a new view of customer loyalty, as can be seen in Fig. 3.1.

R&D is thus in a phase where it has to make changes at the corporate level, in its marketing functions, the R&D strategy, how it deals with financial aspects, manufacturing roles in the organization, and, along with this, the regulations involved.

3.5 Turning Ideas into Financial Returns

We have seen how the organizational structure and processes have evolved over the years and the changes that each R&D generation has brought in, focusing on different human, intellectual, and social assets. Management frameworks have also been developed, which helped in understanding how an organization takes a product to the market, thereby realizing the concept of turning ideas into financial returns.

An approach like this with a focus on technology is required in the following situations:

- New products or services are being launched.
- Improvements in existing products or services are being introduced.

New commercial opportunities and disruptive technologies are being explained in three popular approaches, that is, integrator, orchestrator, and licensor (see Table 3.1).

Table 3.1 illustrates the roles of integrator, orchestrator, and licensor. R&D policies need to be framed around these three distinct roles. Role differentiation and definitions would help R&D scientists involved in R&D activities to focus their

Table 3.1 Highlights meaning, investments required, capability required and the situation when it is best used

Integrator	Orchestrator	Licensor
Description		
Manage all the steps necessary to generate profits from an idea	Focus on some steps and link with partners to implement the rest	to another company to take it to market
Investment requirements		
High. Capital may be needed to set up new manufacturing facilities, for instance	*Medium*. Capital may be needed only to market the product, for example	*Low*. Manufacturing and marketing expenses are borne by other companies
Capability requirements		
Strong cross-functional links within the organization	Ability to collaborate with several partners simultaneously, while not having direct control	Intellectual property management skills
Product design	Complex project management skills	Basic research
Manufacturing-process design skills	Customer insight	capabilities
Technical talent sourcing	Brand management	Contracting skills
–	Culture that can let go of certain areas, while focusing on core competencies	Ability to influence standards
	Ability to move quickly; nimbleness	–

(continued)

Table 3.1 (continued)

Integrator	Orchestrator	Licensor
Best used when		
Speed-to-market is not critical	There is a mature supplier/ partner base	There is strong intellectual property protection
Technology is proven	There is intense competition—a need for constant innovation	Importance of innovator's brand is low
Customer preferences are stable	Strong substitutes exist	Market is new to the innovator
Innovation is incremental	Technology is in early stages	Significant infrastructure is needed but not yet developed

Source: Andrew and Sirkin (2003)

energy and deliver the required results. Effective R&D will drive the economy through being relevant to the market opportunities and better management of its resources.

Questions

1. Summarize the various challenges and problems faced in R&D activities.
2. Explore the various reasons why R&D has to change.

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Chapter 4
Strategic Aspects of R&D Management

Abstract Learning is a key to transformation. Understanding the role of learning in an organization is very important for continuous growth and development. The learning organizations (LOs) are adaptive, quick, and flexible. There are different levels of learning that are determined by the level of complexities carried out in each task or operations. In this chapter, we have explained the levels of learning and types of complexity. Planning is the first step to lead a goal to action. We have discussed the role of corporate planning and corporate strategy as a key enabler for learning organizations in R&D.

Learning Objectives: To understand the learning organization and its importance; to understand the strategic aspects of R&D management; identify the right R&D strategy for the benefits of an organization.

Keywords Strategic aspects of R&D • Benefits of an organization • Learning organizations • Levels of learning • Types of complexities • Corporate planning • R&D as a business • Corporate strategy • Roles of corporate • Factors for R&D strategy • Formulation and selection of R&D strategy

4.1 Introduction

Organizations today are renewing their focus to ensure that they have reliable mechanisms that R&D management focuses on, both for rapid innovation and building the technological strength with a long-term vision. This concern is shared by R&D managers, the customers, and sponsors of organizations. It will ensure competitive advantage for the organization and help build strategic business units (SBUs). The focus is on long-term strategic positioning of the organization and making it an effective R&D organization. With this purpose in mind, the role of learning becomes important and it is essential to understand the tenets of "learning organization."

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_4

4.2 The Learning Organization

A learning organization (LO) facilitates the learning activities of its members and functions in a phase of continued transformation. The term “learning organization” was coined by Peter Senge and he defined it as, “Learning organizations are organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to see the whole together” (Peter Senge 2006). This encourages organizations to shift to a more interconnected way of thinking.

Researchers over the years have worked to understand various facets of the learning organization (LO). The three building blocks of LO as identified by Garvin et al. (2008) are stated below:

- Learning environment in an organization: This is defined by three important factors: they are dependent on the climate for learning that is present in the organization, on how the employees value the differences that each individual brings to the organization, and the importance of being open to new ideas.
- Learning processes in the organization: This focuses on the structure and the learning processes in an organization. Importance is given to experimentation, and having systematic procedures for collecting that information and analyzing the same are some of the major activities. Education and training and sharing of relevant information across organizational employees are the important aspects in this process.
- Leadership for learning in the organization: This is the third component and reflects how the leaders in the organization communicate the importance and value of learning.

The learning process has been identified to have three different levels—single loop, double loop, and triple loop. Figure 4.1 highlights the process.

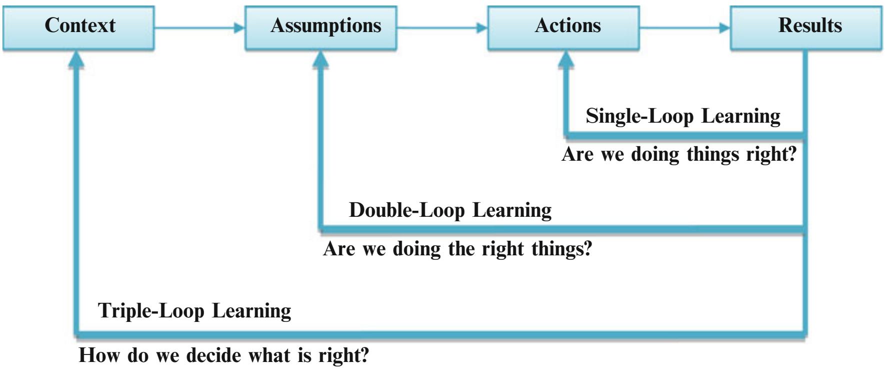

Fig. 4.1 Levels of learning (Source: Levels of Learning, Metro United Way, 2005)

4.3 Levels of Learning

Single-loop learning is the level at which the problem and the solution are close to each other in time and space. It involves the learning of procedures or rules.

Double-loop learning is the level wherein the learning leads to insights about why a solution works. We become learners and observers by analyzing and considering our actions. It is about questioning, understanding the underlying assumptions, having insights and recognizing the patterns, and involving redesigning of an organizational function or structure.

The third level, the triple-loop learning, involves principles. The learning goes beyond the insights we have and the patterns we recognize. With this, we produce new ways of learning and understand the challenges of time and space that affect many a problems and their impending solutions.

The complexity of the tasks determines the level of learning. Simple problems need single-loop learning and may involve focusing on parts of the problem in isolation which rely on past experiences and being open to expert opinions. The more complex problems involve double- or triple-loop learning. This works in new contexts; it is about making learning an integral activity and the focus is on achieving results. There are three types of complexities identified, and the processes involve focusing on understanding all the parts as a single system, understand that solutions emerge and situations evolve, and it involves the concerned people in developing the solutions to the problem in hand.

Table 4.1 highlights the complexities.

Table 4.1 Type of complexity

Type of complexity	Low	High
Dynamic	Cause and effect are close together in space and time	Cause and effect are far apart in space and time
Focus is on various parts or the whole system?	Solutions can be found by testing and fixing one part at a time	A solution can be found only when situation is understood systemically, taking account of the interrelationships among the parts and the functioning of the system as a whole
Generative	Future is familiar and predictable	Future is unfamiliar and unpredictable
Solutions are planned or emergent?	Solutions from the past or other places can be repeated or replicated	Solutions cannot be calculated in advance, based on what has worked in the past. Emergent solutions have to worked out as situations unfold
Social	People involved have common assumptions, values, rationales, and objectives	People involved look at things very differently
Solutions come from leaders or from participants?	A leader or expert can propose a solution with which everyone agrees	Solutions cannot be given by authorities; the people involved must participate in creating and implementing solutions

Source: Levels of Learning, Metro United Way, 2005
Adapted from Kahane (2004)

While we see how organizations today are evolving in the learning process, the strategic aspects of R&D become even more important. These involve corporate planning, understanding R&D as business, R&D strategy as being a part of corporate strategy and not working in isolation, resource allocation process of R&D, and resource allocation across individual units.

4.4 Corporate Planning

Corporate analysis and planning involves a systematic examination and integration of several interrelated elements, such as a corporation, goals, environment, analysis, planning, strategy, policy, policy agent, policy instrument, and implementation. A corporation in the general sense is the entity/body/agency/institution for which planning is being carried out.

A goal is a specific medium- to long-term objective, which is the endpoint to be achieved. Corporate goals must be specific so that, in the case of a firm, for example, there is definition of products and markets with quantified targets related to a specified timetable for the achievement of market shares, turnover, profit, and so on. Thus, not only should the endpoint to be reached be specified (i.e., where the corporation should go), but also at what time the goal should be achieved (i.e., when the corporation should reach the goal) must also be specified.

Analysis involves a study of the strengths and weaknesses of the corporation (i.e., what the corporation can do), and of the opportunities and threats in the environment (i.e., what the corporation might do considering the dangers it faces), and the process is often referred to as SWOT analysis. A strategy is a path for attaining the objective. The chosen strategy must depend on the strengths, weaknesses, opportunities, and threats, that is, it must depend on the outcome of the SWOT analysis.

Planning deals with the selection of a corporate strategy (i.e., how to reach the goal) on the basis of a consideration of alternative strategies. In the case of firm-level planning, the alternative strategies for products could include producing more and marketing more, reducing manufacturing costs, vertical integration of the various steps in production and marketing for the same volume of output, and enlarging the product range and the market. Other alternative strategies could include new markets or the acquisition of new companies through mergers and acquisitions.

A policy is a specific and concrete course of action to implement the strategy. Thus, goals, strategies, and policies constitute a hierarchy in which one proceeds from goals to strategies to policies.

Corporate planning depends on R&D because R&D can come up with (1) new products and (2) new manufacturing techniques to increase productivity and/or to decrease costs. R&D may also identify new threats and opportunities of which the corporation would otherwise have been unaware. It follows that R&D planning must be incorporated into the corporate planning process. But, the outcome of R&D

is not certain and, therefore how does one plan the unplannable? How does one allow for the chance element in R&D?

4.5 R&D as a Business

In R&D, there is a fundamental difference between managing the non-routine creative process in an organization and the routine operations of a factory. In an organization, the managers too do not know the precise answer beforehand (in fact, the purpose of R&D is to find answers), whereas in a factory managers can give preset instructions. Thus, in the management of R&D, managers have to depend on the creativity of those whom they are managing. The creativity requires an environment of freedom for it to fructify. At the same time, there is the necessity of moving toward the goals of the organization.

One way of making the freedom of the participants in R&D compatible with corporate goals is by transforming R&D into a side business that is distinct from the main business of the corporate entity.

Generally, the corporation not only transmits to its R&D organization but also provides funds for R&D. The corporation can insist that the bulk (say 90 %) of these funds is strictly committed to projects that are related to corporate needs. But, there can be a small fraction of these funds (say 10 %) that is left to the discretion of the R&D organization to spend on projects of its own choice even if they are not apparently related with corporate goals. Within the R&D organization, scientists and engineers can be permitted to spend about 10 % of their time on personal research even if it is unrelated to corporate goals. Second, the scientists and engineers feel that their desire to pursue topics that interest them is not curtailed. Third, provision has been made for serendipity, that is, the important faculty of making unexpected discoveries by accident.

The planned "corporate" and unplanned "free" projects in such set-up fall into different categories depending on the outcome of the R&D. A certain number of planned and unplanned projects turn out to be failures and will not yield any commercial value. Many "corporate" projects advance corporate goals, some unplanned projects end up as contributing to corporate needs, other unplanned projects may produce results that necessitate the modification of corporate goals, and a category of unplanned "free" projects turn out to be successes and commercially exploitable, although the resulting technologies are not connected with corporate goals.

Thus, a corporation with R&D activity is really in two businesses; a main business is defined by corporate goals and directed toward satisfaction of identified market needs, and a side business in which it generates and sells technologies of commercial value. This two-business approach combines serendipity and personal research with corporate work and also permits freedom to be consistent with corporate goals.

4.6 R&D Strategy as a Component of Corporate Strategy

Although a consciously evolved R&D strategy requires a considerable amount of effort, four reasons can be advanced for believing that the resulting advantages are worth the effort. First, profit maximization is inadequate as a goal; second, forward planning is essential in endeavors with a long gestation time; third, apart from responding to environmental changes, it is vital to influence them; and fourth, explicit and visible goals serve as an inspiration to organizational effort.

If the responsibility of the selection of R&D projects is entrusted entirely to the R&D department, then the decisions are likely to be taken on a project-by-project basis. The sole criterion is likely to be the individual merit of a project, rather than its contribution to a balanced set of portfolio of projects advancing corporate goals. The problem is that projects are interdependent via resource constraints. Thus, in practice, funds are restricted and projects compete with each other for equipment, manpower, materials, infrastructure, and project management. Maximization of the contribution of a whole portfolio is invariably more important than the maximization of the contribution of separate projects. In fact, a portfolio can develop group characteristics, either by design or by chance. And, these characteristics may involve short-, medium-, or long-term considerations, or a balanced emphasis on all these.

A linkage between corporate goals expressed through a corporate strategy and the choice of a portfolio of projects can be achieved via the R&D strategy. The R&D strategy thus performs a role for the R&D unit, similar to the role that the corporate strategy plays for the organization as a whole (Table 4.2).

4.7 Factors to Be Considered in Formulating an R&D Strategy

There are three main informational inputs to the R&D strategy which are as follows:

Table 4.2 Roles of corporate and R&D strategies

Area of influence	Corporate strategy	R&D strategy
Goals	Related to business environment	Related to corporate environment
Resources	Allocation between functions (marketing, production, R&D, etc.)	Allocations between projects
Business areas	Product/market strategy	Technology/product strategy
	Product/market mix	Project portfolio
Time scale	Long-/medium-/short-term balance	Long-/medium-/short-term balance

1. Environmental forecasts (opportunities and threats)
2. Capability analysis (strengths and weakness)
3. The corporate strategy (goals)

Strategy formulation is an iterative process. The potential projects must be considered in formulating the strategy, after all it is the projects that make the strategy feasible. Further, the likely allocation of resources to R&D must be considered in choosing an R&D strategy.

4.7.1 Environmental Forecasts

Just as environmental forecasting is necessary for corporate planning, to establish what can be done to exploit the opportunities and meet the threats arising from possible future changes in the environment, the R&D strategy, which is an extension and integral part of the planning process, uses forecasts in a similar fashion.

R&D is concerned primarily with changes in technology which will occur in the future. But, technology cannot be forecast in isolation of economic, social, and even political factors. Hence, technological forecasting must cover much of the same ground as general business forecasting. Knowledge of how competitors will respond to environmental change would be extremely valuable. This knowledge is very difficult to obtain, but what is possible is a deduction of what logical reactions competitors might be expected to produce.

It is not easy to answer the question: which is the competition? The stiffest competition may arise from unexpected quarters, and forecasting can reveal new competitive technologies, innovation by invasion and businesses arising from them, identification of future threats and opportunities, avoidance of technological surprises, and identification of new competitive technologies and businesses.

4.7.2 Comparative Technological Cost-Effectiveness

Similar to products, technologies too have life cycles. The body of knowledge in a technology increases until it reaches a point where further research yields new knowledge whose incremental commercial benefit becomes negligible. When this stage is reached, investment in a new branch of knowledge is likely to offer far more promising opportunities for new products, processes, or product improvements. Such a reorientation is not easy to achieve. The relevance of advances that a new technology brings may be completely missed if the company has no experience in it. “Technological forecasting” can help in spotting the relevant trends but does not help in suggesting what should be done about the new trends. The response rate of an R&D department may be very slow because their major assets, people, have vested interests in certain skills profiles, and the new trends invariably demand new profiles. The skill profile of a particular set of R&D personnel can be changed only within a narrow range. And the personnel cannot be replaced easily. Technologists are not made redundant even when their expertise becomes of decreasing value. In fact, even the decrease in value of expertise may neither be noticed nor acknowledged. The obsolescence of R&D expertise is not as easy to detect as that of plant and machinery. Thus, long after the economic returns from a technology have diminished, R&D department may still be coming up with new projects pertaining to that technology.

These difficulties tend to occur in large mature organizations that are no longer growing rapidly, and this constitutes an aggravation because change can be accommodated more easily in growing organizations. Although the imbalance between dying and emerging technologies can be redressed by the induction of new specialists, the mature organization aiming to provide security for its employees finds it difficult to make the necessary responses. The situation can be alleviated by re-training (education does not cease with graduation), re-employment (in different areas not necessarily of R&D), and recruitment.

4.7.3 Risk Versus Payoff

Risk, which can be analyzed quantitatively by weighing the expected payoffs against the probabilities of the occurrence of the outcomes, is inherent in R&D strategies. Risk is associated not only with respect to the individual projects, but also with the portfolio.

The risk associated with portfolio of projects must be a major concern of the R&D strategy, and should reflect the corporate attitude. But this risk is spread over a mix of projects, each of which is associated with its own level of risk. A multi-project laboratory can achieve a mix of offensive, high-risk and defensive, low-risk projects; the mix reflecting the risk propensity of the corporate and R&D strategies.

"Risk analysis" might suggest that a large company, able to spread its risk over a larger number of projects, would opt for an offensive strategy, in contrast to a small company which would favor a defensive strategy. In practice, the opposite may also be true. Mature organizations may be more risk averse, and there tends to be an attenuation of the willingness to accept risk as one goes down the hierarchy.

Planning can never eliminate risk from business decisions. But, at least one can hope that a process of rational analysis will enable the avoidance of most of the obvious pitfalls and an assessment of the risks inherent in the identifiable uncertainties. But, however careful the analysis, there is always something which is either overlooked or could not have been anticipated. The planning process ought to lead to a quantification of knowing risks, but it would be mistaken to assume that this can reflect ever possible eventuality.

4.7.4 Capability Analysis

Before a strategy is formulated, it is vital to make an objective and realistic assessment of strengths and weaknesses from the standpoint of present and future requirements. The strengths and weaknesses of the corporation have a bearing on the R&D strategy, for example, a company strong in marketing and production is unlikely to succeed with product innovation, and a company with strong R&D will be better suited to coming up with innovative products. However, there are also the strengths of the R&D unit which should be apprised. Such an appraisal represents not only the current strength, but also the technological capital, that is, the technological capabilities required to meet future challenges. The gap between the current strengths and the future requirements of technological capital highlights how relevant the present capabilities are for the future and also what build-up of capability is necessary. Obviously, strategy formulation and R&D strengths must be part of a combined exercise.

4.8 Selecting the R&D Strategy

The formulation and selection of an R&D strategy is a process of iteration rather than a one-shot decision-making process. Such an iterative process leading to the evolution of a strategy is natural considering the interrelationship between corporate strategy, environmental analyses, capability audits, the portfolio, and individual projects. Also, the choice between different types of strategies, for example, between offensive and defensive strategies, may be more a question of emphasis than of exclusive selection.

4.8.1 Offensive Strategy

High-risk, high-potential payoff strategies demand strengths in technological innovation, the ability to see new market opportunities in technological terms and the competence to translate these insights into commercial products. Studies on the effect of company size on innovation show that many of the major innovations of the past few decades have come from small companies. However, some market leaders may not be able to avoid an offensive strategy to prevent their position being destroyed by a new product from a competitor. Between the extremes of a small company and the market leader, there is a broad range where there are special reasons arguing for an offensive strategy.

4.8.2 Defensive Strategy

A low-risk, low-payoff defensive strategy is suitable for a company with strengths in production and marketing (rather than R&D), able to earn profits under conditions of stiff competition through low manufacturing costs. However, from the point of view of long-term survival, it must build up sufficient technological “muscle” (particularly at development as distinct from research) to make a quick response to a competitor’s innovation.

4.8.3 Absorptive Strategy

Licensing offers many opportunities through the purchase of results of another company’s R&D investments. In other words, a company need not rely only on innovations generated from in-house R&D. However, internal technological strength is required to identify what to license, and to absorb what has been obtained through licensing.

4.8.4 Interstitial Strategy

An interstitial strategy is based on avoiding direct confrontation, particularly with the market leaders. Instead, the aim of a company following this strategy should be to find a niche in the market suitable to its strengths and corresponding to the weakness of its competitors.

4.8.5 Market Creation

Sometimes, but not frequently, a chance arises for creating a completely new market rather than substituting for an existing market.

4.8.6 Maverick Strategy

There are situations in which the characteristics of new technology reduce the market for the product to which that technology is applied. Since the market leader stands to lose a great deal, it is unlikely to introduce the new technology. But, a maverick has nothing at stakes and an introduction of the new technology represents growth for the maverick even though the total market for that product may be reduced.

4.8.7 Acquisition of People

Instead of buying a competitor's technology, a company may acquire his key staff or even a whole project team. Sometimes, such an acquisition may also suit the competitor because a change in his policies may make some of his human technological capital redundant. Thus, many of the competitor's personnel problems may be solved by their being acquired by another company.

4.8.8 Acquisition of Companies

Technology may be one of the reasons why a large company may wish to buy a smaller firm, which may be highly innovative, but may be unable to sustain R&D costs to conduct the production and marketing. In such a situation, the large firm may use its financial strength to purchase the technological assets of the smaller firm.

It can thus be seen how understanding R&D strategy and adopting the right type of strategy is beneficial for organizations. An organization needs to critically analyze the internal strength in terms of human and capital resources, evaluate its focus, and align activities to meet short-term and long-term goals of the organization. Organizational learning capabilities can be assessed and promoted to realize the goals on the one hand and sustain the activities on the other.

Questions

1. Explain the various levels of learning based on the complexities of tasks.
2. Discuss the various factors to be considered in formulating an R&D strategy.
3. Briefly explain the different strategies in R&D.

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Chapter 5
Project Planning and Budgeting

Abstract Project planning is one of the important aspects of R&D functions. This chapter gives an overview of internal resources and organizational objectives of project planning. The end results of project planning are project deliverables. The project deliverables feature scheduling, planning human resource, communication methods, and risk management. An excellent project planning needs an effective budgeting system and review process. Furthermore, this chapter gives an objective analysis of end-to-end mechanics of budgeting process, modern planning, and alternative approaches. At the end, this chapter covers quantitative methods like AHP and GANTT charts, which objectively assess the process and outcome of a project.

Learning Objectives: To understand project planning definition and stages; to describe R&D project planning and the planning process; to present a holistic picture on the budgeting system, traditional budgeting systems and its categories, mechanics of the budgeting process, modern planning and budgeting systems, and alternative approaches.

Keywords R&D project planning • R&D budgeting system • R&D project deliverables • Budgeting system and its classification • Different approaches for budgeting process • Benefits of planning, programming, and budgeting systems • Pictorial representation of project planning and monitoring process • Project preview and control

5.1 Introduction

Project planning is mainly concerned with understanding the scope of the activities and steps to achieve the identified objectives in a given time frame. It also involves dividing series of interrelated levels of activities and allocation of resources to complete the stated activities. This involves various activities such as setting objectives that can be measured, identifying the essential deliverables of the project, schedule of the project, planning human resources, communication methods, and risk management.

Setting objectives is an important aspect of project planning. Objectives must be derived with a view of internal resources and organizational objectives. Objectives must be derived on the basis of past achievements and failures. The stated objectives

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_5

must be simple and help the members of the team or the organization to clarify the roles and responsibilities. Specific statements must be stated as it enables better planning and resource management. Objectives also help in controlling functions as it enables the members to understand how far they can meet the expectations and the shortcomings in their efforts toward achieving their stated goals.

The objectives should not be too broad and should avoid vague and ambiguous expectations. To the extent possible, objectives need to be stated as specific and measurable statements and should enable the review and corrective actions to be taken by the team member. Setting objectives must be considered as a mode of systematic activity in R&D management involving all the team members. It is extremely important to engage and involve team members as most of the members in R&D have higher educational qualifications and do carry strong opinions about what and how the objectives must be achieved.

Documentation of the objectives is another aspect of project planning. Documentation enables the review processes as well as recognition of the individual and the group contribution after the achievement of the objectives. Absence of the documentation may result in defensive and evasive behaviors among the team members.

5.2 Project Deliverables

Project deliverables are end results stated in terms of quality parameters, volume, and features. Articulating deliverables has to be clearly stated in terms of the time constraints in R&D activities as getting the resources timely will enhance overall planning and execution. Deliverables should be compared with other near products and features. In R&D activities, benchmarking and comparison of the methods, standards, features, and product details will enhance the definition of deliverables. A breakdown structure of various activities, building some modularity in product having a subsystem view will all enable an organization to have a better definition of deliverables.

5.2.1 Scheduling

Scheduling is the major activity of the project planning process. Effective scheduling demands a clear view of the various activities and the task structure involved in any project activity. It also involves estimating the complexity involved in each of the activities. Scheduling then will link the identified activities in a sequence by recognizing various dimensions such as competence of the people, challenges of the resource mobilization, interdependency between various activities, and clarifying the order in which the activities need to be completed.

5.2.2 Planning Human Resource

Project planning necessarily involves identifying and allocating the human resources in R&D. In R&D, it is important to analyze the human resources based on the expertise and the competence of scientists and engineers. Human resource planning itself should support the project planning activities; in other words, it should clearly analyze a demand plan of each of the projects and a supply plan of the various competencies required; matching these two plans may also result in some developmental efforts of the project members as well as the skills and competencies from other teams. At times, the plans should also identify hiring outside expert and consultants for the smooth conduct of the project.

5.2.3 Communication Methods

Communication methods are another important and most neglected aspect of the project planning process. Communication should provide the major objectives of the project, resource availability, expectations of the senior management, detailed work breakdown structures, important milestones and methods of review, decision authorities, and specific timelines. Communication in project planning cannot be viewed as a passive process. It cannot be a one-way communication process from top management to other scientists and engineers. It has to be involved, engaged, dynamic, and a two-way process. Scientists and engineers should be able to escalate the problems in case of deviations arising in the implementation process. Ineffectiveness in the planning process can be corrected through a continuous review process.

5.2.4 Risk Management

Risk is a term associated with "Uncertainty." Effective planning demands the understanding of uncertainties that can arise in project management and execution. Timely availability of information is an essential element of risk management in project planning. Gathering information at the time of project planning involves dealing with two kinds of uncertainties. The first is the rate of change in the technology and also the attitude and competencies of the team members. The second aspect comes because of lack of confidence in the action to achieve a particular result. This lack of confidence may be because of, illustratively, nonavailability of tools, complexity of conducting experimental work, or competencies of people involved in the project. Proper information management is essential for risk mitigation. Connecting the cause and the effect will also help in better certainty and lesser risk. Forecasting techniques, benchmarking, assessment of previous achievements, and analysis of the modes of failure in the previous project will all help in understanding complexities and uncertainties. When these techniques are deployed, it will enable better project planning process.

5.3 The Budgeting System

A budget is a systematic method of allocating financial, physical, and human resources to achieve the strategic goals of an organization (Andersen 2000a, b). Organizations need to develop budgets to monitor progress toward their goals, help control spending, and predict cash flow and profit. Effective budgeting is not without benefits. It often leads to better understanding of the strategic goals of the company, leading to coordinated support toward these goals. It is often perceived that the higher the R&D budget, the higher is the likelihood of a firm to introduce successful new products. Yet, a study of Booz Allen Hamilton Global Innovation 1000 is contrary to this popular belief. Some of the popular approaches to the budgeting process have been matched to the competitor's level of expenditures or the budget is a percentage of the sales. High expenditure is no assurance of success and R&D budget as percentage of sales is a wrong criterion for determining the size of the R&D budget. Increasing the R&D budget to meet the competitor's level often leads to wasted resources (Wind 1990).

Some of the critical questions to be considered by the top management are as follows:

- What is the R&D budget required to achieve the strategic objectives of the organization?
- Is the budget allocation optimal?
- Can effectiveness of R&D be increased?

According to Microsoft, as illustrated in their website (office.microsoft.com), the project budgeting has to consider the work resources, the material resources, and the cost involved therein. These are of three types:

- *Resource rates*: The cost of a work resource is based on the amount of time that the resource spends working on the project. Rate-based material costs are the costs of consumable material resources, such as building materials or supplies, to which one has assigned standard rates.
- *Fixed costs*: One total cost that represents the price for doing a task or project, regardless of the number of resources assigned, the number of hours worked, or the amount of materials used.
- *Per-use costs*: The single amount that it costs each time you use a resource.

No plan is effectively implementable if it is not backed by an appropriate budgeting process implying the allocation of timely funds to accomplish the objectives. During the 1980s, the budget of an organization was viewed as a formal forecast of income and expenditure. In the present context, one view of the budgeting process is that the annual budget is itself a tactical or short-range plan. The short-range plan must in turn be integrated into the strategic or long-range plan which generally has a time horizon of 5- or 10-year period, sometimes extending beyond these. This strategic or long-range plan must consider societal values along with other costs and benefits.

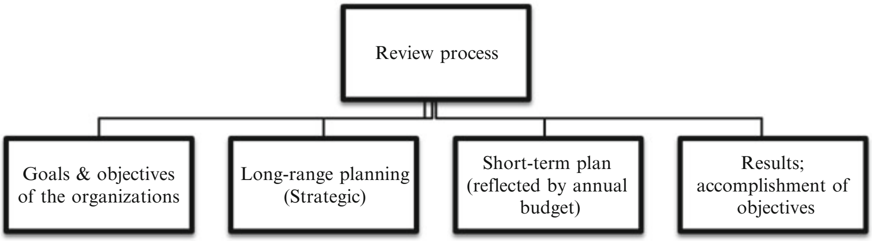

Fig. 5.1 Simplified diagram of the budgeting system

The tactical financial plan and the strategic plan should be blended together by means of programmatic justification in the annual budget. Generally, this is accomplished by proposed expenditures being justified/explained by showing how the budget is related to, and helps accomplish strategic objectives. The procedure can be illustrated through a simplified flow diagram (Fig. 5.1).

5.4 Traditional Budgeting Systems and Categories

The traditional R&D budgeting system can be broadly categorized into one of three different approaches:

- Budgeting by organizational divisions
- Budgeting by type of research
- Budgeting by categories/type of budget

5.4.1 Budgeting by Organizational Divisions

In this process, the allocation of budget is carried out division wise or department wise. The categorization of research work would be organizationally divided into several divisions of departments and the budget allocation is compartmentalized.

5.4.2 Budgeting by Type of Research

In this process, the budget is allocated on the basis of the type of research. Each organization can classify its various R&D projects to belong to one of several types of research work, such as basic/fundamental research, offensive research aimed at innovative breakthrough, defensive research for improving cost-effectiveness, and some research work for the societal image-building process. Accordingly, the budget allocation may be made so as to obtain a judicious mix of these types.

5.4.3 Budgeting by Categories/Type of Budget

These are traditionally based on the categorization of funds available to the R&D organization. For example, in the Indian R&D environment, the budget can be categorized into plan and non-plan, or departmental budgets and projects/scheme budgets, and so on.

Unfortunately, all the traditional budgeting systems described above are descriptive classifications (of the status quo). They do not provide any information on the percentage completion of a project, the probable success of a project, starting of new projects, or other management factors. As a result, they tend to be a descriptive accountant's report rather than a prescriptive or normative policy. As it lacks in policy orientation, the methods are generally useless for decision-making purposes.

5.5 The Mechanics of the Budgeting Process

There are four traditional ways of approaching the mechanics of the budget development process, which influences policy orientation. These can be classified and described as follows:

5.5.1 Self-Funding Division-Oriented Approach

In this system, each definable R&D group in the organization is expected to cover its costs from the benefits of the results of research. The overall management then consists of organizing the supply of needed services to the groups and enforcing the discipline in the marketplace. The R&D management taxes the individual units for services rendered and perhaps builds a small buffer to cover short-term funding gaps. This is a common mode of research management and is practiced in certain universities (such as Harvard), nonprofit research organizations, and also some private in-house R&D of manufacturing organizations. In large and successful R&D organizations, this approach works effectively as it ensures automatic self-regulation of the research group by the market mechanism. However, there are some drawbacks associated with it. It ties the R&D organization as a whole very closely to the short-term whims of the marketplace. It will thus follow the market rather than lead it. Furthermore, this approach encouraged each R&D group leader to attempt to externalize as many cost factors as possible and to hoard group resources. This may lead to a decentralized approach that may not be optimal from the R&D organization's standpoint.

5.5.2 Centralized Allocation Funding

In this process, the budget percolates from the top or head of the R&D organization and moves downward. The R&D allocation is decreed (and therefore this approach is also called the patriarchal decree) by the Head of the organization, with further decisions by other decision makers down the hierarchical process. This system is often used when the budget is assured from above and is the standard approach followed in many government-owned research laboratories. The advantage of the system is that of complete control of direction and balance as well as optimal allocation of resources from the organization standpoint. The disadvantage is that individual initiatives may have to be sacrificed. This may also result in a relaxed pace of research as there are no incentives for progress breakthrough unless there is a drastic change in the policy. This may result in tardiness and consequently poor results.

5.5.3 Allocation by the Force of Demand ("Squeaky Wheel Gets the Grease")

In this procedure, the group that complains the loudest or does the best sales job for the boss gets the maximum budget increase. This tends to be a person-centered approach to R|&D rather than a problem- or goal-oriented approach to funding. The budget is determined incrementally each year based on the previous year's expenditure. The method tends initially to encourage aggressive articulate group leadership if the boss is malleable. But if the boss is strong minded or has preconceived notions/opinions, the success-oriented R&D professionals may leave the organization. Basically, this procedure is a sub optimization mode and not advocated rationally but nevertheless found in practice implicitly in many organizations.

5.5.4 Funding by Formula

Here, the budget allocation is based on the evaluation of certain criteria, which are generally quantitative in nature. In universities, this may include factors such as credits delivered, degrees produced, papers published, number of students, and so on. In government-owned R&D laboratories, the formula may include the number of scientific personnel in the organization, the area in terms of space, volume-related business in the industry, and other factors. In the private sector, the formula may focus on the annual profit and loss statements of the divisions. Formula funding appears to give each group its fair share but often introduces strong, short-term orientation and discourages individual group initiative. In such situations, group leaders may tend to work their way to beat the formula. It should be noted that formulas should not be used as substitutes for good judgment. However, formula funding has some place in reality in determining the need for auxiliary services such as technical, secretarial service, library facilities, equipments, and so on. It is quite possible that an R&D organization may follow a mix of all the four mechanisms of the budgeting process to its advantage.

5.6 Modern Planning and Budgeting Systems

In modern planning and budgeting systems, there exists an explicit and deliberated linkage between the short-range budget and the long-range strategic plan. The modern system is heralded by an integrated systems methodology to planning and budgeting, that is, Planning, Programming and Budgeting Systems (PPBS). The PPBS generally include the following steps:

- *Identification of the goals of the R&D organization*: In this step, the long-term strategic goals as well as the short-term goals for the current planning period are explicitly defined.
- *Definition of success criteria*: Commensurate with the goals and objectives of the organization, performance measures, which explicitly express the goals/ objectives of the project, are defined. A goal that is not definable in terms of quantitative criteria is no goal at all.
- *Explicit consideration of alternative approaches*: To achieve the goals, all possible alternative courses of action are to be considered explicitly. The objective here is to develop different ways of approaching the functional goal without succumbing to the dictates of current technology.
- *Evaluation of options and selection of best alternatives*: The criteria developed in step 2 on the performance measures are to be applied to the alternatives considered in step 3 for systematic evaluation and decision on the best alternative approach.
- *Programmatic description of steps to accomplish goals*: This is called the transition phase, where the plans are systematically detailed with logical/ chronological sequencing of activities of the projects, their estimated duration, resources required, and associated costs. In this step, graphical methods such as PERT (Program Evaluation Review Technique)/CPM (Critical Path Method) networks become important both as tools in planning as well as means for monitoring and control.
- *Projection over several planning periods*: The integration of the short-term plan with the long-term objectives has been implicitly evaluated through projections of the implications of a current project on the future. The plans must develop projections on the likely costs and benefits that are relevant in several planning periods.
- *Iteration*: Planning is an iterative process. After going through the developed plan once completely, one may focus on the reduced number of viable options for a more complete analysis. All the steps and plan of action are revaluated at each stage with an aim for perfection.

- *Action*: A plan is not a program by itself. For effective implementation, it must have an action orientation. It should indicate, as part of its activity description, the action that is contemplated at each stage and also the expected achievements or milestones.

In essence, PPBS can be termed as a rational objective approach to the problem of allocation of scare resources. The PPBS on the program budgeting exercise has some advantages and disadvantages.

5.6.1 Advantages

Advantages of Planning, Programming and Budgeting Systems are many. Below are some:

- The people one deals with in an R&D environment are generally bright self-initiators who tend to be adaptable.
- Rarely heavy capital expenses are involved to initiate a research project and generally several milestones would occur before heavy capital expenses are needed. Thus, with good understanding of PPBS, R&D failure should be rare.
- R&D adapts itself well to task orientation with well-defined time limits and milestones.
- Subjective biases associated with the traditional mechanics of the budgeting process are avoided.
- The budget would be goal-oriented and commensurate with the short- and long-term objectives of the organization.

5.6.2 Disadvantages

Following are the disadvantages of Plannning, Programming and Budgeting Systems:

- PPBS call for explicit knowledge and data. It may need elaborate forms, some unfamiliar jargons and may demand detailed estimates of hard-to-establish facts.
- Unwillingness of scientists to communicate interim results. However, PPBS being an internal exercise, this drawback can be overcome with confidentiality of research work and the monitoring mechanism.
- The tendency of self-motivated scientists to get addicted to their work, to lose objectivity, and to hang on too long to a losing project.

5.7 Alternative Approaches

In the absence of PPBS, some R&D organizations may use the traditional budgeting systems but combine these with some performance measures as measures of effectiveness. Some of the commonly used measures are dollar of new business

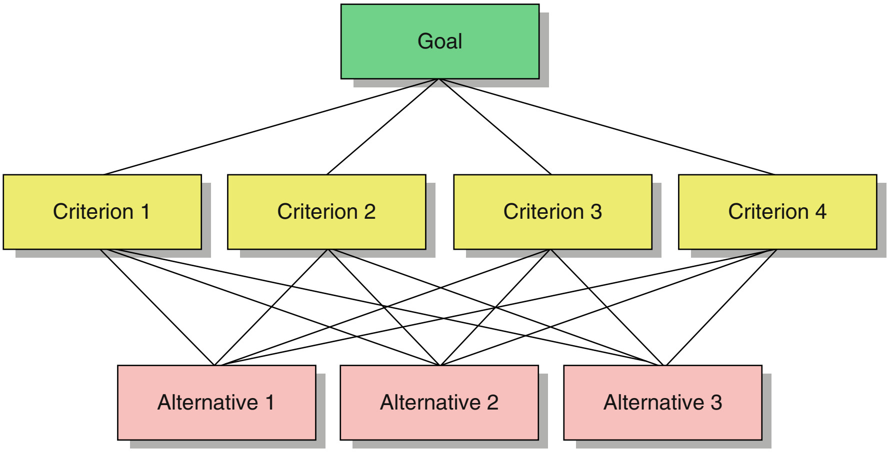

Fig. 5.2 Analytic hierarchy process

generated (or benefit generated) per professional in the group or organization, dollar charged to profitable projects per professional, earnings per dollar of capital investment, and published papers and patents per professional. The other approach could be a detailed comparison method built between different R&D projects. Analytic hierarchy process is described briefly.

5.7.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP), proposed by Dr. Thomas L Saaty in the early 1970s, is a method that facilitates the determination of the total R&D budget, its allocation among the R&D categories and across different R&D projects. The AHP is a three-step process for group-based resource allocation decisions. It consists of the following three steps (Fig. 5.2):

Step 1: The problem is decomposed into a hierarchy of criteria and alternatives.
Step 2: This information is then synthesized to determine relative ranking of alternatives. Using pair-wise comparison, relative importance of one criterion over the other is expressed. Mathematically, this amounts to construction of a matrix incorporating relative importance between two criteria.
Step 3: Finally, a model is applied to this matrix which produces a set of important weights for each element of the hierarchy. Saaty suggested the use of Eigen vectors to determine the relative weights of the elements.

The reader is directed to Saaty (1990) for a detailed description of the AHP process.

Furthermore, sensitivity analysis can also be carried out to assess the impact of changes in the assumptions and judgments on the resulting allocation of resources (Wind 1990).

5.8 The Project Planning and Monitoring Process: Graphical Devices

For any specific R&D project which is approved and taken up, it is essential that appropriate planning, budgeting, scheduling, and monitoring/control exist at timely intervals to ensure that it is progressing toward the desired end. In this process, two graphic tools are advocated and used quite often. The first is the concept of GANNT charts, developed almost a century ago, and the other is the traditionally accepted and established PERT/CPM methods developed in the late 1950s. The three main functions of the graphical aids in R&D is project planning, scheduling, and monitoring, which are communication, analysis, and managerial aid for decision making.

5.8.1 GANTT Charts or Bar Charts

In this method, time is plotted on the horizontal or x-axis and all the tasks or activities are listed, generally in its chronological order, along the vertical or y-axis. Bars are drawn against each task, proportional to the scheduled duration of the task and corresponding to the time periods in which the tasks are to be performed. The general procedure is as follows:

- The task effort bar is an open box that is shaded when the actual performance is made.
- A cursor-indicator of the current time as against the time at which the GANNT chart was started is moved along the time horizon and kept current with lapse of time. In this way, one can tell at a glance as to which activities are current and which are behind or ahead of schedule.
- The anticipated total level of effort for each activity is shown at the right. This is generally in terms of the resource required for the corresponding task.

These are depicted in the form of an example of a GANTT chart:

Resources				
Men:	5	3	1	4
Costs:	100	150	50	–

It is essential for the graphical devices that all the activities of a project with details of its duration, interdependencies, and resources required and an associated cost are estimated and drawn/depicted on the graph. In GANNT charts, the interdependencies cannot be explicitly expressed.

5.9 Project Review and Control

The dynamic nature of research activity necessitates periodic reviews for effective managerial control. The reviews may be undertaken at fixed intervals, at the discretion of research management, or on a rotational basis. These are normally accomplished by internal review committees which are also involved in the planning phase. Some of the most frequently used review methods are as follows:

- Weekly reports from each project leader.
- Monthly progress “programs” with written and/or oral presentations.
- Rotating “technical audits” where each division/group/project is reviewed on a rotational basis at fixed periodic intervals.
- Committee review of segments of each project at fixed intervals.
- Periodic (monthly, quarterly, semiannual, or annual) meetings of top management research committee to review specific projects and the overall research program.

The review process generally includes technical reviews, financial reviews, manpower reviews, and completion date reviews. Furthermore, the review process should also consider the discontinuance of projects. This includes the timing for discontinuing successful projects as well as that for unsuccessful projects.

Project planning and monitoring is an organizational, financial, and step-by-step procedure to achieve objectives in a systematic manner. Practices vary from project to project as well as organization to organization. Procedures and techniques need to be adopted to meet the specific requirements and required rigor in its implementation.

Questions

1. Describe R&D project planning and the planning process.
2. Delineate the mechanics of the budgeting process.
3. State the various advantages and disadvantages of planning, programming, and budgeting systems.
4. Elaborate on the GANNT chart method.

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Chapter 6
Roadmapping

Abstract In the previous chapter, we have emphasized on how planning is essential to make goals into action. But to predict the future, actions need to be carried by R&D organization, which requires an objective vision. This vision is roadmapping. The roadmapping is vital for R&D growth. This chapter gives a brief introduction of the aspects of roadmapping, the factors influencing roadmapping, and types of roadmapping. This chapter also gives a detailed explanation of the process of technology roadmapping and methods and techniques included in roadmapping.

Learning Objectives: To understand roadmapping and technology roadmapping leveraging for the boarder prospective; to present an outline on several types of roadmapping and focus on product-technology roadmapping; to explore the process, components, uses, and benefits of technology roadmapping in global platform.

Keywords Roadmapping and technology roadmapping • Aspects influencing roadmapping • Types of roadmaps • Process of technology roadmapping • Methods of technology roadmapping • Benefits of roadmapping

6.1 Introduction

Roadmapping is an important aspect of understanding the choices before the R&D function and selecting a series of connected choices. In other words, roadmapping provides direction and focus for various activities over a period of time. Typically, the roadmaps provide milestones as well as nature of technologies required, to be acquired or to be developed in order to have leadership in the selected area of R&D activities. Roadmapping tries to address the current requirements, alternatives available to the organization based on the resources, challenges of meeting expectations of the markets, and time and competency constructions. It tries to link needs, resources, expectations, talent, and complexities through systematic and integrated analysis. R&D activities are driven by different paradigms. It includes "know how" versus "know why," donor versus recipient, and static versus dynamic technology market conditions. Each of the technology paradigms in their multiple combinations creates uncertainty and complexity. The challenge is to make the required investment, involve and engage people for appropriate investment of their time and effort, and constantly remind and refocus the goal-directed activities and correct

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_6

actions to integrate the visions of the stakeholders toward deliverables. The activities involved in roadmapping can be elaborated as follows:

1. Factors influencing roadmapping
2. Types of roadmaps
3. Process of technology roadmapping
4. Methods of technology roadmapping
5. Advantages of roadmapping

6.2 Factors Influencing Roadmapping

The major factors influencing technology roadmapping can be broadly classified as follows:

- Nature of individuals and work characteristics
- Group composition and characteristics
- Organizational growth and sizes

Individual and work characteristics include how the individual perceives time and contribution in basic R&D activities, where individuals who spend substantial time in fundamental research would like to see roadmap to be indicated as broad and encompassing. Scientists and engineers who focus on integration of various technologies to deliver a product would like to see very specific plans written out clearly as flowcharts with specific timelines and deadlines. Hence, it is extremely important to carry out a diagnostic study and discussion with every individual involved in R&D activities. Such discussions can recognize common areas of concerns, significant differences, and possibilities of concerns built.

R&D activities vary significantly with regard to group composition and characteristics. Interdisciplinary of the groups demands a high degree of specificity and concern among the group members while discussing and developing technology roadmaps. One should expect substantial disagreements about the problems, methods, tools, resources, and approaches toward identification and steps toward problem solving. Brainstorming and nonjudgmental evaluation of ideas at the early stage is an important aspect of the group. This would enable the integration of different ideas toward resource mobilization as well as activity planning, which identifies the significant milestones in the planning documents. Leadership of the group becomes critical in building concerns and commitment toward effective roadmapping.

Size and stage of the organization in terms of its growth have significant influence in determining the breadth and scope of the technology roadmaps. Small organizations have to really see specific steps to be initiated in its developmental and research activities as the resources are likely to be limited. Large organizations have to deal with intergroup competition and conflicts, resource redundancies, as well as determining competing demands of the stakeholders.

The growth stage can be seen at least at four levels: startups, early stage R&D, matured, and plateau. *Startup stage* roadmapping involves a clear and step-by-step articulation; it involves elaborating the proposal in terms of the following headings: specification of establishing the concept, proof of concept, prototypes, demonstration of the concept, and resource mobilization and support of sponsors toward the use of the technology in the different context. Roadmap has to be brief, specific, and well articulated; it should be simple and driven by the clarity of the entrepreneur. *Early stage* R&D functions are characterized by building credibility within the organization and hence roadmapping activities should be conducted with a conservative approach with the aspirations to meet simple and specific expectations of the stakeholders. In the startup phase, entrepreneurial and wishful thinking would be useful; however, in the early stage, engaging internal stakeholders to develop technology roadmaps becomes comparatively more important. *Matured R&D* has a track record of the development of various technologies to design and *variabilities* to meet varied expectations of the stakeholders. Matured R&D can not only react to the expectation but can also proactively acquire data on the needs of the internal and external customer's debate and discuss on the challenges of meeting the expectations, and further classify and prioritize steps and methods to deliver the required technologies at different points of requirements of the organization. Roadmaps can be elaborate and at times complex as it could be indicative, demanding flexibility and responsiveness of R&D function. Periodical use of roadmaps becomes essential in the matured R&D to maintain the spirit of innovation and delivery. Plateau organizations indicate a significant challenge for R&D to demonstrate its capability and delivery. Establishing roadmaps many a times becomes highly challenging. It is expected that in a plateau organization, activities are likely to be highly standardized, established, and routine. In such conditions, R&D has to generate significant ideas and build capabilities toward game-changing products and innovations. Technology roadmaps will have high complexities as well as uncertainties. Internal and external advice, engaging consultants, and experts become necessary in drawing up an appropriate plan of action.

6.3 Types of Roadmaps

Technology roadmaps can be classified based on the scope, time, and organizational level at which the roadmaps are drawn. Scope of activities can be described from simple to elaborate integration of different technologies depending on their product context. Simple product context would involve bringing more variants, adding features correcting for defiance, and substituting for better efficiency or cost reduction. These steps involve step-by-step change and improvements. When the scope is large, one needs to understand the different disciplines of technologies to deliver a new product. It may involve radical or breakthrough improvements, and substantial judgments need to be made in the channelizing of the activities and to predict the future.

Time is another critical element of roadmapping. It can be classified into short, medium, and long term. Short-term plans are typically in the range of 6to 24 months. These roadmaps are essential in some industries where competition is intense and the organization would like to get the first mover advantage. Many organizations would adopt medium-term technology roadmaps which typically involve 2 to 5 years. Here, the organization would be in a position to state important milestones based on the integration of requirement of the customer's investors and the uncertainties involved in the R&D process itself. Medium-term roadmaps help in effective budgeting and project planning as well as review of the project achievements. Long-term technology roadmaps typically range between 5 and 15 years. The roadmap tends to deal with different levels of technologies, with a portfolio view of a large number of technologies and product leadership to sustain the competitive edge of the organization. Multiple projects, several level of complexities, and variety becomes usually the part of long-range technology roadmaps. Typically, this kind of roadmaps are planned to build the required capabilities at different levels. Roadmaps are extremely useful in defense research, pharmaceutical and drug development activities, and university research. Roadmaps can also be classified based on the level of the aggregation within the organization or society at large. Roadmaps can be drawn at team level where several teams work independently of each other. This kind of a scenario can be observed in a university system or a large R&D organization. Team-level roadmap tends to be more oriented toward basic research and domain-specific activities. They tend to contribute to the fundamental activities rather than independent or near applications. Similar to book roadmaps, the roadmaps can be drawn at the departmental or divisional or strategic unit's level. Organizational-level roadmaps can be classified into two categories: the first category can be based on research view, that is, it tends to be a map based on what resources are available in terms of human resource and capabilities, finance, and so on. Whereas, the other map would focus on the activities of the competitor. Based on the competitor analysis, the required resources, both internally and externally, are captured to develop the roadmaps. Identification of the competitor is crucial for the methodology and it is referred to as identifying "Near competitor." Near competitor is the one who is likely to displace the organizational future technology development efforts or organizational product portfolio.

6.4 Process of Technology Roadmapping

The process of technology roadmaps can be broadly classified into three activities. The first step involves data gathering, diagnostic, and assessment activities. The second set of activities involves identifying the product, required research and developmental activities, generating alternatives, weighting different alternatives, and obtaining concerns to clarify the roles and responsibilities of current and future. The third level of process involves establishing review and monitoring procedures. Roadmaps should contain benchmark, milestones, and clear indicators of success of meeting the customer expectations and needs. The complete process needs to involve experts, hands-on developers and researchers, and engineers and stakeholders.

6.5 Methods and Techniques of Technology Roadmapping

Various methodologies and techniques have been established and validated over a period of time to aid in the development of technology roadmaps. They include development of ontology, brainstorming, technology forecasting, creativity techniques and focused group discussions, sensing interviews, Delphi method, benchmarks, and comparisons.

Ontology is nothing but developing knowledge classification and branching of each of the known areas into subdisciplines and subgroups. It typically follows the library classification of disciplines and subdisciplines. Ontology is nothing but knowledge trees. It starts with identifying a particular discipline, all domain of understanding, divides the area into knowledge, concepts, axioms, proverbs, standards, tools, procedures, practices, and so on, and attempts to link each of these in a systematic way so that one can judge the known areas where the organization has complete mastery. Furthermore, it identifies the required understanding to be acquired or developed.

Brainstorming is a well-known procedure in any creative process where individuals gather in a large room and each individual is asked to think about the existing technologies, the required technologies in the near future, and technologies to be acquired or developed in the long run. In the initial stage of brainstorming, ideas are not evaluated for its relevance or applicability. The philosophies are "ideas are wanted" and "more ideas are good." Each of the participants is asked as many ideas as possible. After the first stage of idea gathering, the group would consolidate, classify, and assess so as to arrive at a systematic plan of action to meet the requirements.

Brainstorming will not only concentrate on technologies, but also on the resources as well as internal and external expectations of the customers.

Technology forecasting involves a systematic understanding of the past. It involves an assessment of past critical incidents of success and failures, lessons learnt, as well as established appreciation of opportunities and limitations. Forecasting is not only done on past experiences and data but one would also focus on challenges faced in implementation and deriving new developments based on the current experiences. Further, internal and external experts are used to build an understanding of future developments initiated by others so that such an understanding could redefine an organization's focus on new developments.

Creativity techniques typically includes standard methodologies of understanding the cause and effects of diagrams; fish bone diagrams, deliberating on before–after studies, the Paratoo charts, ester grams, the scatter diagrams, and use of the graphs can all aid in understanding the causes and deliberating the unnecessary aspects and focus on clarity and required prioritization. Creativity techniques can also be supported with check sheets, which can show the history and pattern of variations. These systematic tools will help in depicting current scenarios and participants can reflect and review and channelize their understanding to come up with new alternatives.

Focused group discussions follow a principal of bringing relevant people together and enabling them to dialog, debate, discuss, and consolidate their views and thoughts from current to their future. Identifying the required stakeholders is an extremely important activity of the focused group discussion. Building rapport or icebreaking activity at the initial stage will help in better quality and generate discussion and debate. A trained facilitator may also enable the discussion process. Several rounds of discussion may be necessary before the group can establish the concerns toward the future.

Sensing interviews is a systematic approach to understand some of the experts who can critically examine and assess the capabilities, challenges, and opportunities. Sensing interview is required to gather the deep impressions and judgments of the experts. Sometimes, the expert may not participate and contribute in a group environment due to a lack of rapport between the expert and the audience. Hence, it is important to understand some of the critical aspects which may influence the interviewing process. Such factors include acknowledgment of the scientist, requesting in advance the time of the experts, which is required to have the undisturbed interview process, ensuring co-operation and comfort level of the experts, and appreciating all the significant ideas of the experts. Sensing interviews provides significant inputs for the roadmaps, in particular, avoiding major mistakes and focusing on significant requirements.

Delphi method involves the use of several experts in a synchronous or an asynchronous manner to gather views and judgments in a systematic manner. Initially, a set of issues and concerns are gathered and presented to different experts, to arrange and prioritize. This step is called polls. Polls are nothing but assessment and judgment of experts. One or more polls can be conducted to reduce the number of issues to a manageable few, understand the difference between the experts, as well as the specified areas of importance for future technology development.

Benchmarking is an established method of comparing and contrasting among the technologies, methods, and alternatives. Benchmarks can be done on some or many aspects to obtain an overall picture of the scope of the activities to be initiated. In benchmark activities, there is always an attempt to identify the best in the class. In other words, benchmarking involves pinpointing the distinctive features of a given technology or a method over the others. Organizations and teams can decide to continue the developmental efforts or discard some of the ideas based on the benchmarking activities. Business intelligence, participation in conference, visits to higher centers of learning, and professional associations could also help qualitatively and quantitatively in effective benchmarking of technologies and alternatives, hence arriving at a better technology roadmap.

6.6 Advantages of R&D

Technology roadmaps need to be simple and effective. Well-drawn roadmaps guide the organization in understanding the current efforts and refocus the energy and effort to the future. Roadmaps also help in mobilizing financial and other resources. Roadmap also enables talent acquisition, development, and deployment. It enables effective manpower plan of obtaining competent people to the organization. It further supports in building the required infrastructure, testing facilities, and instrumentation. Roadmaps avoid unnecessary commitments of resources to useless and irrelevant developmental activities. On the flipside, roadmaps create a blinder and there are possibilities that organizations may neglect a significant innovation and business opportunities.

Questions

1. Describe the different types of roadmaps and technology roadmaps.
2. Explain the three phases involved in the process of technology roadmapping.
3. Write a short note on methods and techniques of technology roadmapping.

Chapter 7
Project Selection

Abstract Project selection is an important phase of finalizing R&D projects. The project selection process includes identification, evaluation, selection, and review. This chapter gives a detailed evaluation of project selection methods based on the availability and accuracy of data. There are quantitative and qualitative analytical methods, and the advantages and disadvantages of each method provide essential tools or techniques for R&D managers.

Learning Objectives: To understanding the meaning of project selection and the different methods used in the selection of R&D projects; to present an outline on the risk analysis approach and decision analysis (DA) approach; to formulate the mathematical programming methods in project selection.

Keywords Project selection in R&D • Diverse methods in R&D project selection • Overview of risk analysis approach • Outline decision analysis approach • Originate the mathematical programming methods in project selection • Illustrative representation of project management review models

7.1 Introduction

Project selection is a process in which each project idea is assessed and the project with the highest priority is selected. The basis of selecting projects is how beneficial the outcome of the project will be, its feasibility, and the chance of success. Completing the project selection process has some benefits:

- There is a transparent and documented record of why a particular project was selected and the reasons stated clearly.
- There is a priority order for projects, which ensures that the group/team understands and has taken into account the importance of the project and also understands how achievable the project is.

Project selection involves participation from agencies, stakeholders, project managers, and team members. The project selection process generally appears as depicted in Fig. 7.1:

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_7

Fig. 7.1 Project selection process (*Source*: Project Selection 2009)

7.2 Significance of Project Selection

The selection of projects is a critical phase in the planning and control of R&D activities. If a project is selected, it invariably implies the rejection of several others. Once a project is selected and funds and manpower allotted to its completion, the decision in the immediate short run is irreversible. The benefits from the results of research, if successful, can only materialize after a substantial elapsed time. For these reasons, the selection process should be carefully structured to avoid inconsistencies and biases.

There are two extreme approaches used in decision-making with reference to project selection: One is a totally holistic, subjective, or intuitive judgmental approach. In contrast with the deductive, analytic approach that is often advocated by academic decision theorists, the first approach is heavily dependent on the intuitive capabilities of the R&D manager and is subject to his blazes and preconceived notions. The second approach needs extensive data, and the decisions are based on the accuracy of the data available. In the past, subjective or qualitative decision styles were used extensively, and in recent years, increased attention is being focused on rational selection procedures based on quantitative analytic methods.

The methods used in the selection of R&D projects can be broadly classified into the following (Fig. 7.2):

- *Economic rating method*: Based on expected performance as evaluated by some economic indicators
- *Ranking, voting, or scoring methods*: Based on evaluation procedures using qualitative judgments and rating procedures
- *Risk analysis approach*: Viewing the R&D project progress as trade-off between risk and costs
- *Decision analysis approach*: Using rational evaluation of information on alternative courses of action and probabilities associated with various outcomes

As can be seen in Fig. 7.2, the decision model can be classified into comparative approach or mathematical approach focusing on benefit measurement methods or constrained optimized methods.

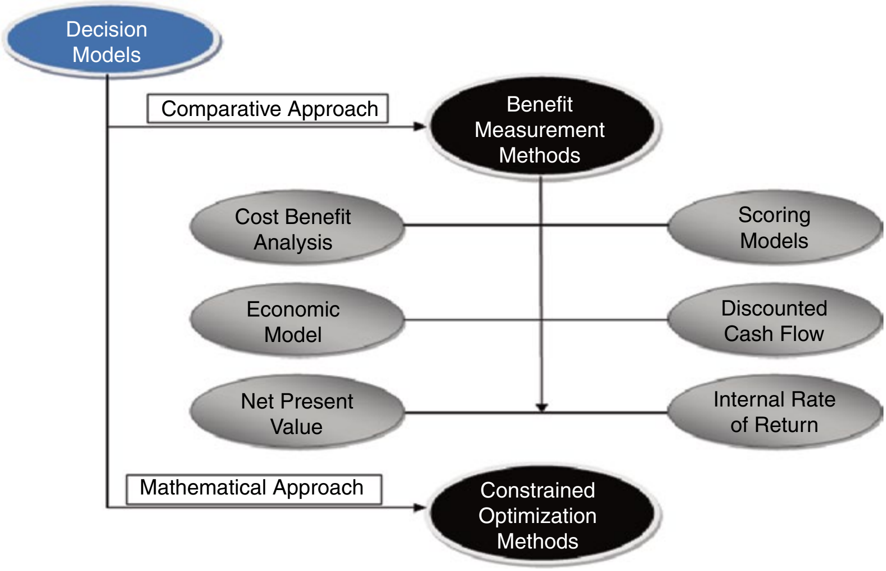

Fig. 7.2 Two of the decision methods and their stages (*Source*: Project Selection Methods 2013)

7.3 Economic Rating Methods

7.3.1 Index of Return

Index of return = {(estimated value (benefit) if research is successful)* (probability of technical success)}/estimated cost of research and development

Index of return is calculated based on estimated benefit of research if research is successful, possibilities of technical success, and estimated cost of research and development.

This is an absolute index where the higher the index of return, the better the project success. Notionally, an index of return less than one is considered unsatisfactory for the R&D project.

7.3.2 Probability Index

The probability index (PI) is defined by

$$PI = \frac{P_T - P_C - A_S - L}{C_{RD} + C_{PED} + C_{MD}}$$

where

P_T = Probability of technical success
P_C = Probability of commercial success
A_S = Annual sales revenue (or increase in sales value due to R&D)
L = Market life span of the results of R&D project
C_{RD} = Cost of R&D
C_{PED} = Cost of production, engineering and development
C_{MD} = Cost of market development

Once again, this is an absolute index. The higher the PI, the better the project is supposed to be. The evaluation depends on measurements and costs, which are difficult to obtain in the initial phases of a project.

7.3.3 Net Present Value

The net present value (NPV) is the value today of a stream of rupee cash flow to be made (inflow or outflow), assuming that these rupee cash flows are capable of earning some stated rate (of interest) between now and then, the time of receipt. The NPV is computed as the sum of the cross products of each period's net cash flow and the discount factor for that year. This is given by

$$= -\mathrm{I}_{\mathrm{o}} + \mathrm{C}_1 / (1+r) + \mathrm{C}_2 / (1+r)^2 + \mathrm{C}_{\mathrm{N}} / (1+r)^n$$
$$= -\mathrm{I}_{\mathrm{o}} + \mathrm{E}_{(t=1)} \mathrm{NC}_t / (1+r)^t$$

where C_N is the net cash inflow in the last period including terminal benefits from the project if any. The factor $1/(1+r)^t$, called the present value factor or discount factor, is readily available in many standard books on financial management for various values of r and t.

The decision criterion is to accept an R&D project if its NPV is positive. Alternatively, it can be stated as follows: If the present value of all future net cash inflows (benefits) is more than the present investment cost of the project, then it is worthwhile to select (or accept) the project. Otherwise, it should be rejected. It implies that in the above equation, accept a project if its NPV is greater than zero, and reject it if its NPV is lesser than zero. An NPV of zero indicates that there are neither benefits nor cost implications from the project. If investments or cash outflows are required in more than one period, the net present value should consider the present value of all net cash flows including all investment costs.

7.3.4 *Internal Rate of Return*

The internal rate of return (IRR) of a research project is the effective rate of interest earned (in expectation) on the money invested in the project. Mathematically, the IRR is obtained by equating the present value of all future cash flows equal to zero:

$$\mathrm{NPV}(R) = -\mathrm{I}_o + \mathrm{C}_1/(1+r) + \mathrm{C}_2/(1+r)^2 + \mathrm{C}_\mathrm{N}/(1+r)^n = 0$$

where I_0 is the initial investment, Ct is the net cash inflow in the period t, and N is the last period (year) in which benefits from the project increased. Solving this equation for R by trial and error would give the IRR. Therefore, it can be said that the IRR is that rate of discount which equates the NPV of all cash flows (inflows and outflow) to zero.

The decision criteria are to accept or select an R&D project if and only if the IRR of a project is higher than the cost of capital for the organization. The IRR intrinsically measures the “profit” in terms of percentage earnings made on the investments on the R&D project. The IRR has two drawbacks: One is that the IRR is obtained by solving an Nth-degree equation in R, and therefore it may give more than one real solution—which one is appropriate is not known with certainty. Quite often in real project computations, the answer is unique. The other drawback is that as per the financial management principles, IRR is not a good criterion to choose among mutually exclusive projects.

7.3.5 *Benefit–Cost Ratio*

The benefit–cost ratio (B/C ratio) is the ratio of the present value of all expected benefits to the present value of all expected costs.

$$\mathrm{B/C\ ratio} = \frac{\text{Present value of all benefits}}{\text{Present value of all costs}}$$

The decision criterion is to select (or accept) a project if its B/C ratio is higher than one. It may be observed that the results of this are similar to those obtained by the NPV method. When a number of research projects have a B/C ratio above one but budget restrictions force the selection of only a few, then the projects are ranked in the order of this B/C ratio. They are then chosen in the order of decreasing B/C ratio.

Ranking of projects based on the B/C ratio and that based on NPV criteria may lead to different ordered sets of projects.

7.3.6 Venture Ratio

Another method which is close to the approach of NPV and B/C ratios is to consider all the net benefits and net costs of a research project in the wake of its estimated probability of success. This method is known as the venture ratio and is given by

$$\text{Venture ratio} = \frac{\left\{\left(\text{Discounted net benefits}\right) * \left(\text{Probability of success}\right)\right\}}{\text{Discounted cost of research}}$$

Then, the decision criterion for selecting a project is to select (or accept) the project if VR>T (VR – venture ratio and T-threshold number). Notionally, this threshold number is higher than unity. Generally, this threshold number varies from 1.2 to 3 with 2 as a typical number for projects which get into ultimate commercialization.

7.3.7 Payback Period

The payback period is the shortest duration within which all the investments can be recovered. All future cash flows after the payback period are treated as income for the project. In this method of selection, the shorter the payback period, the better the project is supposed to be.

The payback period as defined above does not take into account the time value of money. It is totally insensitive to huge cash flows or negligible cash flows after the payback period. In this method, projects with a longer gestation period normally receive a lower priority in the selection criteria. This method is not generally advocated from the financial theorist's point of view. However, it has widespread practice traditionally from the business circles as criteria to overcome risk in a shorter duration. To overcome one of the drawbacks, a revised concept of payback period is to use the discounted cash flows of future periods instead of the absolute values. In this method, the discounted payback period measures the shortest duration within which the present investment equates the present value of future cash inflows.

7.4 Ranking, Voting, and Scoring Methods

These are mainly subjective judgmental methods. However, some of the scoring methods use quantitative ratings for selected factors, and the judgment of the probability of success is based on comprehensive scores.

Ranking: This is a simple intuitive method in which the available projects are ranked in the order of selection preference with no explicit explanation of the criteria or weightages used for selection.

Voting: Decisions on the selection of projects is made by a committee through a democratic voting process. Here also, no explicit explanation of the criteria for choice exists. In both the ranking and voting procedures, paradoxes exist, and these are not advocated by rational decision theorists.

Scoring/rating method: In this method, each criterion or factor of the project being evaluated is accorded a rating or score on a predefined scale. While the numerical scores have no specific interpretations, they are nevertheless supposed to indicate a relative level of satisfaction or achievement of the specific criterion or factor as judged by the individual assessing the score.

7.4.1 The Merrifield Index

One of the most widely recommended R&D project selection criteria based on the scoring method is known as the Merrifield index, which is defined as

$$\text{Merrifield index} = (\text{Probability of technical success}) * (\text{Probability of commercial success})$$

While the probability of technical success is estimated subjectively by competent technical experts, the probability of commercial success is evaluated by a comprehensive rating procedure for 12 factors. These 12 factors are grouped under two categories: "business attractiveness" and "specific company strengths," each of which has six factors. They are as follows:

- Business attractiveness factors
  - Sales/profit potential
  - Growth rate
  - Competitive situation/edge
  - Risk distribution
  - Industry construction/restructuring opportunity (ventures that are significantly technological breakthroughs)
  - Special factors—(possible political, social, and economic surprise interventions including antienvironment laws, foreign exchange risks, etc.)
- Specific company strengths
  - Capital needs vs. availability
  - In-house marketing capabilities
  - In-house manufacturing capabilities
  - Strength and technology base
  - Raw material availability
  - Management and other corporate skills

For each one of these 12 factors, Merrifield suggests a scoring method involving an integer numerical score on an 11-point scale from 0 to 10. Then, all these scores are totaled. In the resulting total score, out of a maximum possible of 120, a total score of 80 or higher is considered a high probability of commercial success. In this method, the probability of commercial success is estimated as the ratio of the total score of a project to the maximum total score of 120. Merrifield suggests that a venture scoring below 70 has a low probability of commercial success (approximately 56.3 %). This estimation of the commercial probability of success assumes a priori technical success in R&D efforts.

7.4.2 Schwartz and Vertinsky (1977) Checklist for Initial Evaluation and Selection

Schwartz and Vertinsky conducted an extensive survey of R&D practices in several R&D organizations and laboratories. From this survey, it was observed that 47 factors were answered as factors often considered in the evaluation and selection of R&D projects. Of these, six factors were found to be significantly influential and therefore were termed key factors. They were the probability of success (both technical and commercial), payback period, IRR on investment, market share, cost of project relative to total R&D budget, and availability of government funding.

7.5 Risk Analysis Approach

The project selection process is a fundamental dilemma facing the decision-makers. In the initial stages of a project, risk is at the highest because the state of uncertainty about the outcome of the project is the highest. The data available would be minimal or subject to errors of estimation. However, the cost of an R&D venture is minimal at the beginning and rises along with the state of certainty regarding the success of the project. The project must fall within the risk threshold of the organization to be allowed to start. If the project continues as per expectations, the state of uncertainty is steadily reduced, and the cost of the project keeps increasing. If the initial cost is high, so is also the risk. The project should then not be taken up. If the risk has been reduced to a comfortable level by the point at which the cost raises rapidly, the project should continue.

In this risk analysis approach, any R&D project will go through three phases:

- The initial, intuitive, or heuristic phase
- The critical managerial decision phase
- The analytic or tracking phase

7.5.1 The Intuitive Phase

In this phase, the ideas of the researcher as regards a project are the key determinants in its selection process. It develops from an individual idea or group development into possible feasibility checks. At this stage, the risk as regards the success of the project is the highest, and costs are relatively low. It is extremely difficult to develop any simple, logical deductive order in the decision process as the project initially develops. Any estimates of the potential costs and benefits at this stage would be associated with a high degree of uncertainty. However, the checklist developed by Schwartz and Vertinsky for the initial selection of a project can be used to begin with. A project should start only if the anticipated risk level at the beginning of the project is below the maximum threshold of risk as defined by the R&D organization. As the selected project progresses, the degree of uncertainty or risk should get reduced. It is quite likely that this would be associated with an increase in the cumulative costs for the R&D project. Overall, the judgment here hinges on the capabilities of the individual innovator, researcher, or project leader and his ability to translate his ideas into probably successful R&D projects.

7.5.2 The Managerial Decision Phase or the Critical Phase

In the intermediary stage, the decision process is very critical. Even if the results of the initial phase are positive, the R&D manager or group leader must exhibit leadership in this phase. If the actual risk level and costs are below their anticipated levels, then the decision is to continue with the project. If both of them are above the respective anticipated levels, the decision is to terminate the project. If the risk is lower but the cost is higher or vice versa, it leads to areas of managerial indecisions. Here, the R&D manager must exhibit his superior judgment. This is because the initiator may be unrealistically optimistic or even down in the dumps after his initial enthusiasm. Rarely can one count on an objective evaluation from the innovator or researcher; he would need more resources, money, and time. R&D management must keep a careful watch during this period.

If the rate of expenditure is rising rapidly and the risk appears to be declining too slowly and similarly if the payback period is lengthening, the return on investment is decreasing, or the potential market is escaping, then the R&D manager should not allow the project to continue. The point at this stage should not be the ultimate technical success or failure; the point is that the expected B/C ratio is declining or continued investment is no longer attractive. A negative decision may be difficult to make at this stage. But to throw good money after bad is a key sign of managerial failure.

7.5.3 Analytic Tracking Phase

After the project weathers the initial and critical phases, the final commercial marketing phase begins. Here, every aspect from investment to possible benefits is evaluated critically and analytically. Although risk is reduced in this phase, investment is greater. Much of the evaluation is conducted using rational (deductive) selection procedures such as those advocated by the economic rating methods. Decisions are based on detailed financial and technical analyses of the commercial viability of the R&D project.

7.6 Decision Analysis (DA) Approach

Decisions analysis (DA) requires that the possible outcomes from research along with their probability and the value of each outcome be established in advance. In the decision analysis method, basically two methods are used in evaluating a project: One is the traditional evaluation of all the decision alternatives in the wake of various uncertainties if the outcome under each possible combination is known. This is normally represented in a tabular form, and either the expected value criteria or the satisfying criteria are used to choose the best alternative.

The other approach is the *decision tree approach*. A decision tree is a graphical method of expressing, in chronological order, the alternative actions that are available to the decision-maker and the choices determined by chance. Normally, these are represented in terms of nodes and forks. The nodes/forks are of two types: decision fork represented by a box and chance fork represented by a circle.

A basic equation of DA is as follows:

A, B, C are possible outcomes with probabilities P_1, P_2, P_3, respectively, if decision D_1 is taken. Similarly, P_1, P_2 are the probabilities for the outcomes A′, B′, which are the possible outcomes if decision D_2 is taken. Then, the expected values of the respective decisions are computed and compared.

$$EV(D_1) = P_1A + P_2B + P_3C - (CD_1)$$
$$EV(D_2) = P_1'A' + P_2'B' - (CD_2)$$

where (CD_i) is the cost involved with decision i; $i = 1,2$. Then, the decision alternative with the highest expected value is chosen as the best.

7.7 Tax Implications in Evaluation

Many a time when researchers or R&D managers try to evaluate the benefits/costs associated with any project, they ignore the effects of tax and depreciation in their computations. When a research project becomes a commercial venture, it is subject to all the norms and regulations associated with firms taking up such ventures for commercial purposes. One factor that influences these decisions significantly is the effect of corporate taxes or firm-specific taxes on an investment project. These are significant as the tax rates in many countries are very high at 50–60 % of the income.

Tax affects the flow of funds from a project in three ways: (1) tax on the annual profits, (2) tax benefits due to depreciation of capital assets, and (3) tax on capital gains or tax savings due to terminal loss when an asset is sold. Further, there are two methods of depreciation: (1) straight line method and (2) declining balance method. Normally, most governments permit only the declining balance method of depreciation for purposes of tax payments.

Let capital cost allowance rate (CCA) (or depreciation rate) = d

Taxation rate for the organization = t
Cost of capital (discount rate) = k
Investment cost of capital assets = c

Then, the undepreciated cost of capital (UCC) or book value of the capital asset at the end of year n can be shown to be (for declining balance method of depreciation)

$$(\mathrm{UCC})_n = c(1-d)^n$$

The present value of all future tax savings (up to an infinite life period) due to CCA when the declining balance method is used for depreciation is given by

$$\frac{\mathrm{Cdt}}{(\mathrm{K}+d)}$$

If S is the salvage value of the capital assets at the end of *n* periods, then the present value of (1) the salvage value, (2) the resultant capital gains tax if any, and (3) the subsequent loss in tax benefits due to nonavailability of the CCA benefits can be shown to be

$$\left[\frac{1}{(1+k)^N}\right] * \left[\left\{\mathrm{S} - (\mathrm{S} - (\mathrm{UCC})^N\right\} * \mathrm{t} * \left((\mathrm{UCC})^N \ \mathrm{d.t}\right) \Big/ (k+d)\right]$$

Finally, the NPV after accounting for all the tax and depreciation aspects can be given by

$$\mathrm{NPV} = -\mathrm{C}_0 + \mathrm{E}_{(i=1)}\left[\frac{(\mathrm{NC}_i(1-t))}{(1-k)^i}\right] + \left[\frac{(\mathrm{Cdt})}{(k+d)}\right] + \left[\frac{\left\{\mathrm{S} - \left(\mathrm{S} - (\mathrm{UCC})_N\right)\mathrm{t} - (\mathrm{UCC})_N\,.\mathrm{d.t}\right\}}{(1+\mathrm{K})^N}\right]$$

where C_i is the cash inflow (net) in period I and N is the life of the project. The decision then is to accept a project if and only if its NPV is positive.

7.8 Mathematical Programming Methods in Project Selection

Suppose there are several projects, all of which are favorable when evaluated using the NPV criteria or the IRR method, but restrictions on the availability of funds prohibit the acceptance of all these projects. In such a situation, a question arises as to which set of projects should be accepted. Mathematical programming methods can be used to resolve the problem of project selection.

Let

$j = 1, 2\ldots M$ (represent M projects)
a_{tj} = cash inflow (benefits) from project j in period t
C_{tj} = cash outflow (costs) from project j in period t

Then,

$$b_j = E_{(t=0)} P\left(a_{tj} - c_{tj}\right) / \left(1+r\right)^t$$

represents the NPV of project j, where r is the discount rate

$$J = 1, 2 \ldots m$$

Now, suppose A_t is the budget available in period t. Then, assuming that the cash inflows generated by the accepted projects can be used for financing, an integer linear programming model is

$$\text{Maximize } Z = b_j x_j = b_1 x_1 + b_2 x_2 + \cdots + b_M x_M$$

subject to

$$\begin{aligned}
&\left(C_{11} - a_{11}\right) x_1 + \left(C_{12} - a_{12}\right) x_2 + \cdots + \left(C_{1\mathrm{M}} - a_{1\mathrm{M}}\right) X_M \le A_1 \\
&\left(C_{\mathrm{T}1} - a_{\mathrm{T}1}\right) x_1 + \left(C_{\mathrm{T}2} - a_{\mathrm{T}2}\right) X_2 + \cdots + \left(C_{\mathrm{TM}} - a_{\mathrm{TM}}\right) X_M \le A_{\mathrm{T}} \\
&\text{And } X_j = \{1 \text{ for all } \; j = 1, 2, \ldots, M \\
&\;0
\end{aligned}$$

This is an integer linear programming model in which the variables x_j can take on either the value 0 or 1. If in the final solution $x_j = 1$, it means project j should be accepted, and $x_j = 0$ implies that it should be rejected. The objective function represents the NPV of all the accepted projects. The model objective is to choose only those projects which maximize the NPV of all accepted projects for the organization subject to budget limitations in each period.

7.9 The Two Perspectives

Figure 7.3 projects the owner's perspective, Fig. 7.4 depicts the suppliers' perspective, and Fig. 7.5 illustrates the process of project review. These show the two perspectives on the project—that of a project owner, which is the organization involved in the project, and the supplier.

Figure 7.3, follows four important steps toward project selection: they include the acceptance of feasibility studies, a critical examination for request for proposal, vendor selection, freezing of designs, and approval of detailed planning documents and final acceptance. Similarly, the prospector view involves various steps involving bid stroke, no-bid decision, bid approval, signature of contract, and order approval for subcontractors, declaration—ready for preliminary acceptance and finally leading to project closure. In this manner, the organization can follow different steps in selecting any project through several "standardized" steps.

Figure 7.5, standardizes project management selection and review methods. Effective review procedures help in project selection.

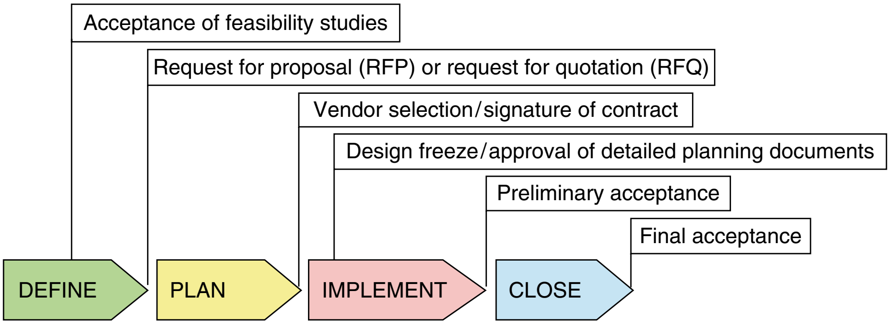

Fig. 7.3 Project owner perspective (*Source*: Project Selection 2009)

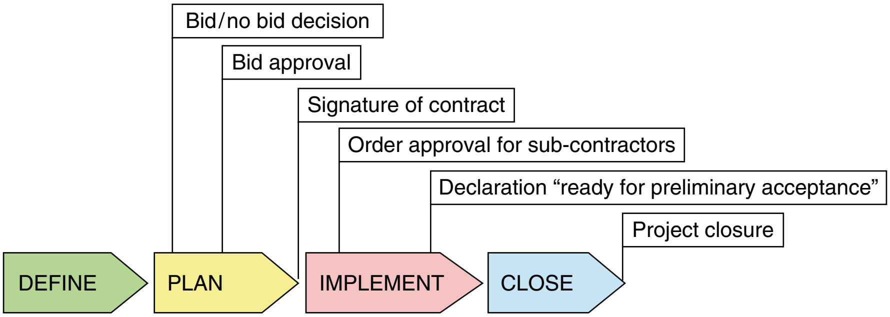

Fig. 7.4 Supplier perspective (*Source*: Project Selection 2009)

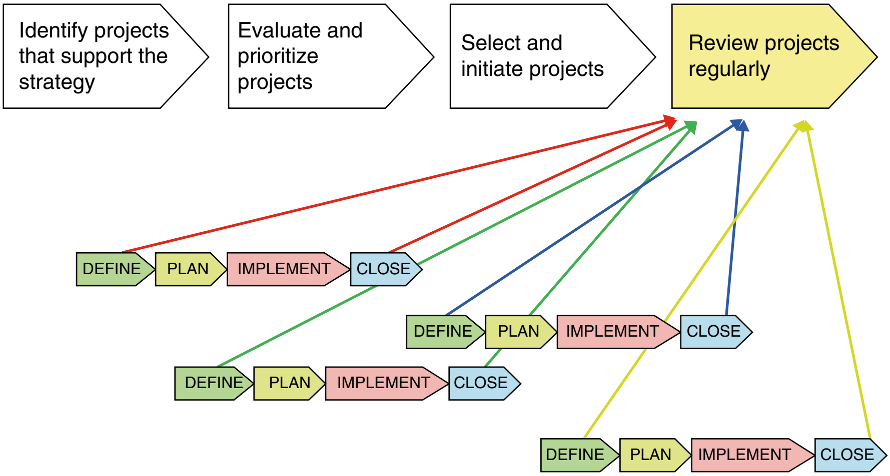

Fig. 7.5 "Standardized" project management review method (*Source*: Project Selection 2009)

7.10 Expert Judgment

Expert judgment is one of the techniques used in project management to accomplish various tasks including project selection. This refers to using expert advice from one or more sources to make a decision:

- Senior management
- Specialized unit within the organization
- The stakeholders in the project, consisting also of the customers and sponsors
- The consultants
- The professional and technical associations
- Various industry groups
- Subject-matter experts from within or outside the performing organization
- Project management office (PMO)

The methods that can be used to gain expert opinion could be individual consultation, interview, survey, or panel group discussions.

Questions

1. Briefly describe the methods used in the selection of R&D projects.
2. Delineate the mathematical programming methods in project selection.
3. Explain with diagrams the two perspectives of project selection and review methods.

7.11 Project Selection Terminologies

Box 7.1: Some Important Project Selection Terminologies

Present value (PV): PV indicates the present value of future cash flow. Projects having higher PV will be better. Present value of a future cash flow is discounted to reflect the time value of money.

Net present value (NPV): NPV is the difference between cash inflow and outflow considering the present value of both cash inflow and outflow. Again, a project with higher NPV is better. NPV should be positive for the project to be selected; negative NPV indicates negative cash flow.

Internal rate of return (IRR): IRR is the rate at which the present value of investments is equal to the present value of return on all investments made. If there are multiple projects in consideration, a project with higher IRR is a better option.

Payback period: Payback period is the time required to recover the cost of investment for the project. Payback period alone does not consider time value of money or rate of return on the project. If other parameters are the same, a project with minimum payback period is better.

(continued)

Box 7.1 (continued)

Benefit cost ratio (BCR): BCR is the ratio of benefit in terms of money to monetary cost of the project. If budget is not a constraint, higher the BCR, better the project. All costs and benefits should be in terms of present value while comparing.

Economic value added (EVA): EVA™ is net profit after deducting tax and capital expenditure. The project having more EVA is better for the company.

Opportunity cost: Opportunity cost is the profit lost when one project is selected over others. For selection among multiple projects, a lesser–opportunity cost project should be selected.

Sunk cost: Sunk cost is the cost that is already incurred and cannot be reversed. Sunk cost should not be considered while taking a decision on project selection.

Source: Chandana (2012).

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Chapter 8
Project Evaluation

Abstract Project evaluation is a dynamic process in R&D management. This chapter provides objectives of the project evaluation, the risks associated with project selection and criteria for evaluation for research proposals. R&D project evaluation is an art combined of Quantitative measures and expert judgments to assess and evaluate R&D projects. At the end of the chapter we have given a brief assessment on criteria for evaluations of project proposals, its costs and benefits and selection.

Learning Objectives

1. To understand the meaning, need and benefits, and costs of project evaluation.
2. To enumerate the various risks associated with R&D projects, selection, and assorted criteria for evaluation of research project proposals.
3. To explore the estimation of costs and benefits of R&D projects.
4. To describe the several factors to identify the different possible fields of benefits.

Keywords Project selection • Evaluation • Assessment of risk • Compatibility • Estimation of cost and benefits • Project selection

8.1 Introduction

Project evaluation is a continuous process in R&D management. It is conducted based on the objectives of the project, milestone achievements, and the relevance of the project to the overall organizational goals. R&D project evaluation is an important decision-making activity and demands good leadership as well as participation of members of the organization. Data-based judgments are extremely important, and experts may have to resolve conflicts and differences. Projects involve multiple objectives and multiple criteria of success. Quantitative measures and expert judgments must be combined to assess and evaluate R&D projects. One should also assess how these ideas will be proved at the laboratory level and when transferred to the field or to any organization, the impact it will have in the field in realistic terms. Market conditions and other dynamic factors, such as moves of the competitors, changing demands of the customers, and socioeconomic conditions, may also define and determine the scope and success of the project.

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_8

8.2 Risks Associated with R&D Project Selection

The four major types of risks associated with the evaluation and selection of a research project are the following:

- The selected project may be unsuccessful.
- If a project is a successful one, then the results may be unprofitable.
- A rejected project might have been successful and profitable.
- If successful and even if profitable, the results may be beyond the scope of the organization's operations.

Since the number of proposals for possible research projects is almost always large, errors in the evaluation and selection process of the projects may lead to any of these risks. Moreover, the budget availability is also normally limited. The selection of one project will invariably imply the rejection of several other projects. Once a project is selected and funds and manpower are dedicated to its completion, the decision is the immediate short run, which is irreversible. It should be noted that the benefits are the results of research, if successful; it can only materialize after substantial elapsed time. It is evident that substantial costs and time are incurred before the benefits from a project start to materialize.

8.3 Choice Among Projects

The choice among projects is always based on some form of project assessment, be it in the research manager's intuitive judgment or a detailed economic analysis of the possible consequences. We are here concerned about methods of project assessment that enable R&D management to make a rational selection from among the various research opportunities available to them.

8.4 Criteria for Evaluation of Research Project Proposals

In the evaluation of research project proposals, the individual efforts of various factors should be considered. The weightage or priority given to these factors would depend on the goals and objectives of the organization undertaking the research project. These factors can be conveniently grouped into seven categories as follows:

- Technical factors

– Availability of the necessary scientific skills
– Adequacy of research facilities
– Adequacy of supporting staff/manpower
– Probability of technical success (this depends on the technical approach used for specific solution)

• Research direction and balance

– Compatibility of the organization's long- and short-term research objectives
– Maintenance of research balance among product categories and services offered

• Marketability factors

– Market potential in the immediate future and in the long run.
– Promotional requirements
– Competitive environment from direct competition and/or substitutes
– Adaptability of existing distribution methodology
– Service requirements for guarantee and upkeep
– Compatibility with current and long-term marketing objectives (for the R&D of a manufacturing firm)
– Compatibility with the existing customer group and reputation in the marketplace (for the R&D of a manufacturing firm)

• Production factors

– Capabilities of production facilities
– Availability of the necessary skilled manpower for production
– Utilization of familiar/existing production processes or adaption of new technology to the production process
– Freedom from hazards

• Financial factors

– Expected new capital outlays required
– Expected costs to complete the basic research project
– Expected costs to complete the development
– The economic benefits likely if the project is performed
– Expected increase in revenue or profit for the organization undertaking research
– Expected rate of return (or profits) for the firm undertaking investments based on the results of research
– Expected revenue from royalties/patents from the project, if any

• Timing of research

– Timing of research completion
– Timing of production engineering development completion
– Timing of marker development
– Timing of research work in relation to other competitive efforts or threats from substitute

• Other factors

– Stability of the results of research in the market in the wake of depression, environmental hazards, war (or heavy defense spending), substitutions, and so on
– Growth factors in other related areas as a result of research: For example, outcome of byproducts, export potentials, diversification into other areas (for firms using the results of research)

– Possibilities of obtaining patents and protection from biased copying
– The need for continuing defensive research for market hold

The existence of a fairly detailed list of factors as listed above, though not exhaustive, indicates both the complexity and the necessity for a systematic method of accumulating the required data and evaluating each factor. It also indicates the difficulties encountered in bringing the individual factors together into a composite judgment.

8.5 Data for Evaluation and Selection

• Technical Factors
  Primarily, these are the data related to promise of success. The most difficult but necessary requirement in this area lies in making an estimate of the probability of technical success. However, this is difficult as a number of factors influencing this and the assessment tends to be subjective. If a given project were not unique it could hardly be classified as an R&D project. As a result, there is barely sufficient information to judge on the probability of success.

  Normally, estimation of probability of success is accomplished by assessing the state of the art in that particular field and evaluating the qualifications and skills of the research personnel. The other technical factors that would influence the probability of technical success can be listed as experience, ingenuity of personnel, ability to try and adapt to different approaches, and so on. Many a time, the assessment of a probability of success presumes a limit on the time, resources and manpower availability for achieving the desired results. The broader the background of experience the researcher has the more accurate and reliable his assessment of probability will be.
• Timing and Balance
  Timing of the expected completion dates must be evaluated in its relation to the research effort of the competitors and the organization's other research projects. This is dependent on the resources available for the project. The estimates of costs, manpower, and timing are interdependent.

  Defensive research becomes important if the competitors are heavily engaged in research which could render the organization's product or product lines or processes obsolete. In offensive research, which aims for breakthrough in new product, processor technology and timing becomes very important for the success of the project.
• Market Considerations
  The stability of the potential market should be carefully considered prior to approval. A product/process which can withstand the market through depressions, war, changes in governments, defense spending, or other shifts in the economy contributes much more than a product having the same potential but unstable in a volatile market. Similarly, research products or processes which

promise a captive market through patents (or processes which are difficult to copy) may be much more valuable than others. When an organization involved in production undertakes research, there may be synergies from the possibility of using currently used raw materials and processes as well as factors such as economy of scale.

Although research and production cost factors are included in most project evolutions, marketing costs apparently do not receive such careful considerations mainly because the market potential cannot be assessed at the stage of R&D project initiation. Marketing "cost-volume relationship" greatly affects this assessment. Costs of new marketing channels are also to be evaluated. A market comprising few large customers is different from that comprising a large number of small customers. Considerable weight age should be given for customer service and/or guarantee.

- Financial Factors
  By far these are the most critical and those which ultimately reflect on the R&D management's ability to foresee future needs and trends. For the evaluation of the financial factors related to the success of an R&D project, the following information is required.

  – The resources needed to perform the project.
  – The timing of the different resource requirement.
  – The costs incurred if the project is performed.
  – The timing of these costs.
  – The economic benefits likely, if the project is performed.
  – The timing of the achievement of these benefits
  – Any other benefits likely if the project is performed
  – The degree of uncertainty attached to all these estimates

8.6 The Estimation of Costs and Benefits of R&D Projects

8.6.1 The Planning Phase

The resources needed for a research project cannot be deduced easily from the statement of the aims and objectives of the project. The research strategy has to be defined and the whole project planned to show the various activities, their interactions, and the possible consequences. It is advisable that these are done in as much detail as possible and necessary for the evaluation process in the beginning, and later on, if selected, for project execution, monitoring, and control.

The strategy proposed to be followed must be outlined with clear details on the activities involved. Their expected time periods, interdependencies, resource requirements, and costs involved. It is advisable here to use organized methods of PERT/CPM networks for project planning. The strategy should also indicate the expected project outcome or possible outcomes from research. Generally, these are expressed in the form of possible outcomes together with the probability that each outcome would be reached and a statement of the time. Resources and costs required to achieve these should also be indicated.

8.6.2 *Estimation of Costs*

A basic step in the estimation of costs is the estimation of resources required for the project. The requirement of each type of resource for every activity in the project plan must be estimated. This should also include the estimation of the necessary manpower with various technical background, skills, and levels. Only in such a situation, which can be expressed in the form of a network, can a project be analyzed and evaluated in terms of its resource requirements and costs. In the simple case, the analyses reduce to the simple totaling of the requirements of each resource or class of resource and the corresponding costs. This may be illustrated as follows:

Let there be $i = 1, 2, m$ distinct activities in the project, mutually exhaustive

Let the resources be indexed by $j = 1, 2\ldots n$

Let r_{ij} = Requirement of resource j for the i th activity

R_j = Total requirement of resource j for the project

$$R_j = \sum_{i=1}^{m} r_{ij}$$

If C_j is the cost per unit of resource j, then the expected total cost of the project, C, is estimated by:

$$\mathrm{C} = \sum_{j=1}^{n} C_j R_j$$

However, this total represents the total cost in absolute terms. In many situations, the use of resources, and therefore the costs, spread over several years. If we give due weightage to the time value of money (to adjust for the associated interests, inflation, risks, etc.) the present value of costs should be computed. This could be done as follows:

Let $t = 1, 2\ldots, T$ represents the time periods (years) of the project, where T is its duration

r_{ijt} = Requirement of resource j for the i th activity in time period t

R_{jt} = Requirement of the j resource in period t

c_{jt} = Cost per unit for the j resource in t period

C_t = Cost of the project in the t period, with $C(0)$ as initial investment costs and

$\mathrm{PV}[\mathrm{C}]$ = Present value of all future costs toward the project

Then, $R_{jt} = \sum_{i=1}^{m} r_{ijt}$ and

$$C_t = \sum_{j=1}^{n} c_{jt} r_{jt}$$

If r is the discount rate, the present value of all future costs is given by

$$\mathrm{PV}(\mathrm{C}) = C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \cdots + \frac{C_T}{(1+r)^T} = \sum_{t=0}^{T} \cdots \frac{C_t}{(1+r)^t}$$

The values of $(1/1+r)$, known as the present values or, value today of ₹1/cash flow occurring at the end of t years if discounted at an annual rate r, are available for various values of T and t is in many books on finance.

In estimating the costs it should be noted that the costs depend on the intended speed of the project. To determine the ideal cost time combination it is advisable to use the critical path method (CPM) of project networks to assess the optimum cost time tradeoffs.

8.7 Evaluation of the Benefits

The benefits from research mean different things to different individuals and organizations. Therefore, care should be taken to define what constitutes the "benefits" from a research project. The objective is to identify various possible fields of benefits and then, ideally, quantify these benefits in financial terms as "cash inflows." This depends on several aspects and the following factor may be kept in mind.

- Identification of the beneficiaries
  This depends on answer to the question, "to whom are we evaluating the benefits?" There might be several possibilities, such as team of researchers, the R&D organization, a firm taking the results of R&D, a section of the society, a nation and scientific community or mankind as a whole.
- Direct/indirect benefits
  Benefits may be of two types: direct benefits which are generally easy to quantity, or indirect benefits (such as enhance prestige, goodwill, etc.) which are difficult to quantify.
- Type of research
  Complexities in the measurement of benefits would also depend on the nature of research. These may be broadly categorized into four:

  – Offensive research
    Offensive research usually relates to the creation of new technology and new products or new processes, which are innovative or breakthroughs of high creative caliber. In this situation, estimation of benefits is to be made under conditions of high degrees of uncertainty.
  – Defensive research
    Defensive research is usually associated with work to reduce production costs or otherwise enhance the sales potential of the product/process. These are normally aimed to prevent competitor's influence and may involve "cosmetic changes" in this situation. Estimation of benefits could be made with a lower degree of uncertainty.

- Basic or fundamental research

  It is usually dictated by the urge to search for knowledge, unfettered by considerations of possible consequences; normally from universities and educational institutions. These are intended for the benefit of future research or for the benefit of mankind. These are traditionally of high value but measurement of benefits is highly impossible in many cases or, if possible, is associated with a high degree of uncertainty. Evaluations of the benefits of such projects are generally subjective and may be required only for funding purposes. The benefits associated with such projects can be categorized into two groups: First, those with immediate material benefits and second, for those where the material benefits cannot be assessed in the immediate future.
- Mission-oriented research

  Mission-oriented research is one in which the goals of research may be the achievement of a specific mission, such as creating atomic energy potential, launching of space vehicles, development of indigenous weapon systems, and so on. Investments are required for R&D which may be of a very high order and may also include the development of infrastructure. The estimation of benefits in such situations is extremely difficult as they extend beyond social and financial aspects. Quite often these are based on national perspectives and may be undertaken at varying priorities.

• Estimation of benefits

After the identification of relevant benefits and beneficiaries, appropriate measurement criteria should be developed to convert these into cash flows at relevant points of time. Once the cash flows an in-period t are assessed. The present value of all future benefits should be calculated.

Let B = Present value of all future benefits

$$= \frac{a_1}{(1+r)} + \frac{a_2}{(1+r)^2} + \cdots + \frac{a_N}{(1+r)^N}$$

where N is the life of the project, a is the benefit in the last year including liquidating benefits, if any, r is the discount rate. Generally, the life span of the benefits N is much higher than the project duration T considered for cost purposes earlier. Additionally, the benefits may start flowing after a certain elapsed time from the start of the project, in which case it should be further discounted to the current time period to reflect the present value appropriately.

If there are various scenarios affecting the outcome/benefit from a project, then, for each such outcome define the terms

B_i = (Discounted) present value of benefits f; the scenario is 1 (outcome 1 (letter 1))

P_i = Probability of outcome 1

And i = 1, 2… p, that is, there are p scenarios, mutually exclusive and exhaustive

Then, the expected present value of benefits, taken over all outcomes is given by:

$$E(B) = \sum_{i=1}^{p} P_i B_i$$

It should be noted that in many cases there are several possible benefits which cannot be expressed in readily convertible cash flows. Many a time the estimates or "guesstimates" are used for assessing the benefits from such intangibles.

- Multi-stage evaluation
  Some of the projects cannot be evaluated right away, that is at the time of initiation. In such cases, the evaluation is done in a phased manner. At each stage the likely outcomes/benefits of research in the wake of results achieved up to that stage, costs expected for future periods as estimated at that point of time, and the worthiness to continue the project beyond that stage are evaluated.

8.8 Summary

Project evaluation is a dynamic process in R&D management. This chapter provides objectives of the project evaluation, the risks associated with project selection and criteria for evaluation for research proposals. R&D project evaluation is an art combined of quantitative measures and expert judgments to assess and evaluate R&D projects. At the end of the chapter, we have given a brief assessment on criteria for evaluations of project proposals, its costs and benefits, and selection.

Questions

1. State the range of criteria for evaluation of research project proposals.
2. Give a brief description of the estimation of costs and benefits of R&D projects.

Chapter 9
Human Resource Management in R&D

Abstract Human resource (HR) management investigates the strategic role of individuals, groups, structure, and organization in planning, development and management of R&D. Managing human resources is complex, diverse, and interdependent. This chapter explains what human resource management is and how it relates to R&D management by emphasizing the role of engineers, scientists, and professionals among R&D personnel. The next section of this chapter focuses on how R&D manager can use HR concepts, tools, and techniques like human resource planning, inventories, demands, performance appraisal, staffing plan, career planning, and development. At the end of this chapter, we have emphasized the role of career planning in two levels, that is, individual-centered and organization-centered career planning. Further, we have given a brief review on career planning tools which will be a key guide to R&D HR managers.

Learning Objectives: To characterize the terms engineer and scientist, and also understand their professional features in R&D; to explore the link among staffing plan, recruitment plan, and development plan with career plans of the scientists and engineers in human resource planning and development system; to describe various aspects in career planning and people management.

Keywords Human resource management in R&D functions • Differentiate the professional features of engineers and scientists in R&D • Roles and responsibilities of scientists and engineers in R&D • Explore the end-to-end recruitment plans for scientists and engineers in R&D • Assessing to meet organizational need standards • Career planning and development of R&D scientists and engineers

9.1 Introduction

Human resource (HR) management in R&D function is challenging as well as complex. Educated manpower is the main characteristics of R&D personnel. It is expected that they would be better qualified, likely to have bachelor's, master's, and PhD degrees. One should expect a fair degree of specialization and narrow domain expertise. In other words, they bring knowledge expertise to create new opportunities

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_9

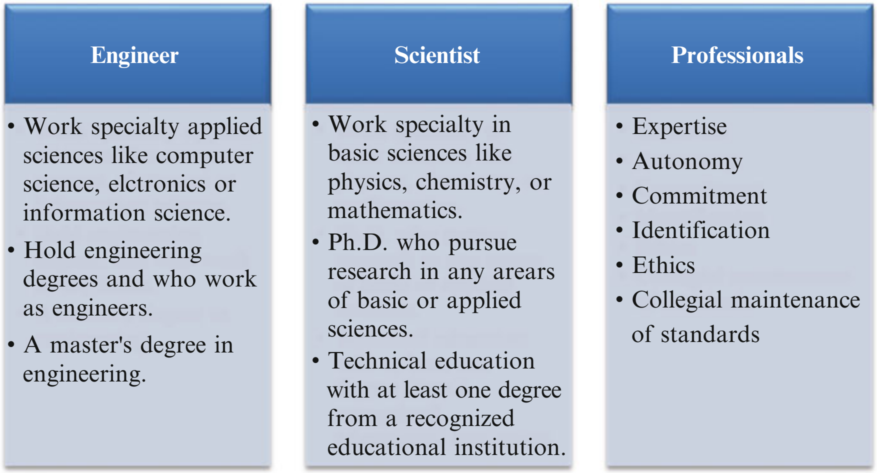

Fig. 9.1 Showing the characteristics of engineer, scientist, and professional

to the organization through research, development, engineering, and innovation. Converting their ideas into new products demands understanding of behavioral science and knowledge. We need to analyze the implication of the process of education on the nature of work as well as in personnel relationships. We also need to explore how specialized knowledge could affect the quality of teamwork. This chapter basically recognizes the difference between roles and responsibilities, aspirations, and career management of scientists and engineers.

The research evidence reveals that the role orientations of scientists are different from others. Scientists tend to be professionally oriented, while others tend to be institutionally oriented (Badawy 1971). Badawy (1971) has revealed that scientists are found to perceive certain aspects as important motivators. They include the following:

- Advancement opportunity
- Opportunity to do meaningful work
- Increased responsibility
- Freedom to work in one's own way, recognition, citation, and achievement

The above four factors emphasize treating scientists as a separate professional group. It also means that their interests, values, and personality traits are different (Raymond Cattel 1965). We first talk about the meanings of terms "engineer," "scientist," and "professional." We attempt to explain the characteristics based on the organizational contexts that are constantly being utilized and also the nature of tasks. In a study of professions, with respect to scientist and engineers, Kerr et al. (1977), summarize the characteristics of the terms "engineer," "scientist," and "professional" (Fig. 9.1).

Engineer

- Those who identify their work specialty as some form of engineering.
- Those with a major field in engineering.
- Those who hold engineering degrees and who work as engineers.
- Those with a master's degree in engineering.
- Those "engaged in engineering work at a level which requires knowledge of engineering science equivalent at least to that required in a 4-year college course, with a major in a certain field of engineering." Kerr et al. (1977)

Scientist

- Those identifying their work specialty as physics, chemistry, or mathematics, whose job title was consonant with their work specialty and who characterized their work as predominantly research.
- Those who have a technical education with at least one degree from a recognized educational institution, and who devoted most of their time to professional research and development activities
- Those with a PhD degree in physics, chemistry, genetics, biochemistry, or mathematics; who are engaged in scientific work; and who devote all of their time to professional research and development activities.

Professionals

- Experts, normally stemming from prolonged specialized training in a body of abstract knowledge.
- Autonomy, a perceived right to make choices which concern both means and ends.
- Commitment to the work and the profession.
- Identification with the profession and fellow professionals.
- Ethics, a felt obligation to render service without concern for self-interest and without becoming emotionally involved with the client.
- Collegial maintenance of standards, a perceived commitment to help police the conduct of fellow professionals (Kerr et al. 1977).

9.2 Scientists and Engineers as Professional Group in R&D

Increased specializations of labor, technical expertise, requirements for knowledge creation, and utilization have been the primary forces in the movement toward professionalism. In modern society, there is a trend toward increased emergence of professionalization of various occupational groups. A new profession desires to attain the status and autonomy of the traditional professions. But the fundamental reason for this emergence is the need for development of expertise in many fields. The primary contribution of a scientist or an engineer is intellectual in nature. The function is one of providing knowledge for use by organizations which employ scientists to create and utilize knowledge. Thus, scientists and engineers need to work within the organization and also contribute to the development of scientific knowledge as a profession (Marcson 1960). Scientists and engineers have very unique professional features. They are summarized as follows:

The Professional Features

- They have strong commitment and dedication to profession.
- Their specialization develops a strong sense of identity with their profession.
- They insist on high degree of freedom and autonomy in areas of their work.
- They are more concerned with recognition within the profession than in the organization.
- Their expertise normally comes from specialized training through a body of knowledge.
- The scientists generally have education with high degree of specialization.
- The autonomy component is very important to scientists.
- The scientists tend to encourage independence of thought and action in their work (Hower and Orth 1963).

Research and development is a knowledge-driven process, its effectiveness depends on many factors such as uncertainty with regard to outcome, obsolescence of technology, capability of organizational funding, team building, and motivation of scientists. Management policies and practices need to focus on the basic characteristic of R&D activities, such as uncertainty, specific infrastructure, complexity of technology, know-how and other related variables of scientist's motivation, and their professional interests. Combination of uncertainty, high technical expertise, and task autonomy leads to treating R&D scientists as special group of body of knowledge.

In this context, we shall discuss the major activities of technology-based innovation process and concentrate on recruitment, selection, placement, and career path of scientists and engineers. For a clear understanding of these issues, it is necessary to first look into the various activities of R&D personnel and their critical role requirement.

9.3 Activities of the Innovation Process

The major steps involved in the technology-based research, development, and innovation process are identified as follows:

- Pre-project
- Project possibilities
- Project initiations
- Project execution
- Project outcome evaluation
- Project transfer

Pre-project: Before formal project activities are undertaken in a technical organization, considerable technical work is done, which provides a basis for later innovation efforts. Discussions that are both internal and external to the organization are carried out by scientists, engineers, and marketing people. Ideas are discussed in rough-cut ways, and broad parameters of innovative interest are established. Technical personnel work on problem-solving efforts to advance their own area of specialization.

Project possibilities: Specific ideas for possible projects arise from the pre-project activities. They may be perceptions of possible customer interest in product or process changes. Customer-oriented perspectives may originate with technical, marketing, or managerial personnel, who develop these ideas from their own imaginations or direct contact with customers or competitors.

Project initiations: Activities occurring during this phase include attempts to match the direction of technical work with perceived customer needs. Inevitably, a specific project proposal is written, and proposed budgets and schedules are proposed. Counseling and encouragement from senior technical professionals or laboratories and marketing management is provided to the emerging project team.

Project execution: After project approval, the activities increase and someone takes charge of planning, leadership, and coordinating activities. These efforts are related to the many continuing activities of the scientists and engineers assigned to the project. For example, technical people make special attempts to monitor the results of previous activity as well as relevant external information. Senior people try to protect the project from being controlled too tightly or from being cut off prematurely. The project manager and other enthusiasts fight to defend their projects virtues. The project continues toward completion of its objectives.

Project outcome evaluation: At this stage, the results are compared with prior expectations and current market perceptions. The interim results are transferred either to manufacturing or to further stages of development.

Project transfer: The project's details may require further technical documentation to facilitate the transfer. Key technical people may be shifted to the downstream unit to transfer their expertise, since downstream staff members in the technical or marketing areas often need instructions to assure effective continuity. This "pass down" continues until successful innovation is achieved.

Although the project activities do not necessarily follow each other in a linear fashion, there is more or less clear demarcation among them. Each stage and its activities (different activities are undertaken during each stage) moreover, require a different mix of "people" skills and behavior to be carried out effectively.

9.4 Roles and Role Requirement

Once the organization lays out its objectives with regard to its research process the next step is to identify the role requirement. Five different work roles are critical to innovation. They include the following:

- *Idea generating* involves analyzing or synthesizing about markets, technologies, approaches, or procedures from which is generated an idea for a new or improved product or service, a new technical approach or procedure, or a solution to a challenging technical problem.
- *Entrepreneuring or championing* involves recognizing, proposing, pushing, and demonstrating a new technical idea, approach, or procedure for formal management approval.
- *Project leading* involves planning and coordinating the diverse sets of activities and people involved in moving a demonstrated idea into practice.
- *Gatekeeping* involves collecting and challenging information about important changes in the internal and external environments.
- *Sponsoring or coaching* involves guiding and developing less-experienced personnel in their critical roles, behind-the-scenes support, protection, advocacy, and sometimes "bootlegging" of funds

Each role is critical and demands unique skills. A deficiency in any one of the roles contributes to serious problems in the innovation efforts. Further, each role is played by few individuals, making critical role-players even more unique. Thus, if any one of these individuals quits, the recruitment would become a difficult process as most critical functions cannot be filled by new recruits to an organization.

Yet another role of "routine" technical problem solving must be carried out as well. It requires professional training and competence. Studies conducted in various organizations show that 70–80 % of technical efforts fall into this routine problem-solving category, and critical unique functions constitute 20–30 %. The critical functions do not have specified job descriptions but represent necessary activities for R&D, such as problem definition, idea nurturing, information transfer, information integration, and problem pushing.

Besides the above-mentioned roles, a different business environment will demand additional roles. It is desirable for every organization to have a balanced set of abilities for carrying out these roles as needed. Identifying the roles that human resource (HR) demands is incomplete if we do not look into personality characteristics required for these roles. Idea generators are experts in one or two fields, enjoy conceptualization, and are comfortable with abstractions. This person enjoys doing innovative work, and is usually an individual contributor, often working alone.

Entrepreneurs show strong application interest, often covering a wide range. They are energetic and determined but are not likely to contribute to the basic knowledge of a field. Project leaders focus on decision making, information, and questions. They are sensitive to the needs of others and are able to use the organizational structure to get things done. They are interested in a broad range of disciplines and how they fit together. Gatekeepers possess a high level of competence. They are approachable and personable and enjoy face-to-face contact of helping others. Sponsors possess experience in developing new ideas. They are good listeners and helpers are relatively objective and often are senior people, who know the organizational ropes.

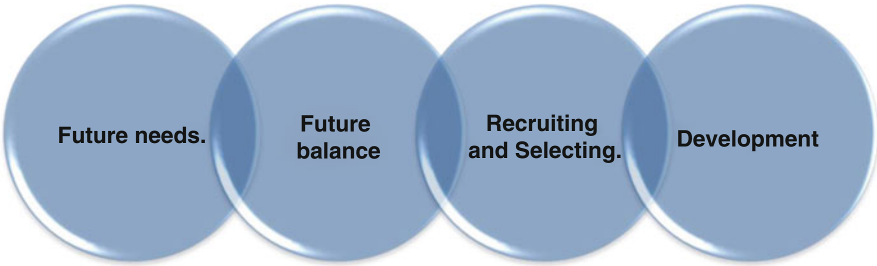

Fig. 9.2 The basic steps of human resource planning

9.5 Human Resource Planning

Organizations undertake human resource planning to enable them to meet their future "people" needs in the same way as they plan to their nonhuman resources. It is designed to ensure that the personnel's need of the organization will be constantly and appropriately met. Four basic steps in human resource planning are as follows (Fig. 9.2):

- *Planning for future needs*: How many people with what abilities will the organizations need to remain in operation for the foreseeable future?
- *Planning for future balance*: How many people presently employed can be expected to stay with the organization? The difference between this number and the number the organizations will need leads to the next step.
- *Planning for recruiting and selecting*: How can the organization bring in the number of people it will need.
- *Planning for development*: How should the training and movements of individuals within the organization be managed so that the organization will be assured of a counting supply of experienced and capable personnel?

9.6 Human Resource Demands

Human resource demands are influenced by various factors. The key factor however, is the organizational plans. Such plans are both long term and short term. Long-term plans of the organization should be examined carefully for its implications on HR demands. Some of the critical factors are as follows:

- Whether the organization is thinking of diversifying in the same line of business or entering new lines of activities.
- Whether the organization is planning to move toward new levels of technology and whether the organization has the required technological background or not. If the organization has the required technological background then the issues are

to recruit young technical personnel with potential and to train them. If the organization has no background then the issue would be the one going to the technical leaders and obviously their search and recruitment is a challenging one.
- Whether the organization is planning for collaboration? (The details of the collaboration will help in identifying the skill, knowledge, and experience levels of the R&D personnel.)

Organization short-term plans are reflected in its budget allocations made to R&D department. When there are resource constraints, the resource available to any particular activity defines the demands of the R&D personnel. Apart from the organizational long-term and short-term plans, the competitiveness of R&D as a whole will also influence the nature of demands. It is seen that R&D image influences the turnover of R&D personnel. The detailed analysis of the personnel turnover will help in identifying the required level and quality of personnel. If the turnover is higher among the senior R&D personnel or group leaders, then it takes considerable time to induct and train such people.

9.7 Human Resource Inventory

Once the HR demands are clear and understood, an assessment of the present HR inventory is needed in order to have a fair idea of the current potential and where and when the process of staffing, development training, and recruitment will be needed for future potential, and whether specialists or project groups or task groups are needed. The skills and aptitude currently available have to be assessed. This can be ideally done through performance appraisal.

9.8 Performance Appraisal

During performance appraisal, each individual work is measured against the performance standards or objectives established for his or her job. As defined in Merriam Webster's Dictionary "appraising is a process of estimating or judging the value, excellence, qualities or status of some person or thing." The effective functioning of performance appraisal system depends first on establishing realistic performance standards for each position in the organization following which individual behavior needs to be monitored, corrective actions need to be planned, and should the desired level of performance not be met, future plans for improving already satisfactory performance may be spelled out.

Some of the objectives or purpose of the performance appraisal are as follows:

- To improve performance through feedback. The frequency of such appraisal would be once a week or once a month. The appraiser essentially acts as a guide.

- To initiate personnel actions such as promotions, transfers, and rewards. Commonly occurring once in 6 months and here the appraiser takes up the role of a judge. As a judge, an individual appraisal whether or not to reward and when and how much to reward.
- To plan for training and development. Such appraisals are normally done once in 2 or 3 years. The appraiser identifies the strengths and weaknesses of the individual, discusses with the individual where new opportunities are available, and mobilizes required resources to meet the identified needs of training and development.
- To manage succession planning and career planning. The frequency of which is about once in 4 years. The appraiser need not necessarily be the direct boss; however, a committee of superiors can evaluate the individual. They make necessary forecast about the individual's potential, and the role of the appraiser is one of recommending and making futuristic decisions.

9.9 Appraisal Tools

Appraisal tools broadly include the appraisal form, assessment report, critical incident technique, Behaviorally Anchored Rating Scales (BARS), and so on. One of the most common procedures for appraising job performance is rating scales. The rating scale system is quite simple. The task of the judge is to make a judgment concerning the degree to which the individual possesses or is described by a particular characteristic. The task of the judge is to give each knowledge worker a score from 1 to 9, which describes his "degree of dependability." The criterion score of an individual is usually the average score of all judges.

Some typical factors included in an appraisal form are job knowledge, quality of work, initiative, creativity and imagination, judgment, job attitude, drive, self-expression, acceptance of criticism, ability to work with others, leadership, speed of learning, stability, and physical fitness. Appraisal can be done by individual self-assessment scales or self-rating scales. The individual does the rating himself, gives his opinion on how he feels about his performance on the job, his interpersonal relationships with his colleagues, his job satisfaction, and so on. Of course, the major wellness here is that he may give a very biased opinion of himself. Thus, it is also necessary to include ratings from others.

Two performance appraisal techniques that concentrate on giving feedback to the individual with the intention of performance improvement are critical incidents and BARS. The critical incident technique developed by John C Flanagan (1954) makes use of special forms for recording descriptive statements called critical incidents of specific behavior, which represented either outstanding or definitely detrimental behavior. Recordings are made by the supervisor. This technique, in addition to making behavioral data available for feedback purpose, may contribute to selection, human resource planning, training and wage, and salary functions. BARS, the second highly behavioral-oriented appraisal approach, is a sophisticated quantitative modification of the critical incident technique.

9.10 Appraisal Interview

In the performance appraisal process the interview is the central communication medium through which feedback is provided to individuals to help them improve their performance. In understanding this medium, three basic questions have to be kept in mind:

- Who is to conduct the interview?
- What kinds of problems are encountered in appraisal interview and feedback process?
- What different types of decision strategies may the appraiser and appraisee take to improve the performance of the latter?

Some of the problems encountered in traditional interviews like leniency effect, bias, halo effect, and so on may easily slip into appraisal interviews too. Such ratings error should be minimized if an effective appraisal system is to be maintained.

In the performance interview situation both positive and negative feedback are required if a fair assessment of performance is to be expected. Performance appraisal interviews may be improved by modifying both the method used in communicating information to subordinates and the contents of the communications. Success can be achieved if the superior dominates less, and listens more to subordinates. In this way, subordinates release their frustrated feelings more willingly. Improvement of listening skills should be an important facet of management training programs. Supervisors in appraisal interviews can help guide the subordinates toward specific improved performance by focusing attention on behavior rather than traits and involving not only the employees but also themselves and the organization in the efforts to change. This involvement of worker, supervisor, and organization may be aimed at improving two dimensions of the subordinate's behavior and skills: (1) specific job performance and (2) self-development.

Besides, in the R&D setup, individuals' working history can be assessed to discover his performance over his entire career period, his educational qualification and projects he has led, the number of publications, and his general status in the organization. Taylor together with Smith, Ghiselin, and Ellison (1961) studied some dimensions of scientific performance. Using the factor analytic method they interviewed scientists at two Air Force research centers concerning their scientific productivity and characteristics of effective scientists. Their analyses resulted in some 15 relatively distinct dimensions of scientific contribution. They are productivity in written scientific work (general), short-term written productivity, rated excellence of research reports, originality of work and thought of written reports, professional society membership, rated work output (supervisors and coworkers), rated creativity and productivity (supervisors), rated global assessment (supervisors), general likability in organization, general visibility in organization, official organizational recognition, "Organizational-man" tendencies, current organizational status, contract monitoring load, and length of work experience. The only serious predictors they found of salary were the number of people supervised and the primary activity in which the scientist was engaged.

Irrespective of the method of appraisal of scientists and engineers, the performance appraisal is a dynamic and complex process. It has to achieve the objectives of improvement, personnel actions, development and career planning, and succession planning, effectively. It is in this context that the performance appraisal is also seen as a matching process, it matches the organizational requirements with the individual needs. A carefully planned and administered appraisal system could be a valuable tool for human resources planning and development.

9.11 Present Human Resource vs. Organizational Needs

An assessment of the current human resources through performance appraisal helps in identifying the quantity and quality of the available talents. Further, it will also help in estimating the potential required to carry out the present organizational objective in the near future. A major exercise, however, is to look into whether the present human resource is adequate to meet the organizational plans. Whether the characteristics of the individuals required to play the various roles of the research process are available. Once an agreement is reached regarding the above aspects, it could be expressed in the form of staffing plans, recruitment plans, and development plans.

9.12 Human Resource Supply Plans

Human resource supply plans include staffing plans, recruitment plans and development plans. These plans can also be integrated with individual career plans. These three plans are discussed in the following paragraphs.

9.12.1 Staffing Plans

Staffing plans include the strategies and actions for the use of the existing manpower. Such strategies and actions include promotions, transfers, short-term assignments also known as acting assignments, and so on. Promotions could be seen as a vertical transfer of a person as a form of reward. Transfers generally refer to horizontal movement of persons from one job to the other. Such transfers may be moving of R&D personnel within the department as well as moving them from one functional department to the other.

9.12.2 Recruitment Plans

Recruitment plans provide an idea about the number of people required at certain levels that should be brought from outside the organization. The purpose of recruitment is to provide a large enough group of candidates so that the organization will be able to select the qualified employees it needs. The organization should decide what levels of staff they want to recruit and the qualification they should possess. This has to be guided by the recruitment policy of the organization in terms of the entry levels, reservations, and so on. Specialized recruiting is mainly used for higher level R&D executives or specialists. The recruitment of scientists and engineers poses a problem because of the following reasons:

- Scientists and engineers are in short supply.
- No company would be able to recruit sufficient staff for all avoidable positions.
- Some of them are irreplaceable.
- The damage may be highest if individuals are selected by competitors.

In selecting the scientist or engineer, the organization should examine his past track records, past experience, his background, his exposure, and whether he has worked in the same fields of interest as in the organization. Sources for recruitment of scientists and engineers are the same as those for the common employee. However, a careful examination of the sources is very important for their effective use. Advertisements have to be made in professional journals. Campus recruitment should be most useful if it is focused on higher centers of learning. Recommendations from senior professors and colleagues are important to screen and select.

9.12.3 Development Plans

Development plans spell out details of training activities within as well as outside the organization. Such plans may be expressed as the number of days a particular scientist or an engineer will be sent for training, or number of areas and required number of days of training effort planned by the organization.

The most critical aspect of the human resource planning and development system is to match staffing plan, recruitment plan, and development plans with career plans of the scientists and engineers.

9.13 Career Planning and Development: Selected Terms

A career can be defined in many ways. It is generally described as a sequence of separate but related work activities that provides continuity, order, and meaning in a person's life. Career planning requires identification of goals and development of abilities to achieve career goal with the help of career planning and development.

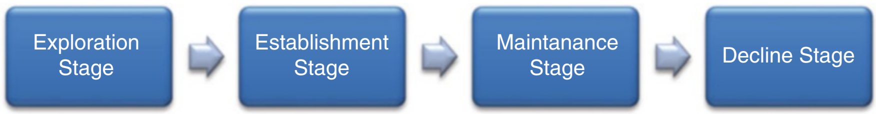

Fig. 9.3 Major stages in a career

A *career path* is the sequential pattern of jobs that forms one's career.

Career goals are the future patterns one strives to reach as part of a career. These goals serve as benchmarks along the career path.

Career planning is the process by which one selects career goals on the path to those goals.

Career development is those personal improvements one undertakes to achieve a personal career plan.

The abovementioned terms have been selected from different sources and provide a basic understanding of concepts related to career planning and development.

Theorists over the years have stated many ways in which careers progress, move, and develop. In this competitive world, it is essential to focus on career planning and make it a conscious decision. Career planning and development is a process through which a person becomes aware of his or her own personal career-related attributes and understands that there will be a lifelong series of stages that contribute to his or her career fulfillment. It is an ongoing, organized, and formalized effort that requires the participation of the individual, their manager, and the organization.

The topic of career development is of growing concern to organizations. The concept of career may refer to objectives criteria, job titles, and some kind of visible progression through refined stages or steps. In analyzing the concepts of career development and career planning, the term "development" is considered to carry with it the notion of improvement, while the term "planning" means "thinking ahead." The major stages in a career include the following (Fig. 9.3):

- Exploration stage (pre-career entry)
- Establishment stage (early career), that is, mutual recruitment, acceptance and entry, first job assignment, leveling off, transfer and/or promotion, and granting of tenure
- Maintenance stage (mid-career)
- Decline stage

9.13.1 Goals of Career Planning and Development

- To provide *recognition* by giving task force assignments, organizational representation opportunity, training new people, and appreciating a specific noteworthy contribution.

- To bring back *challenge-oriented performance* by relating performance to total company goals, and creating competition.
- To *revitalize workforce* through reassignment by self-development programs, knowledge, and skills (people, organizational, and communication).
- To bring changes in supervisory attitudes.

9.13.2 Basic Features of Career Planning

- Career planning follows a bottom-up approach. The process begins with the individuals, team level, and then works upwards, and ends with organizational intervention.
- Here the employee identifies the needs and along with it the methods to fulfill those needs on a regular basis.
- The aim is to match the career goals of the person with the opportunities that are available within the organization.
- Career planning is a way of achieving both employee progression and organizational efficiency and it is not an end in itself.
- Both the individual employee and the organization have to take collective responsibility.
- Career planning aims to meet the differing demands of individuals, the organization, changing market, the growing competition, and the growing importance of specialized skills.

Figure 9.4 shows the process of career planning. It begins with self-exploration and an understanding of interests and skills; the research to be done; attaining the experiential education; decision making, which plays a crucial role, along with job search; and finally, managing the career that the individual is now in.

9.13.3 Career Planning: Individual and Organization

Career planning is an integration of efforts from both the individual and the organization. It is about understanding the organizational vision and goals, preparing profiles accordingly, and plan the career development of the employees.

9.13.3.1 Individual-Centered Career Planning

Individual-centered career planning focuses on individuals' careers rather than organizational needs. It is done by employees themselves, and individual goals and skills are the focus of the analysis. Such analyses might consider situations both inside and outside the organization that could expand a person's career. Effective

Fig. 9.4 The process of career planning

career planning at the individual level first requires self-knowledge. An R&D member should have answers to the following questions: What are the issues faced in a day? How hard am I really willing to work? What is most important in life to me? What trade-offs between work and family or leisure am I willing to make? What is the vision in my life? What are my values?

9.13.3.2 Organization-Centered Career Planning

Organization-centered career planning focuses on jobs and on constructing career paths that provide for the logical progression of people between jobs in an organization. These paths are ones that individuals can follow to advance in certain organizational units. Effective career planning at the organizational level first requires knowledge about the organization with respect to objectives, aims, and goals. Figure 9.5 depicts this.

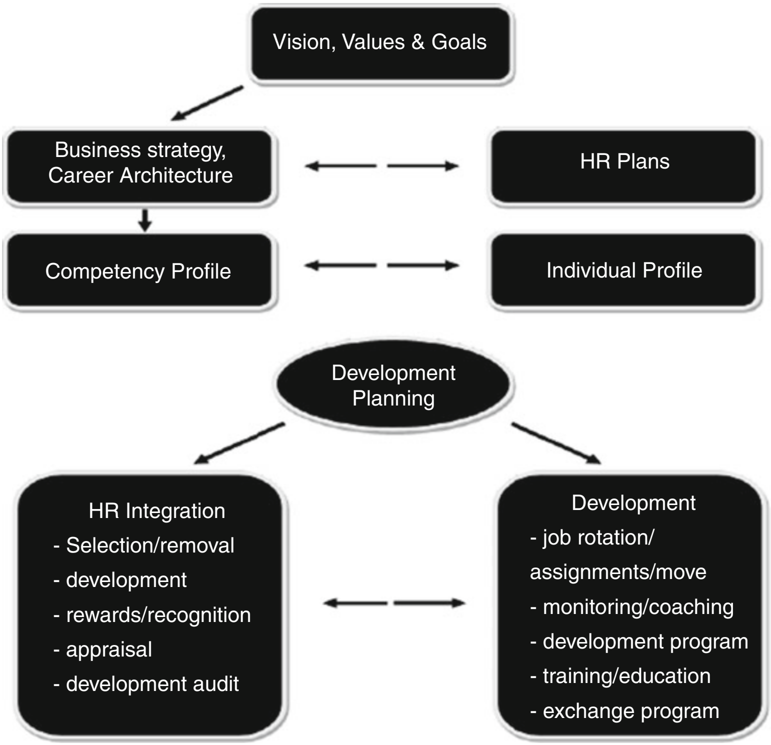

Fig. 9.5 The stages of career development

The issues of career management may vary according to the career stages. The number of and kind of career one chooses in one's attempt at reaching one's "career goal" refers to one's "career path." Conflicts in the R&D career are seen because of the "Dual ladder" concept, where the engineer may sometimes have to play the role of a manager as well as an engineer and so is the case with the scientist.

Driver (1985) suggests four basic career concepts.

- The first is the linear concept, resembling the stereotype view of careers, where the individual chooses a field early in life and develops a plan for upward movement in that field.
- The second is the steady state, where the individual selects a job or field early in life and stays with it. The individual with linear career concepts, Driver says, are motivated by the need for achievement, whereas those of the steady state are motivated by security.
- The third concept is that of the spiral career concept where individuals are motivated by personal growth. They enjoy new jobs or fields, work hard performing well, and keep moving to entirely new fields that offer new challenges.
- The fourth group is the transitory, who drift with no particular pattern from one job to another, only occasionally moving up in the organization. They appear to

be pursuing the need for independence. In addition, Driver talks about a plateau individual who has risen to a certain level and then remains at that level. This concept of career plateau may be defined as "the point in a career where the likelihood of additional hierarchical promotion is very low." In a declining career, a person rises to a certain level, remains there for a time, and then begins a descent back to lower levels.

Schein's Career Anchors refers to an occupational self-concept, a personal sense of the type of work an individual wants to pursue and what that work implies about the individual. Career Anchors begin to develop early in people's career, as a new employee comes to know how they fit in to the organization and how they contribute to it. While organizations can help individuals manage their careers, career management is ultimately the individual's responsibility. Like organizations, individuals who develop plans for the future are more likely to achieve their goals.

9.13.3.3 Individual Career Planning

Individual career planning (ICP) (Fig. 9.6) involves what one wants from one's work, career, and life. ICP can be approached like any other type of planning, although it resembles a strategic planning most closely. A nine-step career strategy that includes systematic career planning (given by A.N. Schoonmaker) has the following steps:

- Accept the fact that there are some inescapable and irreconcilable conflicts between you and your organization.
- Accept the fact that your superiors are essentially indifferent to your career ambitions.
- Analyze your own goals.
- Analyze your assets and liabilities.
- Analyze your opportunities.
- Learn the rules of company politics.
- Plan your career.
- Carry out your plan.
- Chart your progress.

A simplified model of the individual career planning will explain the process more clearly.

Some strategies for career development that R&D personnel can improve and obtain a current exposure to new opportunities are:

- *Job rotation*: It is a system where workers move from one job to a completely different one. By giving the workers the opportunity to develop different skills, job rotation offers challenge and motivates achievements. In this case, it can be from research to marketing or research to production, and so on.
- In-house company seminars, where they can frequently share their research and receive peer feedback.

Fig. 9.6 The ICP model

- Encouragement to take continuing advanced education programs during or outside office hours.
- Sabbaticals.
- Encouraging them to attend local and international meetings.

The R&D managers should not view the different activities of R&D in its isolation. An integrated approach helps in better management of high talent HR in R&D.

9.14 Career Planning Tools

Career planning tools are of various types. They comprise self-assessment tools and peer assessment tools to understand the employee competency. Psychometric assessments like aptitude, personality, and interest tests will help the organization and the individual understand how to work more effectively in making their career choices. Developmental tools are provided to employees to assist in their learning and development and understand their learning profiles. The employee is also encouraged to draw career architecture to map and outline the relationships between various careers in the organization.

Career planning increases employee engagement and reduces turnover. It benefits the organization and helps in building its HR and ensures a competent workforce.

While there are many theories proposed by researchers, it is important to understand positive motivators as delineated by Herzberg et al. (1959). The positive motivators identified by Herzberg are achievement, recognition, the work itself, responsibility, and advancement.

- *Achievement*: The manager ideally has to provide a set of targets and work with the employees in stages, celebrating each victory. In this manner, the employees understand what is expected of them and how they can stretch their boundaries.
- *Recognition*: This is essential as employees have to feel appreciated. They have to know that their good work is being noticed. The role of feedback here becomes very important and they have to know that it is constructive in nature, aimed at improving their capabilities.
- *The work itself*: The work itself should be interesting and challenging.
- *Responsibility*: This is the most lasting positive motivator. When an employee gains responsibility, that is seen as an advancement, which then gives rise to a sense of achievement. There is improvement in work and this works as multiple motivations.
- *Advancement*: This is a very important motivator for employees. It could be long term or short term in nature. Promotion, salary rises, and job prospects are the long-term aspects and the short-term issues involve increase in responsibility, acquiring new experience, and broadening the experience. The team has to understand that both short-term and long-term aspects of advancement are important for career growth.

Questions

1. Compare and contrast engineers, scientists, and professionals based on their characteristics. Also discuss the professional features of engineers and scientists in R&D.
2. Explain in detail the foremost steps involved in the technology-based innovation process and the different work roles that are critical to innovation.
3. State the various human resource demands in organizations and the methods adapted to meet these demands.
4. Explain individual career planning with the ICP model.

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Chapter 10
Attraction and Retention of Talent Management in R&D

Abstract This chapter highlights the need for talent management to undertake a strategic analysis of the HR processes in R&D organizations. The talent management is a performance-oriented, conscious, deliberate approach undertaken to attract, develop, and retain people with the aptitude and abilities to meet the current and future R&D needs. This chapter has given a brief introduction, operational definitions, and its scope in R&D activities. At the end of this chapter, we have discussed required competencies for talent management and the challenges of retaining talents to maximize the return on their human capital investments.

Learning Objectives: To understand talent, talent management, talent specific to the research activity and developmental activity, and global talent management; to present an outline of competencies required for talent management and Freudian psychology of reward and punishment applied to effective learning; to present an overview on talent management in India and the challenges faced.

Keywords Talent management in R&D organizations • Global talent management • Outlining the competencies of effective talent management • Outlining the talent specific to research methods • Challenges of retaining talent in the R&D centers • Leadership and career development

10.1 Introduction

In research organizations, knowledge becomes increasingly important for sustaining competitive advantage. Knowledge vests in the organization by the virtue of people. Creating the hub of talented people and evolving it according to the current needs is a challenge and critical for knowledge-intensive organizations. Many organizations also use the term talent management or talent attraction and development to indicate the importance of scientific manpower management in R&D organizations.

Talent is a function of ability and willingness. Some people are more able as well as willing; some are able and not willing, and we also find some who are not able but willing. Organizations may also have a set of people who are not able and not willing. The first step toward managing talent is to understand the human resources (HR) based on the above categorization.

Capability can be developed through effective guidelines of the leaders. Abilities are best formed through giving assignments, critical problems, and providing

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_10

systematic feedbacks to improve capabilities. Willingness and motivation can be described as both intrinsic and extrinsic. Scientists are expected to be driven by intrinsic motivation than by extrinsic motivation. Intrinsic motivational factors include challenge, respect, and self-esteem. Extrinsic motivation includes recognition, promotions, monitory benefits, appreciation of others, and so on. The second step in effective management is in recognizing motivational levels of scientists and engineers.

The third important step is to assess and understand the attraction of the job and the challenge it can provide for scientists. An achieving climate and appropriate appreciation and system can increase willingness of scientists and engineers to contribute and excel in their areas of work. This chapter provides an overview of talent management process and provides tools to enhance the utilization of the talent in an R&D function.

10.2 Definition of Talent and Talent Management

It is complex to derive the precise meaning of "talent management" (TM) because there have been many assumptions made by authors who write about TM. The terms "talent management," "talent strategy," "succession management," and "human resource planning" are often used interchangeably leading to confusion (Lewis and Heckman 2006). Several recent articles in the practitioner-oriented literature describe "talent management" as "a mindset" (Creelman 2004); a key component to effective succession planning (Cheloha and Swain 2005); and, an attempt to ensure that "everyone at all levels works to the top of their potential" (Redford 2005). Olsen offers a characteristic view, "A company's traditional department-oriented staffing and recruiting process needs to be converted to an enterprise wide human talent attraction and retention effort" (Olsen 2000).

It is the responsibility of the talent development head to identify talent. Perspective of talent in knowledge-intensive firm is likely to be different from that in an operations or a supply chain firm. Talent is in some ways a function of people and their capability to convert their knowledge into organizational gains.

Sometimes the term talent management is used interchangeably with human resource management where the focus is on the whole of the workforce rather than on highly talented people. In general, talent management is a subset of HR practices where talent refers to top-grade workforce and talent management practices concerns recruitment and development of talented people fulfilling the organizational goals and maintaining competitive advantage. What constitutes "top grade" may be debatable and will differ according to core competencies and mission values of a firm.

We can have three different notions of talents:

- Star people ("A-performers")
- The specific skills and competencies of these individuals (the talents of the A-performers)
- Key positions within the firm to address the linkage between these talented individuals and their organizational role ("A positions")

Research and development can be differentiated on the basis of whether the activity looks for alternative technologies or improvement of existing technologies in scientific domain, or it directly contributes to the design of a new product. Therefore, understanding talent in R&D can be taken as slightly different.

10.3 Talent Specific to the Research Activity

The time it takes to complete a research in pharmaceutical researches is very long and product development cycle ranges typically from 8 to 10 years. The investment in terms of labor has to be done upfront and returns will come after a lag of many years. Direct return of a research or a finding is speculative in initial years and uncertain. Long-term planning is required.

Long-term planning of resources involves long-term training of talent, individually and in groups and managing knowledge effectively. Competencies in a knowledge worker relating to these three attributes are sought for:

- *Long-term and future-oriented training* of human resources is necessary. Working for next generation technologies is the buzzword.
- *Team work* is indispensable because the complexity of research has outgrown the limits of individual capacity. We don't expect any more Einsteins who propose theories on their own. The *work culture and nature of collaboration* within the team and among the teams are to be watched out.
- Integrating *knowledge management practices* into work culture. Discipline of storing and processing information is essential to the success and confidence of the new finding. *The rigorous process of research* has to be followed.

10.4 Talent Specific to Developmental Activity

The product development life cycle time has reduced due to agile technologies and concurrent engineering. Matching up hot technologies and stepping into risky white space is a challenge. Although similar to the research activity in all other terms, the development activity provides saleable products immediately. In other words, development activity is product focused.

- *Knowledge of competitive products* and product lineups are required. Historical product evolution specific to the product at hand is required.
- *Vision of the development of technology* and technology implementation is critical. Investing in outdated technologies leads into cash traps.
- Project realization has to go through numerous stage gates which must be rigorous. The collaborative and interactive structures in the organization should be capable of doing effective critical reviews. *Egoistic emotions* leading to curbing of new ideas will be catastrophic for the organization.

Since the traditional R&D is dead, talent specific to R&D can no longer enjoy any special privileges over any other industries. R&D has to be up-to-date and the R&D worker has to be up-to-date too, or else they both perish.

Too much of expectation in an R&D function for short period may lead to disappointments. Very long methodologies are followed from laboratory-level experiments to testing and product development, which may take a long time. Training a new candidate requires the same time period equivalent to the life cycle development of one particular technology. It is important for this industry to have low turnover rate and develop because of the time intensiveness of the R&D of a new product. Carrying forward of previous learnings and lessons from the past will help to remove redundancy. Where collaborative and cumulative addition of knowledge is required to form a product, efficiency of team effort determines the success.

To quote an example, launching of a DRDO missile and ISRO rockets are best examples of brilliant team efforts guided by excellent leaders such as Vikram Sarabhai and APJ Abdul Kalam. When we lose one team member that specific skill set is hard to find. Hence, understanding of organizational goals and core competency requires experience and taking over a position requires time. It took Cyrus Mistry almost a year to fully take over all Tata companies. Replacement by new recruitment takes 150 % of annual remuneration of the employee. This includes direct or indirect costs involving project losses due to stalling, training, and headhunting.

10.5 Tacit and Explicit Aspect of Talent

Western mind-sets give exclusive recognition to explicit talent; Japanese firms take care of experience as the tacit factor in employment. Creativity has a large tacit part as is evident by success of Asian firms. While Western firms relied on SAT, GMAT, and GRE scores, the recognition of tacit part has grown recently.

The biggest differences are in internal development: 62 % of the Indian firms frequently track progress in overall talent management, compared with only 26 % in the United States; 65 % frequently measure the development of skills of employees versus only 21 % in the United States; 45 % frequently track the ability to promote from within through succession versus 21 % in the United States; and 46 % frequently use metrics to assess the development of leaders versus 28 % in the United States. By these measures, US companies were simply less interested in employee issues altogether than their Indian counterparts—and especially less interested in developing their own talent. This reflected a much greater "hire and fire" strategy in the United States, a more arm's-length overall approach to the management of people.

10.6 Global Talent Management

Companies are also looking to emerging markets to unlock potential commercial opportunities and this poses new talent management challenges. Preferences of employees from different countries need to be taken into consideration in this process. For instance, offering international experience is an effective retention technique in India, whereas an experience in multiple areas (even at the same level of seniority) increases employee satisfaction and retention in China.

Multinational enterprises that view global talent management as a critical activity can be expected to undertake formal succession planning and have a formal development program for their high potentials. The succession planning represents "a deliberate and systematic effort by an organization to ensure leadership continuity in key positions" (Rothwell 1999).

10.7 Competencies Required of Talent Management

The following competencies are required in R&D function.

10.7.1 Leading by Example

One of the important qualities of a good manager is to demonstrate the capabilities in R&D engineering areas of action. The leader must be extraordinary and capable and up-to-date and correct.

10.7.2 Negotiation Skills

The manager of an R&D function needs to create a win-win situation among the team members. In particular, project selection, allocation of resources, review of milestones, and discontinuation of a given project could lead to conflicts differences, embarrassments, stress, and depression. One needs to have the confidence to resolve the issues at the early stage and provide encouragement and face-saving opportunities to build the coherence and sustain the relationship rather than chaos, confusion, and uncertainties.

10.7.3 Developing People

Competent managers are not only achievers by themselves, but also ensure success of other team members. Good managers are also called as "success pilots," providing opportunities, understanding one's capabilities, strengthening achievement motivation, and creating and sustaining learning opportunities through reflection are all possible effective methods of developing people.

10.7.4 Documentation and Communication

Significant achievements come around intense experimentation and problem-solving acts. Before a success it is important that an effective leader captures both success as well as failures in a systematic way. Absence of tracking past failures and the reasons for failure would lead to repetitions of the mistake, waste of resources, and disappointments among the team members. Reuse of success experience is helpful in correcting and strengthening of the organizational process. It also helps in effective decision making and better use of facilities and infrastructure. Communication is another side of the documentation. Systematic communication of the experiences and periodic reflection of the team members on past success and the failures help build collective intelligence. Competent managers understand the implication of both documentation and communication and create mechanism, process, and platforms for effective implementations.

10.7.5 Directing and Controlling Skills

Directing scientists and engineers is both an art and a science. Competent managers understand the loose and tight properties of directing in an R&D setting where there is a significant presence of highly educated manpower. For some people, vision and a big picture of the future are sufficient to align the thoughts and action to achieve the goals, whereas for some, in particular, young talent benefit from holding and micromanaging and directing specific activities. The combination of general versus specific goals and details need to be worked out in order to influence creative efforts of the scientists and engineers.

10.8 Challenges

Retaining talent in the research organization where life is monotonous is a challenge. Also, the workforce must be kept focused. Projecting the tranquil environment of the research environment as a better life and emphasizing the adage "whatever glistens is not gold," is a nice idea!

There is a general feeling that people choose higher education because they were some sort of social entrepreneurial failures in their lives or the big brands did not recruit them. This view is highly questionable but it becomes relevant when someone is looking for passion to work. PhDs are structured to be academic, give hardly any insight into the job competencies. And, PhD students eventually become a part of R&D. This fallacy ejects the scientific minds from the research organizations, and the intrinsic creative minds which could be developed are left out. What we finally get are trained experienced thinkers and the question remains as to how passionate they are.

Let us take the case of a drug development company. Candidates who join afresh often lack specific drug development skills and experience. This is partly due to the drawbacks of education programs in India and China, where the focus has traditionally been more on theoretical concepts rather than their application, hence resulting in an abundance of candidates with advanced scientific and technical degrees but without the necessary skills to transfer their knowledge to the jobs effectively.

Branding the organization as a firm doing intellectual work makes an employee feel attracted toward doing independent research tied to organizational goals. It is also desirable to provide some time for individuals to pursue their own individual passion and research interest. This balance of research satisfying individual needs and organizational goals has to be achieved, although cash flow in traditional R&D is narrowing.

Effective use of crowd sourcing can be used where the crowd is the internal people only. For large firms to innovate, it would be easier to develop innovation based on experiences and ideas of their internal people. It should be the talent manager's responsibility to see that this incentive is effectively offered across all functions and identify star performers based on reviews from senior management, the concerned department, and peers. Motivation of each part of the organization to generate ideas keeps the spirit alive in the most routine jobs. Therefore, an HR person in an automobile company cannot be excused of innovation.

The following are the key challenges facing R&D organizations seeking talent in emerging markets.

- Ever-widening gap of demand and supply intensifies competition for the right talent.
- Talent shortage is exacerbated by rising attrition and employee dissatisfaction.
- Lack of robust career planning program hinders the development of future leaders.

Beyond compensation, companies' retention strategies have not kept pace as R&D workers have become more sophisticated.

The demand for more sophisticated talent poses an even greater challenge. It is relatively easy to recruit people for clinical operational activities in the R&D process, such as data management and statistical analysis. However, it is extremely difficult to obtain skilled and experienced talent in drug development functions such as clinical design. Talent with sufficient management and leadership skills to contribute effectively to global firms is rarely found and difficult to recruit.

Key factors that attract research scientists include company brand, status of working in a prestigious MNC, opportunity of recognition through scientific publications, and the freedom to conduct advanced research activities. However, these attributes are not sufficient to retain talent in the development group, since they tend to be more dynamically connected and influenced by external marketplace trends. They are attracted to opportunities that will enhance their marketability via exposures to broader areas of responsibilities, more flexible career paths, and trajectory toward leadership roles.

As MNCs strive to enhance their R&D presence in emerging markets, career and leadership development for local talent becomes increasingly important in creating sustainable long-term success for companies. The criticality of career and leadership development is underscored by the fact that the size of R&D organizations in emerging markets has increased dramatically over the years.

At the same time, R&D organizations were becoming more tightly integrated with the corporation and responsible for more challenging global R&D tasks. Operating a large-scale R&D center of strategic significance to the corporation, with hundreds of employees, is a daunting task and demands a high caliber of talent.

Sourcing and attracting talent: Innovative sourcing solutions can help position companies to identify talent more accurately and cost-effectively. Strategically locating the R&D centers close to the talent pool is the first step. Forming alliances with top universities offers multiple advantages: co-developing unique curriculums prepares graduates for their future job functions; scholarships attract outstanding students and enhance the company's brand image broadly; and internships and post-doctoral programs in company research laboratories can be the launchpads for potential talent to be engaged and trained in drug discovery and development at an early stage. This can also generate goodwill with local educational institutions.

Highlighting unique training and career advancement opportunities can also help distinguish a company favorably among candidates.

10.9 Retention

Managing talent attrition risk is no less important than recruiting talent. Due to the relatively inexperienced nature of the young workforce, the time and efforts required to get a new recruit fully trained are significantly more in emerging markets as compared to developed countries. The importance of retention is further accentuated by the aggressive "talent poaching" from competitors as an increasing number of MNCs continue to build and expand their R&D presence in emerging markets.

The journey of effectively managing talent retention for a company begins with a profound understanding of the needs and values of their R&D talent. It takes persistence and commitment for companies to continuously discover symptoms, diagnose underlying causes, and address them relentlessly. A self-critical lens may be difficult for companies to adopt, especially given the cultural bias toward upholding the authority image at senior leadership levels. However, the ones with courage to do so will likely reap tremendous benefits. Implementing an exit interview process that offers more than just lip service is critical for companies to uncover issues and begin their resolution.

In addition to understanding why employees leave a company, an equally important but frequently neglected perspective in preventing talent attrition understands why employees stay with a company. By methodically reviewing the reasons from both sides (loyalists and defectors), a company may discover its own secret weapon which can be a very important competitive differentiator, yet one which may not even be fully recognized by its leadership team.

Closely examining reasons why employees stay with a company can shed light on the unique attractiveness of the company, such as it may be a creative and fun place to work. These favorable attributes tend to be more culturally oriented, therefore not easily replicated by competition. On discovering such factors, companies need to protect, maintain, and strengthen them.

10.10 Leadership and Career Development

In order to make the most of the potential of the workforce, companies need to adopt a systemic approach to continuously grow talent throughout their tenure. Robust on-the-job training can help a company build a solid foundation for the employees to improve performance in their primary job functions. To further increase the competency of the workforce, a company should also develop a continuous education program and enforce it (i.e., mandatory credits) through the deployment of a broad internal training curriculum via multiple delivery mechanisms including online learning. A cross-functional rotation program is another effective tool to expand functional knowledge in the workforce and drive talent growth, despite any potential organizational hurdles with its implementation.

Questions

1. Differentiate talent specific to the research activity and talent specific to developmental activity.
2. Briefly discuss the challenges faced by talent management in India.

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Chapter 11
Creativity in R&D Organizations

Abstract Today R&D organizations deal with broad spectrum of contemporary challenges like market pressures, technical complexities, and limitations which demand a high degree of creativity and innovation in R&D organizations. This chapter explains the role of creativity in organizations and factors influencing the organizational creativity. Further, we have provided a brief account on creative process, creativity climate, and barriers of creativity, creativity training, tools, and techniques to measure creativity. The final section of this chapter emphasizes on core job dimensions and its characteristics in R&D to elicit, manage, and mapping creativity. Further, idea development and management emphasizes on continuous engagement of employees leading toward creative organization.

Learning Objectives: To provide overview on the role of creativity and innovation in organization, specifically R&D organization and the factors affecting organizational creativity; to describe creativity and the various aspects related to it, such as creativity process, creative climate in a scientific organization, barriers to creativity, training for creativity, and techniques of creativity; to explore a range of ways to build greater creativity in R&D.

Keywords The overview of creativity in R&D organization • The affecting factors in organizational creativity • Ideas and innovations in R&D organizations • Techniques of creativity • Core job dimensional characteristics in creativity • Redesign of job in R&D organizations • Supervising creativity in R&D • Idea management

11.1 Creativity in Organizations

Organizations today are knowledge based in nature and the role of creativity becomes important with increasing focus on technological innovation. The role of organizational culture becomes important in this context, as it influences the degree of creativity and innovation in the organization (Martins and Terblanche 2003). Creativity is not simply an inherent quality in a person, process, product, or place. It is an important aspect in today's organizational level. Organizational creativity gives importance to both social and group creative processes. It is a phenomenon that ensures that there is an environment for creative activity (Sundgren and Styhre 2007).

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_11

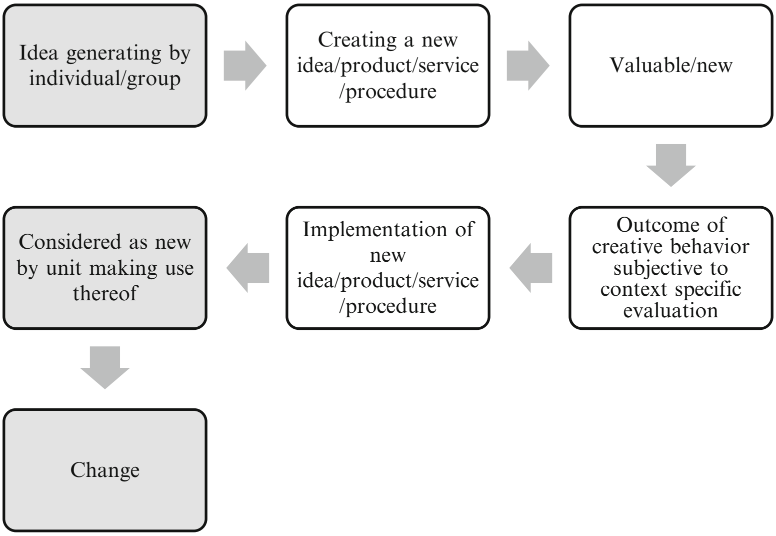

Fig. 11.1 Role of creativity and innovation in an organization (*Source*: Martins and Terblanche 2003)

Figure 11.1 shows the role of creativity and innovation in bringing about change in organizations.

Organizations have to focus on building "creative circles," through which people in the organization have a way to discuss new ideas and innovations in a conducive environment, thus fostering creativity. The Snowflake Model of Creativity states different psychological traits found in creative people that organizations should make a note of. They are as follows:

- Objectivity and the encouragement of criticism.
- Mental mobility.
- A high tolerance to complexity.
- Inner motivation—a zealous passion for work.
- The ability to excel in finding problems.
- "An enjoyment of risk taking." (Burke 1994).

There are various factors that affect organizational creativity. They are organizational climate, leadership style in the organization, resources and skills available, structure and systems, and organizational culture (Andriopoulos 2001).

Figure 11.2 illustrates these factors.

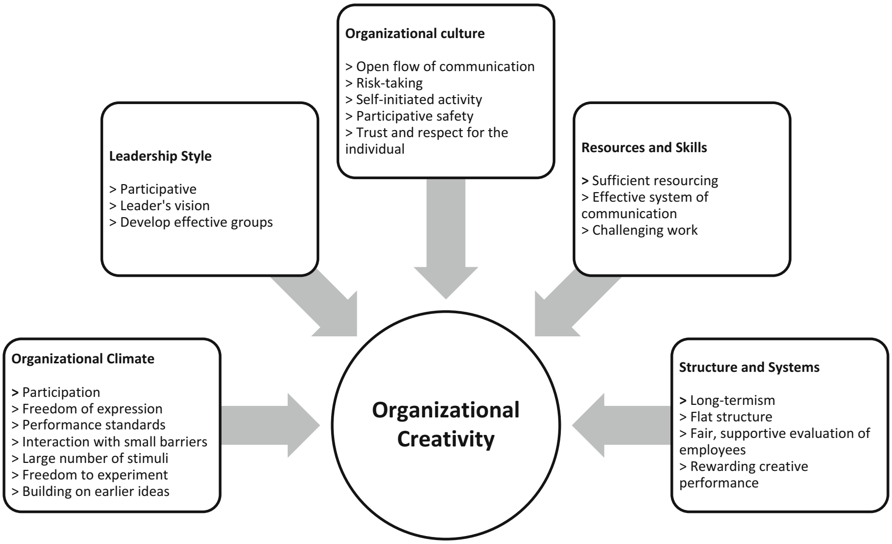

Fig. 11.2 Factors affecting organizational creativity (*Source*: Andriopoulos 2001)

11.2 Creativity in R&D Organizations

Creativity is essential to R&D work. Every individual has some amount of creativity in him. The more exposed he is to limitations in which a creative response is encouraged and fostered, the more creative he becomes. In other words, creativity can be a planned effort; that is, creating a situation where the need arises to nurture and develop creative technological innovation.

11.3 What Is Creativity?

Definitions and interpretations of "Creativity" are many. Karger and Murdick (1963) described creativity as an intuitive process, which reaches a solution to a problem without going through step-by-step reasoning. It employs the individual's knowledge, often subconsciously and may follow a period of unstructured thinking. Raudsepp (1963) felt the process "entails a selective structuring of vague ideas." Taylor (1964) distinguishes between creativity and productivity. He says that creativity is reflected in the originality and value of the product, and same productivity is required before the creative person is identified and recognized by society. He continues to say that it is true that there is a high correlation between productivity and creativity.

Allen et al. (1960) spoke of creativity not as a single ability but a cluster of abilities. They have isolated some factors of creative ability, such as sensitivity to problem, ideational fluency, flexibility of set, ideational novelty, synthesizing ability, analyzing, reorganizing or redefining ability, span of ideational structure, and evaluation ability.

Some identifiable characteristics of creative individuals are as follows:

- People are creative to some degree. These creative potential surfaces only in stimulating environments.
- Creativity can be learned. Creative potential can be increased under favorable conditions, high motivation, appropriate training, and an encouraging environment.
- People can be creative in different ways. Creativity is not a single ability but a cluster of abilities. People vary in their creative abilities.
- Some kinds of creativity can be tested.
- Creative intelligence equates comparably with IQ intelligence. Although high intelligence may be necessary for high order of creative ability, it does not ensure it.
- There is little evidence to show the reduction of creativity potential with age. Creative skills are often reduced because they are not exercised.
- Low morale reduces creativity.
- Creativity is therapeutic.
- Only a small percentage of our creative potential is utilized.
- Creativity can be focused undisciplined freedom, which is not a necessary prerequisite to creative output. Industrialists can think of creativity in terms of focused objectives. The results of focused creativity are more satisfying and effective than random, undirected efforts.

Furthermore, creative R&D personnel tend to be independent intellectual non-conformists, valuing to set their own goals and to pursue them in their own way. Studies show that scientists are characterized by a very high level of intelligence, and that they are in the upper 2 % of the population when classified according to IQ; although a high IQ may be needed for high order of creative ability, it does not ensure it. Besides intellectual factors, emotional factors and culture and environment in which the person does creative work are influencing factors.

11.4 The Creative Process

The exercise of creativity can take place in any phase of the total creative process in each of these phases, and both ideation (idea generation) and evaluation (judgment as to the utility of the idea) must occur, if creativity is to be achieved. Some basic steps for the creativity process are listed as follows:

- *Preparation*: The preparation stage involves a great deal of hard work and high level of motivation. An individual’s thoughts change rapidly and constantly receive new ideas.

- *Incubation*: A single idea or concept recurs spontaneously from time to time with some modification occurring, while the subjects are thinking of other matters.
- *Inspiration*: The point at which the idea or concept is distinctly formulated.
- *Validation*: The idea or concept is tested by research, experimentation, or other means.

11.5 The Creativity Climate in R&D

It is absolutely essential to set up a creative climate in an R&D setup. Karger and Murdick (1963) suggest ten steps to promote a creative climate in a scientific organization:

- Where possible, give engineers a choice of problems.
- Permit freedom for responsible engineers.
- Give time for far ideas to incubate.
- Minimize distractions and trivia.
- Be receptive to new ideas.
- Allow for personal differences.
- Provide proper tools to accomplish the job.
- Encourage personal intellectual growth.
- Establish a review and recognition system for technical achievement.
- Set the pace and establish a pattern for creativity in organization.

11.6 Barriers to Creativity

If there is a tendency in any organization for the formation of cliques, members tend to conform to group norms and mediocrity prevails. The creative individual must participate in the group but he must not be highly involved and become a communistic conformist. The timing of his innovation activity is important. He must not cause undue stir in the group.

Resistance to change is another barrier to creativity. Fear of change can be attributed to uncertainty and to the vested interest which might be disturbed.

The group approach and indiscriminate use of committees can hinder creativity of an individual, unless he can dominate the group with his creative ideas, but most likely he will be overwhelmed by force of members.

Other responsibility barriers to the creative process are ignorance, lack of ability, negative attitudes, indecision, overspecialization, entrance caution, and fear of ridicule.

11.7 Training for Creativity

Because of its increased popularity in recent years, many consultancy firms have begun to specialize in creativity training. Although there is a general consensus that certain aspects of creativity can be taught, there is less agreement on how it should be done. A few principles are offered here as follows:

- People who participate in creativity training gain self-confidence and judge themselves to be more creative.
- Teaching the theory of creative behavior, not just creative techniques for long-term effects.
- Showing participants examples of desirable outcomes improves the production of creative solution.
- People who work with those whom they like do better than people who work with whom they dislike.
- Warm up for practice exercises seem to enhance both quality and quantity of solutions.
- Extraneous activities, such as transcendental meditation do not seem to effect creative production.

11.8 Techniques of Creativity

A number of techniques have been developed to stimulate creative thinking. The most widely used techniques for generating creative ideas is brainstorming (Alex Osborn 1953). Here, a problem is presented clearly to the brainstorming panel, and each member is requested for an idea for several rounds. No one can criticize anyone's ideas. In this way various creative ideas are generated.

A technique that combines the convergent thinking principle of forming categories with the brainstorming principle of generating many alternative solutions is the technique of attribute analyses (Crawford 1954). In this method, given an object that one wishes to design, be it a tangible object or an activity, we identify first its major attributes. Next we take up each attribute and generate as many alternative ways of securing the attribute as we can. After generating these alternative designs, we need to evaluate them in terms of criteria such as cost, marketability, and so on. A usual technique for solving many complex technical problems is the technique of synectics, created by Gordon, Advertising executive and management consultant (Gordon 1961). These techniques are based on the principle that constructive psychological strain can lead to original solutions to problems. Basically, it consists of mechanisms that bend and stretch the mind in every direction through the style of poetry. It is a technique for churning the mind so that novel visions and insights rise to the surface.

Another technique that can be usefully combined with any of the other four techniques is the checklist of questions, also developed by Osborn (Osborn, Applied imagination (1953)).

11.9 Core Job Dimensions

Creativity training aims to help trainees develop motivation and abilities congenial to creativity. Thus, the question that arises is will internal motivation occur on the job? According to Oldham and Hackman (1981), there are three critical psychological states for internal motivation to occur. They are the following: (1) experiencing meaningfulness of the work, (2) experienced responsibility for the outcomes, and (3) knowledge of the actual results of work activities. Further they say, “What are needed are reasonably objective, measurable, changeable properties of the work itself that foster these psychological states and through these states enhance internal work motivation” (Oldham and Hackman 1981). Figure 11.3 shows the five core job characteristics interacting with the psychological states resulting in the creative outcome.

11.9.1 Five Core Job Characteristics with the Psychological States

Skill variety: Refers to the degree to which a job requires a variety of activities in carrying out the work, involving the use of different skills and talents of the person.

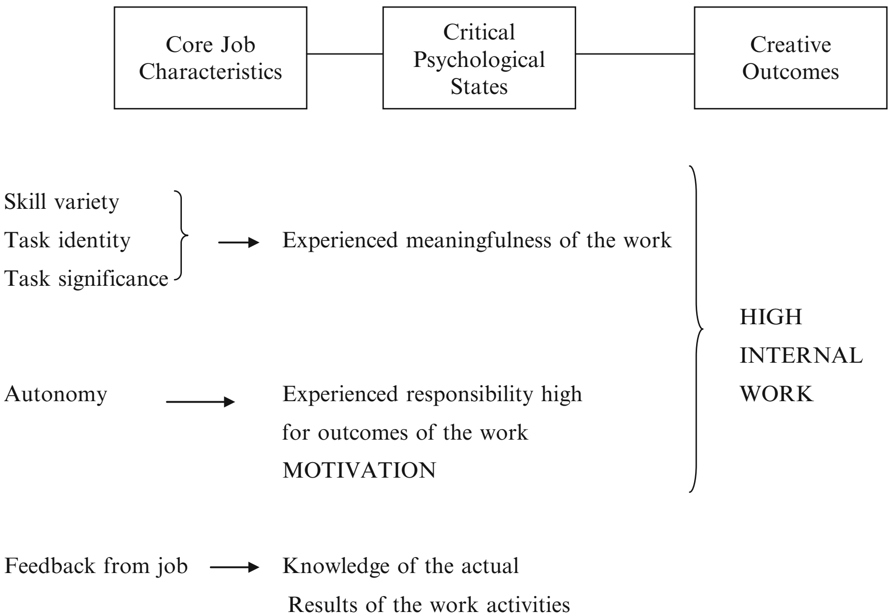

Fig. 11.3 Core job dimensions (*Source*: Oldham and Hackman 1981)

Task identity: The degree to which a job requires completion of a "whole" and identifiable piece of work, that is, doing a job from beginning to end with a visible outcome.

Task significance: The degree to which the job has a substantial impact on the lives of other people, whether those people are in the immediate organization or in the world at large.

Autonomy: The degree to which the job provides substantial freedom, independence, and discretion to the individual in scheduling the work and in determining the procedures to be used in carrying it out.

Job feedback: The degree to which carrying out the work activities required by the job provides the individual with direct and clear information about the effectiveness of his or her performance.

11.10 Job Redesign in R&D

When redesigning certain jobs within a unit in the organization, one has to decide on whether work redesign is feasible for that unit. One has to know to distinguish between those aspects of the job that need improving and those that are fine as they are. It is also important to know how to identify how ready the people are who will be involved for the change. The diagnostic instrument Job Diagnostic Survey (JDS) can be ideally used to obtain answers to some of these questions. The major intended uses of the JDS are as follows: (1) to diagnose existing jobs prior to work redesign, as one input in planning whether how redesign should proceed; (2) to evaluate the effects of work redesign, for example, to determine how much jobs have changed, to assess the effects of the changes on employee motivation and satisfaction, and to test for any spin-off effects of the job changes on employee growth need or satisfaction with the work context. Alternative instruments for assessing characteristics of jobs have also been provided by Jenkins et al. (1975) and by Sims et al. (1976).

11.10.1 Four Steps Can Be Suggested for Using the JDS for Job Redesign

Step 1: Conducting the JDS, that is, administration of the JDS.

Step 2: Compare the survey data with the JDS normative data. Means and standard deviations are available for technicians and professionals. However, norms for the Indian group are not available.

Step 3: Feedback and discussions.

Step 4: Job redesign, training for creativity, evaluation, and improving creative climate.

The JDS can be effectively used to improve performance in the R&D department. Organizations also work to increase employee creativity. Unsworth (2001) considered the paradigms of the type of problem and driver for engagement and gives a typology for creativity. This also considers the perceived personal risk aspect (Dewett 2004a, b). Figure 11.4 below exhibits this typology.

While the role of the organizational culture is important to understand employee creativity, it is also essential to have a leader who promotes creativity in the organization (Escribá-Esteve and Montoro-Sánchez 2012). Thus, for an R&D organization, the process of creativity, the factors affecting creativity, and the role of creativity is paramount to understand how innovation takes place.

Open **Problem type**	**Expected Creativity** Required Solutions to Discovered Problem Example: Idea to improve process-nature of outcome not specified. *Modest Perceived Personal Risk*	**Proactive Creativity** Volunteered Solution to Discovered Problem Example: Unprompted suggestion directly relating to one's own work. *High Perceived Risk*
Closed	*Low Perceived Personal Risk* **Responsive Creativity** Required Solutions to Specified Problem. Example: Idea to improve process-nature of outcome specified.	*Modest Perceived Personal Risk* **Contributory Creativity** Volunteered Solutions to Specified Problem Example: Unprompted suggestion not directly relating to one's own work
	External	**Internal**

Driver for Engagement

Fig. 11.4 Modified version of Unsworth's (2001) Topology of creativity (*Source*: Dewett 2004a, b)

11.11 Managing Creativity in R&D

Creativity is not a latent ability. It is a skill and built by learning and applying the right disciplines. The key to building greater creativity is to generate ideas, manage ideas, and give recognition to and appreciate idea. Linking the idea from hidden is essential. The more idea links you make, the more creative your team will become.

11.11.1 Generate New Ideas

Standard idea-generation techniques concentrate on combining or adapting existing ideas. This can certainly generate results. But here, the focus is on equipping the reader with tools that help him/her leap onto a totally different plane. These approaches push one's mind to forge new connections, think differently, and consider new perspectives. These techniques can be applied to spark creativity in group settings and brainstorming sessions as well. All these techniques are aimed to: (1) breaking thought patterns; (2) connect the unconnected; (3) shift perspectives; and (4) employ enablers.

11.11.2 Brainstorming

This is one of the best known and most used in the business world group-based creativity process for problem solving. It is a technique for generating a large number of ideas from a group of people in a short time. It can be used for generating a large number of ideas or solutions for well-defined strategic or operational problems, such as for engineering design processes. It also forms a basic framework or constitutes the initial phase for the implementation of many other groups based on creative techniques.

11.11.3 Storyboarding

It is a creativity technique for strategic and scenario planning based on brainstorming and is used mainly by groups. It requires a leader, a secretary, and takes place in a group of 8–12 people. The leader arranges the ideas generated by brainstorming in a logical order on a white board creating a story. This technique allows identifying the interconnections of ideas and how all the pieces fit together. It can be used to identify issues, problems, solve a complex problem, and determine ways to implement solutions.

11.11.4 Checklists

This creative technique is used mainly for product improvement or modification. It involves applying a series of words, verbs, adjectives, or phrases contained in checklists or tables to an existing product or service or its attributes. Osborn's checklist is the best known and includes the verbs: put to other uses, adapt, modify, magnify, minify, substitute, rearrange, reverse, and combine. Each verb also contains an expanded definition in the form of questions.

11.11.5 Mapping Process

The use of maps is particularly useful in strategic management thinking in organizations, helping to organize discontinuities, contradictions or differences, and bring pattern, order, and sense to a confusing situation, acting as a spatial representation of a perspective. There are many forms of mapping, including computer-based tools to support mapping.

11.11.6 Morphological Analysis

This method is another product improvement technique, permitting the in-depth analysis of products or processes. It involves applying a set of words to a product or process. Normally, one set of words is verbs and the other set is attributes of the product.

11.12 Idea Management

Idea management provides an organized method for collecting and moving ideas from conception to selection. It is a structured process for the following:

- Developing a targeted idea search strategy
- Soliciting ideas that address the defined problem
- Developing a methodology for capturing ideas
- Establishing idea evaluation criteria
- Evaluating and scoring/ranking ideas
- Determining which ideas have the greatest potential to add value to the organization
- Taking action on the most promising ideas

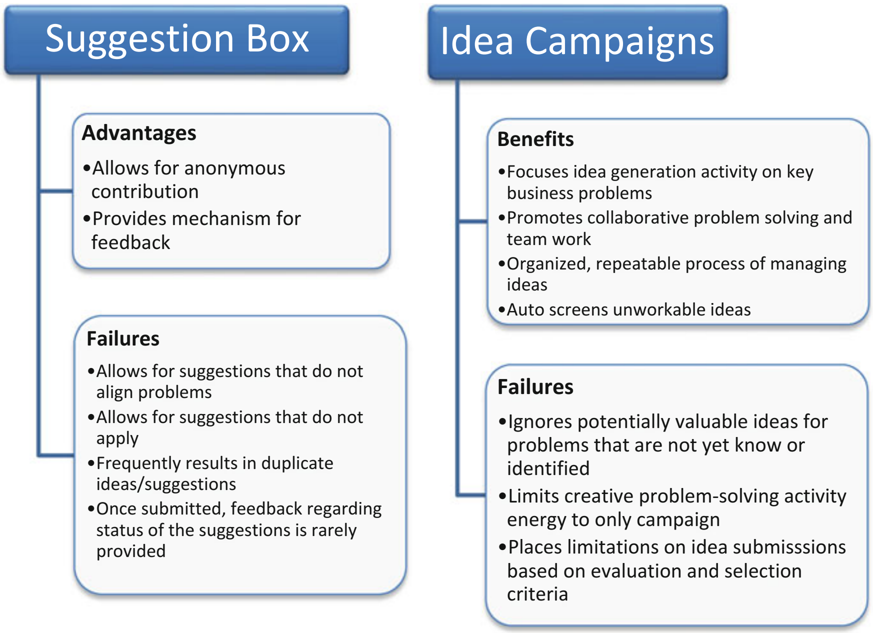

Fig. 11.5 Advantages and limitations of two main models for idea management

There are two main models for idea management: the first one is (a) open suggestion scheme and (b) targeted idea campaign. Many organizations today blend both types for effective idea management. Figure 11.5 summarizes the advantages and limitation of these two models.

Suggestion box is traditionally a physical box with a slot in the top to submit ideas, comments, and concerns anonymously. From 1994 onwards, physical suggestion boxes began to be replaced by email or other electronic submission methods. NCR was the first major organization (1892) to use the suggestion box as a source of employee ideas for new product development.

The idea campaigns are events focused on generating ideas and solution relating to a specific business problem or need. It begins with the identification of the "problem to be solved." The idea campaign is communicated, marketed, and promoted to increase participation of development teams and later these ideas are captured, assessed, scored, and selected.

Many organizations and even idea management vendors envision a software tool that allows anyone in the organization to submit ideas into a central repository. Ideas in the repository are reviewed by an innovation team who decide which to forward for further development and which to reject. Most suggestion schemes fail after 12–18 months, for the following reasons:

- Suggestion overflow
- Duplicate idea submission
- Many irrelevant ideas
- Opacity

Fig. 11.6 The process of idea management

Idea management is a structured process for capturing ideas from across the workforce and evaluating those ideas to determine which have the greatest potential. For effective idea management, a good organizational climate, climate of experimentation, and continuous loop of feedback-based learning is essential. Figure 11.6 shows the process of idea management.

11.12.1 Recognition and Appreciation

Once you have generated and identified the potential of each of your ideas, the next challenge is to set up your ideas toward recognition, appreciation, and collaborative idea development. The main means of motivating employee's idea management include promotion and rewards.

11.12.2 Promotion of the Idea

Promotion at minimum should include e-mail notification to all participants of an idea campaign. The e-mail should provide the following:

- Information about the ideas campaign, especially the challenge.
- Explain why the challenge is a business issue and the importance of the selected ideas.
- List rewards associated with the campaign.

In addition to e-mail promotions, posters (elevators are a great place to put promotional posters), T-shirts, and announcements in divisional meetings are all good ways of promoting idea campaigns.

11.12.3 Rewards

Rewards are a key motivational tool. They need not be big. Indeed, big rewards are often less effective than small rewards. There are several reward types:

- Recognition.
- Small gifts for every idea.
- Slightly larger rewards for the most creative ideas (this motivates people to stretch their thinking and be more creative).

- Whatever rewards choice you make, be sure your colleagues know about it.
- Rewards are one of the biggest motivators for participating in an ideas campaign.

11.12.4 Collaborative Idea Development

Once the innovation challenge has been formulated and the ideas campaign launched, it is time to generate ideas. Participants submit ideas and collaborate on each other's ideas in an open, transparent environment.

During the collaborative idea development phase, feedback should be positive and participants should be encouraged to push their ideas further. Criticism must be prohibited. Such a positive environment is essential for the incubation of creative ideas—and it is creative ideas that turn into your most significant innovations. Negative feedback is discouraging not only to the recipient of the feedback, but also to other participants. And as soon as people fear their ideas will be criticized, they quickly stop being creative.

Questions

1. Briefly discuss with a flow diagram how creativity has contributed in bringing change in an organization.
2. Define idea management and explain the two main models for idea management.
3. Define Job Diagnostic Survey. When and why is there a requirement of this instrument?

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Chapter 12
Interpersonal Relationships, Teams, and Team Building

Abstract R&D organizations are driven by a wide range of challenges, which requires diverse skills, expertise, and experience. Teams enable these characteristics to facilitate rapid, flexible, and adaptive responses of R&D organizations. The chapter begins with a brief introduction of teams and an evaluation on the role of interdisciplinary teams and cross-functional teams in R&D setups. Further, we have attempted to view the role of team members and their paradoxical behavior ranging from affection, belief, and consequences. Understanding these behaviors is very important to facilitate cooperation and collaboration in R&D organizations. Teams in R&D face conflicts under the influence of power, multiple goals, and varied interests. Hence, to understand and deal with these conflicts, behavioral modification is necessary. Thus, the present chapter attempts to cover behavioral modification techniques to enhance communication interdependency and team efficiency. Finally, the chapter concludes with the role of communication and types in facilitating team collaboration and cooperation.

Learning Objectives: To understand the types of teams, team development models, team member roles, categorization on effective and ineffective team characteristics and team performance models; to explore team-building interventions; to present a detailed picture on communication in R&D and various aspects related to it; to describe conflicts, various levels of conflicts, and types of conflicts in an organization.

Keywords Team development in R&D organizations • Team building intrusions • Team performance categorization in R&D • Role of interdisciplinary teams in R&D • Organizational silos • Paradoxical behavior in R&D settings • Organization development for team building • Leadership-directed interventions: Managerial grid • Influence, communication and conflict in R&D perspective • Need for Communication in R&D

In this chapter, we provide an overview of teams, dynamics of behavior in R&D teams, and different methods of team building. It also provides insights into communication and interaction, which happens among scientists and engineers and

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_12

provides solutions to improve communication and interpersonal relationships for better teams, team performance, and productivity.

12.1 What Is a Team?

> A team is any group of people organized to work together interdependently and cooperatively to meet the needs of their customers by accomplishing a purpose and goals. (Heathfield 2013)

Organizations have different types of teams based on their functions and disciplines.

- *Functional or departmental teams*: These teams comprise people from the same department who work on the same problem and perform the same function.
- *Interdisciplinary teams*: These teams comprise experts from different fields who work toward a common goal. A complex project requires multiple skill sets and expertise.
- *Cross-functional teams*: These teams comprise people from different departments and performing different functions. They are brought together to work on a specific problem and process. Cross-functional teams could then work as self-directed teams.
- *Self-managing teams*: These teams comprise people who, over time, take on responsibility and find direction and work together.

12.2 The Role of Interdisciplinary Teams and Cross-Functional Teams in an R&D Setup

To solve multidisciplinary problems, R&D teams have to move away from monodisciplinary solutions. As technology is becoming more complex and scientific disciplines are overlapping, interdisciplinary R&D teams are the order of the day. This minimizes redundancy, balances diversity, and complementarily helps to attain a synergy of information, knowledge, culture, and technique. When interdisciplinary teams work together, there is an improvement in the creative performance that leads to innovations, creating original products and processes. Various researchers have looked at cross-functional capability and stated what organizations should have, what the leadership needs are, and how the teams should work together (Table 12.1).

Table 12.1 Cross-functional capability

Organizations should have:	Leadership needs:	Team membership should have:
Competent and lean functional knowledge groups	Strategic Leadership	Understanding of the vision, what the organization is trying to accomplish over the next 3–5 years—the value propositions
	Describing 3–5 year vision	
Process for forming, assessing, and dissolving teams	Identifying opportunities—value propositions	
Measurements of performance with supportive incentives	Determining the skills needed	Solid grounding—good in own discipline
Learning culture: interactivity, openness, creative conflict, reflection on practice	Operational leadership	
	Finding the skills needed	Respect for what each function contributes and for each other
Interactive strategic hierarchy	Facilitating	
	Pushing and following-up	Clear mandates—empowered to act
	Functional knowledge leadership	Team skills
	Recruiting talent	Character values—helping others succeed
	Developing people	
	Keeping up with innovation	

Source: Michael Maccoby (1999)

12.3 Organizational Silos

"Organization Silos are when individual people, departments, or companies, conduct business in a vacuum without taking into consideration the impact their actions have on the entire organization." (Frank Leistner 2012) These are thus the dysfunctional units or departments in an organization. In silos, there is poor communication, data duplication, process bottlenecks, and functional prioritization, with little consideration to the greater organizational vision.

12.4 Team Development Model

Bruce Tuckman in (1965) developed the Model for Stages of Team Development. It initially comprised four stages, such as forming, storming, norming, and performing, and in 1970, he added the fifth stage called adjourning. Each stage is marked by different challenges and specific actions to meet the mission of the team (Fig. 12.1).

Fig. 12.1 Tuckman's team development model (*Source*: Tuckman 1965)

The five stages are

- *Forming (awareness)*: This is the first stage when the team members are brought together. There is a level of uncertainty about the group's purpose and goals. Members, while being motivated and enthusiastic in their approach, are yet to build on the mutual trust and express themselves openly. In this stage, it is important to understand other members of the group and define the leadership in the group.
- *Storming (conflict)*: This is the second stage, where different ideas, agendas, and work styles and approaches compete for consideration. There is conflict within and outside the team as there is role ambiguity and each member wants to exert influence. By the end of this stage, the members of the team can identify their respective roles, the expectations at individual and group level, and how the group can now work with each other.
- *Norming (cooperation)*: This is the third stage, where after the conflicts have been resolved, the team works to establish procedures and plan their task. At this moment, roles are clarified further, and the focus is on decision-making to accomplish the goal. The team now builds harmony, trust, and mutual respect, and there is a synergy of expertise and thought process.
- *Performing (productivity)*: This is the fourth stage, where the interdependence of the members becomes evident. The focus is on consistent performance to achieve the desired results. At this moment, the team members are knowledgeable, motivated, and competent and take the desired decisions, and along with high performance, the team functions effectively.

- *Adjourning*: This is the fifth and final stage, and the focus is on wrapping up the project. Team members, while feeling happy about accomplishing the task, may also experience emotional moments as this association will now be disbanded. To achieve closure and completeness, it is important for the team leader at this moment to recognize the efforts of the team members and appreciate them for the work well done.

To understand the complete implications of the Tuckman model, it has to be understood that

- The duration and intensity of the different stages differ across teams.
- Teams usually have to progress through the earlier stages to begin performing.
- In case new members join the team midway, the team may track back to an earlier stage of development.
- It is possible that some teams spend a long time in the initial stages and may never complete the entire five stages.
- While the model presents the stages like discrete steps, in reality they may actually merge or repeat as new issues emerge.

12.5 Groups vs. Teams

It is desirable to differentiate between a group and a team. A team is expected to have more cohesiveness and more "we" feeling among group members than emphasizing on individual brilliance or confidence. In other words, groups are collections of people assigned and placed together to achieve a task. Toward that group, members may share views and feelings with others; however, all groups cannot be called teams. Teams are expected to perform much better and exhibit strong interpersonal and mutually supportive relationships.

The various aspects they differ on are as follows:

Accountability: Groups are measured by individual accountability. Team members have to be mutually accountable.

Rules and norms: Groups have formal rules and norms. In the case of teams, rules and norms are leader directed and determine how a team performs.

Work environment: In a group work environment, a manager takes decisions and assigns tasks, while in a team, the manager in collaboration with team members decides the task details.

12.6 Team Member Roles

Team members play various roles to ensure that the team meets success. Dr Meredith Belbin identified a set of eight roles, which, if present in a team, help them to achieve their goals and be successful. The roles are coordinator, shaper, plant, monitor-evaluator, implementer, resource investigator, team worker, and finisher.

- The coordinator takes on a role, setting the agenda to meet the desired objectives, establishing priorities, and summing up roles; he/she is decisive without being dominating.
- The shaper gives shape to the effort of the team. He/she seeks the pattern in the discussions, checks the feasibility of the project, and ensures that they get results.
- The plant is the thinker, who provides ideas, suggestions, and proposals, which are original, out of the box, and even radical in nature.
- The monitor-evaluator is the objective team member who analyzes the tasks and ensures that the team does not make mistakes.
- The implementer is the person who converts the decisions and strategies into defined and manageable tasks, sorting out the objectives and ensuring that they are pursued logically.
- The resource investigator is the person who plays a multiple role as the team's salesperson, diplomat, liaison officer, and explorer. He/she goes out of the team and brings in ideas and information.
- The team worker works like a cohesive agent, especially when there is pressure and stress. He/she takes care of any disruption in the team and ensures that the team stays together.
- The finisher is the person who ensures that the task reaches completion with a relentless follow-up at every stage.

12.7 Paradoxical Behavior in R&D Settings

Even though the members in R&D teams are expected to work together, many a time they exhibit exactly opposite behaviors of cooperation and collaboration. These behaviors have been seen as paradoxical behaviors. They develop because of the vicious interaction between the team leaders and the members. Unresolved differences, authoritative leadership, pursuit of self interest at the cost of the group roles, personal anxiety, and lack of promotional opportunities and mobility within the organization can lead to undesirable and unacceptable behavior. Illustratively, some of the paradoxical behaviors and team symptoms are produced below. Researchers have recognized these as neurotic symptoms. Neurotic behavior is characterized by anxiety and paranoia.

12.7.1 Paradoxical Behaviors

1. Members suffer pain, frustration, irritation, and anger when attempting to cope with the problem (e.g., thoughts such as "The politics of this research project are driving me mad," "I can't stand to go to project meeting anymore").

2. Members agree privately as individuals on the problem (e.g., "The problem is that the research project won't work. It's not technology feasible").
3. In meetings, they fail to accurately communicate their desires and/or beliefs to one another. In fact, they mislead one another. (e.g., "yes, I essentially feel that the project has merit, despite the technical problems we have encountered, I don't think we should give up yet").
4. On the basis of exchanging invalid information, members make collective decisions. (e.g., "All members who are in favor say 'yes'," "All opposed say 'No'", "The decision is unanimous").
5. Since the results are counterproductive, members experience greater frustration, anger, irritation, and dissatisfaction. (e.g., "I am mad").

12.7.2 Neurotic Team Symptoms

- Pain and frustration: It involves backbiting and loss of self-esteem. Members become less efficient and look for ways to avoid the job.
- Blaming others for the problems: There is a "backroom" conversation. Such conversations involve "Boss' behavior; he is termed as incompetent, ineffective, out of touch."
- Subgroup formation: During coffee meeting or over lunch, sharing rumors, complaints, fantasia, and strategies increases the overall anxiety level.
- Members act contrary to data and information they possess.

12.8 Organization Development for Team Building

Managing these symptoms and behaviors is crucial, and organizational development (OD) has emerged as a field to deal with some of these issues. Organizational development is concerned mainly with the planned change of organizations, the development of its human resources, and its performance. In behavioral science and perhaps in an ideal sense of the term, OD is a long-range effort to improve an organization's problem-solving and renewal process, particularly through a more effective and collaborative management of organization culture with special emphasis on the culture of formal intact work teams, with the assistance of a change agent, or catalyst, and the use of the theory and technology of applied behavioral science, including action research. The basic intervention model which runs through most OD efforts is *action research*. Basically, the action research model consists of a diagnostic phase, action planning, action implementation, and evaluation.

12.8.1 Diagnostic Phase

The diagnostic phase is one during which the organization senses the existence of a problem and focuses on attending or solving/improving it. The problem is often identified by analyzing data/information on the subject with the help of a change agent/consultant.

12.8.2 Action Planning

Action planning is the process in which various strategies are examined and an optimum is selected with a view to achieve the desired change using minimum cost, time, and resources.

12.8.3 Action Implementation

Action implementation is the phase when changes are introduced into the system. This normally results in much stress in the system. Constant feedback is extremely important as it is sometimes necessary to change the strategy.

12.8.4 Evaluation

Evaluation is the final stage, when the change agent disassociates himself from the system after successful implementation of the change. At this stage, he evaluates the whole change effort covering strategies, conditions, design, and implementation of the change. This model aims at

- Enhancing congruence among organizational structure, process strategy, people, and culture
- Developing new and creative organizational solutions
- Developing the organization's self-renewing capacity

The scope here is limited to the OD and R&D interface at the team level. Nobel Prize winner Susumu Tonegawa may be right in saying it is not necessary to have effective teamwork in creative research. However, this may be so in pioneering basic research, but for industrial research, one needs to build teams, and effective ones at that. Research and development managers have to get work, goals, and purpose done through subordinates, and success depends on their productivity, motivation, and cooperation. In other words, they have to perform as a team.

According to Beckhard (1969), there are four purposes for team building:

- To set goals or priorities
- To analyze or allocate the way work is performed according to team members' roles and responsibilities

- To examine the way the team is working, that is, its process, such as norms, decision-making, communication, and so forth.
- To examine relationships among team members.

Beckhard points out that all these purposes are likely to be operating in a team-building effort. "But unless one purpose is defined as the primary purpose, there tends to be considerable misuse of energy. People then operate from their own hierarchy of purpose and, predictably, these are always the same for all members"(Beckhard 1969).

The criteria for an effective team are understanding, mutual agreement and identification with respect to the primary task, open communication, mutual support, mutual trust, management of human differences, selective use of the team (when to meet, when to use their time), appropriate member skill (skill needed for performance of the task and for maintenance of the team as a viable group), and leadership. We thus see that various aspects differentiate an effective team from an ineffective team. Table 12.2 lists these characteristics.

12.9 Traditional Team-Building Interventions

There are various interventions adopted to build teams. One category of interventions looks at a skill-based, problem-solving, personality-based, and activity-based nature of interventions:

12.9.1 Skill-Based Interventions

This is about building new skills in the team, reaching consensus, improving communication, ensuring that the feedback mechanism is working, resolving conflicts, and listening effectively.

12.9.2 Problem-Solving Interventions

This is essential when a team faces specific project problems. The team meets at a particular location to brainstorm and work out the solution. These are problem-solving retreats.

12.9.3 Personality-Based Interventions

These help in improving the interpersonal skills among team members. This helps to improve communication and increase the effectiveness of the team.

Table 12.2 Categorization on effective and ineffective team's characteristics

Aspect	Effective team characteristics	Ineffective team characteristics
1. Atmosphere	Informal, engaged, relaxed, open, comfortable, nonthreatening, participative	Unduly formal, disengaged, tense, guarded, intimidating, stiff, fragmented, under challenged
2. Group objectives	Tasks or objectives understood and accepted, free discussion leading to group commitment, no hidden agendas, regular reviews, measure of a group's success is task achievement	Group task or objectives are unclear, no evidence that the group either understands or accepts a common commitment, often in conflict with each other and with group's task
3. Communications	Open and honest; flows freely up, down, sideways; everyone is given a hearing; individuals build on each other's ideas; conversation takes place inside and outside formal meetings	A few people dominate discussion; selective listening; information is hoarded, withheld, and flows mainly down; mixed messages
4. Handling of conflict	Viewed as natural, even helpful; comfortable handling conflict; disagreements are not suppressed, overridden, or smoothed over; focused on issue, not the person	Protocols not understood or used; avoided and discouraged; becomes destructive, personal, politicized; resolution regularly leaves some individuals uncommitted
5. Decision making	By consensus, real issues openly discussed, full commitment by team, little formal voting, simple majority not accepted as a proper basis for action	Forced or majority voting, dictated decisions, emphasis on power, various levels of commitment, dissonance present within group
6. Criticism	Criticism is frequent, frank, and constructive; oriented toward removing obstacles that are preventing the group from getting the job done; little evidence of personal attack, either openly or in a hidden fashion	If present, it is embarrassing and tension producing; often appears to involve personal hostility; tends to be destructive, seeing only negatives; there is little building on others' contributions
7. Expressing personal feelings	People freely express their feelings and ideas, both on the problem and on the group's operation; few hidden agendas; feedback readily accepted; high levels of trust, respect, care	Personal feelings are hidden; viewed as inappropriate for discussion or would be destructive if brought out on the table; risk avoidance
8. Task achievement	Clear, agreed-on plans and roles; high commitment to follow-through; group regularly weighs performance against objectives and takes steps to ensure success; diversified team member types, skill competence, and talents	Action decisions and individual roles tend to be unclear; low follow-through, variable commitment; performance is rarely reviewed; poor performance is rationalized; undisciplined; reactive; action-oriented vs results-oriented

(continued)

Table 12.2 (continued)

Aspect	Effective team characteristics	Ineffective team characteristics
9. Leadership	While the team has a formal leader, leadership functions shift from time to time based on circumstances, skills, and team needs; control is not an issue but how to get the job done; positive norms established and modeled by the leader	Single-leader dominated; leader may coerce, compromise, or abdicate; establishes norms for the group and leads from own value system
10. Review of team processes	The group is conscious about its own operations; periodically, it will stop to examine how well it is doing or what may be interfering with team functioning; peer recognition; rewards based on group contributions	Discussion on the performance effectiveness or operation is avoided; discussions about problems are kept private and not brought to the group; rewards are based on subjective, often arbitrary, appraisals

Source: Effective and Ineffective Team Characteristics (2013)

12.9.4 Activity-Based Interventions

In this, team members participate in physical challenges such as camps, hiking, and games. These interventions focus on teamwork, problem solving, trust building, and risk-taking behavior. The focus is on building team solidarity.

12.10 Team Building in R&D Interventions

In R&D management, team-building interventions take on a whole new meaning and comprise the following interventions:

12.10.1 Goal-Directed Interventions: The Awareness, Acceptance, and Commitment Model

These interventions are planned for a team with a specific goal in mind. In the awareness stage, the focus is on being aware of the problem at hand, understanding the role of the perceptions, and all the aspects involved to solve the problem. In the acceptance stage, understand what decisions need to be taken, demarcate the leadership role and actions, and focus on the team relationship. In the commitment/action model, the plan is to build an effective team that will reach the goal. The Bruce Tuckman model can be used in this context.

12.10.2 Role-Directed Interventions: Role Analysis/ Negotiation Techniques

In case the team has any confusion with their roles, it is essential to employ role analysis techniques. Each team member has a defined role and, with that, some stated expectations. Role analysis is an exercise that helps a team understand what the role is supposed to achieve, a rationale for its existence, and the attributes of an effective role taker. This intervention helps avoid role ambiguity. This helps to improve the participative culture in the team.

This helps in career planning, ensures job satisfaction, reduces role stress, helps performance planning, and helps appraisal review. Dayal and Thomas (1968) developed a technique of role analysis. The following four steps are involved in Role Analysis Technique (RAT) (Dayal 1969). As will be seen, RAT distinguishes between prescribed and discretionary elements in the activities performed by the role occupant.

- The "focal role" individual initiates discussion of his role by analyzing the purpose of the role in the organization and how it fits into the total range of activities and its rationale.
- The focal role individual lists on the blackboard his activities consisting of the prescribed and discretionary elements. Other role incumbents and his immediate superior question him on the definition of his tasks. If there is confusion in their perceptions, the ambiguity is cleared.
- The focal role individual lists his expectations for each of those other roles in the group which he feels most directly affect his own work: "Role senders" state their expectations, and after discussion, the "focal role" and the "role senders" arrive at an agreement among themselves on their mutual expectations.
- The focal role individual writes up his role. This consists of all aspects of his work discussed above.

12.10.3 Leadership-Directed Interventions: Managerial Grid

In this type of intervention, the focus is on team leadership. Blake and Moulton in 1962 defined managerial and leadership interventions based on concern for production and concern for people:

> *Concern for People* relates to the degree to which a leader considers needs of employees and team members before deciding how to accomplish a task. A high degree of concern could be coupled to a more democratic leadership style, whereas a low concern for people could be coupled to an autocratic leadership style". "*Concern for Production* relates to the degree to which a leader emphasizes production effectiveness and efficiency when deciding how best to accomplish tasks. (Blake and Moulton 1962)

Figure 12.2 highlights the main features of this intervention.

The grid styles represent five orientations in individual leadership behavior. The axes are attitudinal, and the combinations of these result in leadership styles that are defined in behavioral styles.

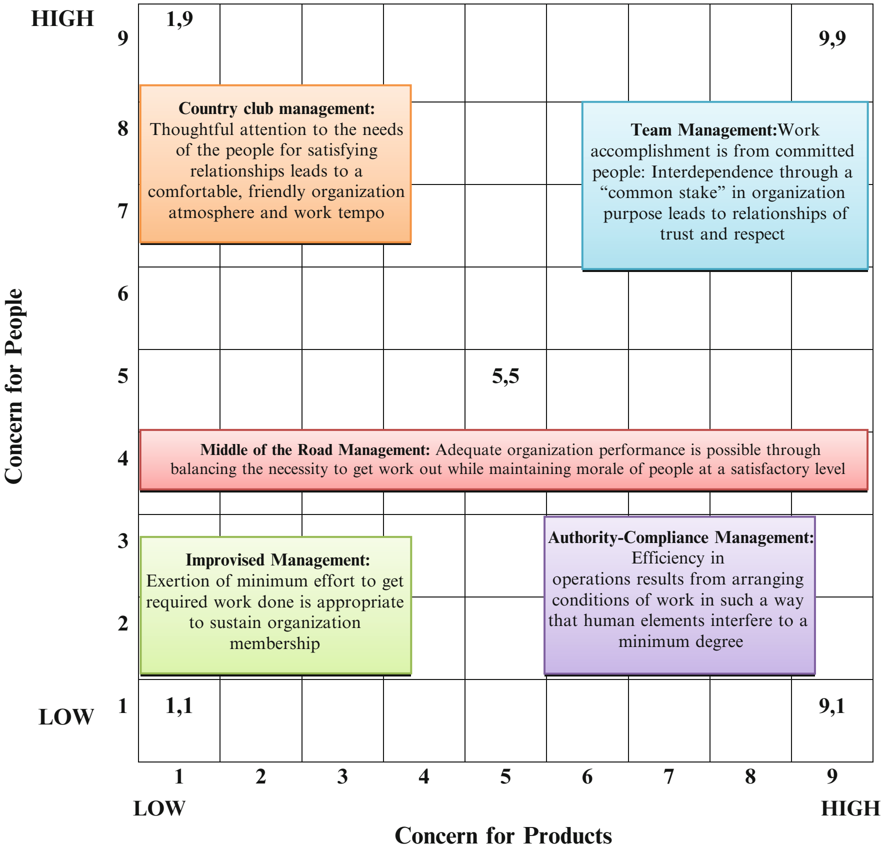


Fig. 12.2 Managerial grid (*Source*: Blake and Moulton 1962)

The teamwork grid comprises the following behaviors:

- Active listening (listening to understand)
- Open-mindedness
- Clarifying behavior or inquiry (clarifying others' views and probing into underlying rationale)
- Candid critique (nonjudgmental feedback unencumbered by status or social reticence)
- Focusing on facts rather than opinions
- Confronting the underlying causes (attitudes, beliefs, values, knowledge differences) of conflict

12.10.4 Relationship-Directed Interventions

This intervention technique works on the relationship in a team. Table 12.3 gives the concept of the Johari window.

Table 12.3 Relationship-directed interventions: This intervention technique works on the relationships in a team

	Things I know about myself	Things I don't know about myself
Things others know about me	Arena	Blind spot
Things others don't know about me	Hidden arena	Unknown area

This intervention helps in self-awareness, personal development, improving communications, interpersonal relationships, group dynamics, team development, and intergroup relationships. This was developed by American psychologists Joseph Luft and Harry Ingham in the 1950s, calling it "Johari" after combining their first names, Joe and Harry. This is especially relevant due to emphasis on, and influence of, "soft" skills, behavior, empathy, cooperation, intergroup development, and interpersonal development. The four regions of the Johari window are (see Table 12.3)

- *Open area, open self, free area, free self, or "the arena"*: What is known by the person about himself/herself and is also known by others
- *Blind area, blind self, or "blind spot"*: What is unknown by the person about himself/herself but which others know
- *Hidden area, hidden self, avoided area, avoided self, or "façade"*: What the person knows about himself/herself that others do not know
- *Unknown area or unknown self*: What is unknown by the person about himself/herself and is also unknown by others

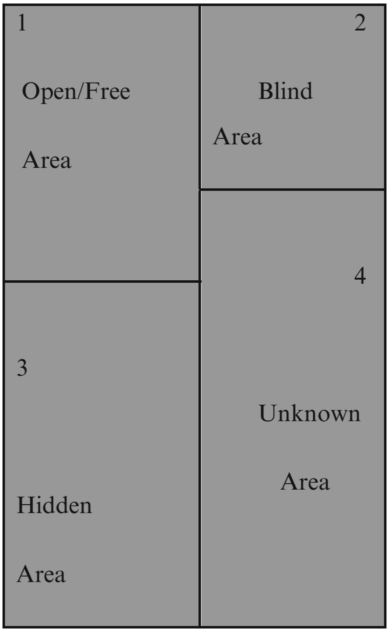
The goal of any team is to develop the "open area" for every person because when we work in this area with others, we are at our most effective and productive state, and the team is at its most productive too. This ensures good communication and cooperation. The open area/arena can be increased by ensuring that there is a good feedback mechanism. Managers/leaders have to facilitate feedback and disclosure and promote an open culture.

Team members and managers take responsibility for reducing the blind area and thus in turn increase the open area by giving sensitive feedback and encouraging disclosure. Managers promote a climate of nonjudgmental feedback and reduce fear. Sensitive communication and active listening plays a role in reducing the blind spot.

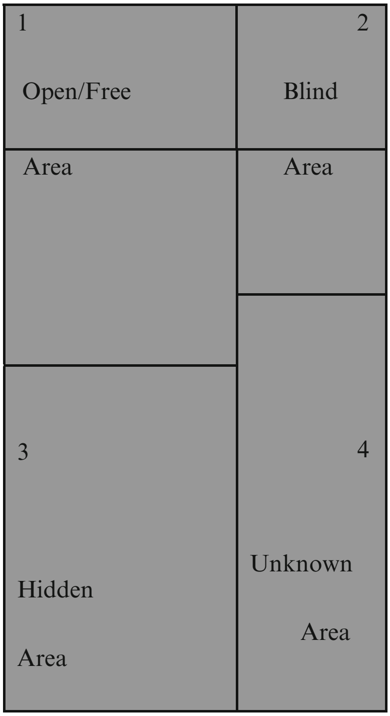
The hidden area represents information, feelings, and so on, anything that a person knows about himself/herself but which is not revealed or is kept hidden from others. This also includes sensitivities, fears, hidden agendas, manipulative intentions, and secrets, anything that a person knows but does not reveal. Whether to reduce this area is the prerogative of the individual.

The unknown area can be discovered through a self-discovery process or discussion with the team.

- The Johari window model for a new team member or a member within a new team



- The Johari window model for established team members



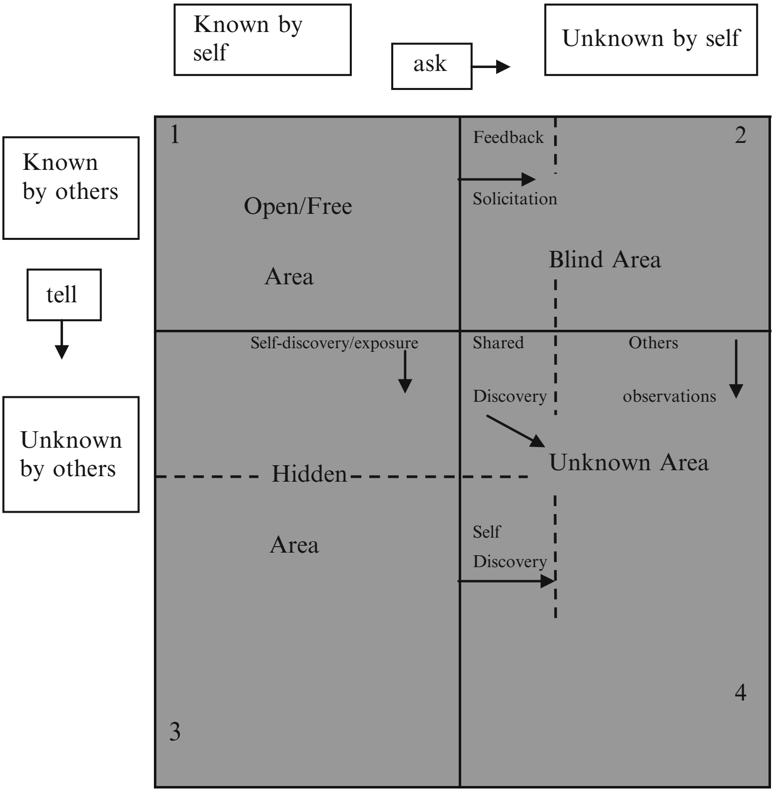


Fig. 12.3 The complete Johari window model (*Source*: Johari window. http://www.usc.edu/hsc/ebnet/Cc/awareness/Johari%20windowexplain.pdf)

We thus see how different intervention techniques can help develop teams and ensure they work more effectively for an organization (Fig. 12.3).

12.11 Influence, Communication, and Conflict in the R&D Context

The quality of interpersonal relation among members influences organization morale and productivity. Such relationships can be thought of in terms of three sets of relationship: self and subordinates, self and colleagues, and self and boss or supervisor. The nature of the relationship is dynamic and amenable to change. This is because of the differential distribution of powers, information, and authority. An effective interpersonal relationship is a product of individual initiative, one's personality orientation, and organizational climate. Dynamics of this relationship are examined in relation to the process of influence, communication, and conflict in R&D situations. Managers in an R&D context try to pursue two basic goals:

1. Ensure that performance is maximum. Once the manager has established targets and plans, he must initiate and motivate the available human talents to achieve effective performance and attain set goals. This would involve effective interaction between the manager and his subordinates.
2. Besides this, the manager also looks toward the development of individuals. This is done through providing encouragement and an enriched environment in which they can increase their current knowledge, where they can improve their attitudes and their interpersonal relationship.

The goals of ensuring performance and development of individuals can be achieved through the understanding of the process of influence, communication, and conflict.

12.12 Influence and Power

Influence of knowledge workers, that is, scientists and engineers, is a complex process. One way of understanding the process of influence is to examine the power bases of the person who is trying to influence the other. In other words, we have to examine carefully the different power bases of the R&D manager and their effectiveness.

12.12.1 Different Power Bases

The different power bases are

- *Referent power*: Referent power based on the influence's desire to identify with or imitate the influencer. The strength of the different power depends on the prestige and admiration the influence shows to the influencer.
- *Expert power* is based on the belief that the influencer has some relevant expertise or knowledge that the influence lacks.
- *Legitimate power*: Legitimate power exists when the influence acknowledges that the influencer has a "right" or is lawfully entitled to extra influence within certain bounds. This is also called positional power.
- *Reward power*: Reward power is based on the ability of the influencer to reward the influence for some work or order carried out by him.
- *Coercive power*: Coercive power is based on the ability of the influencer to finish the influence for not meeting requirements expected of him. This is the negative side of reward power.

With R&D personnel, coercive and positional powers are unlikely to be effective; in fact, use of these power bases may generate more resistance, hatred, and alienation. The effective power bases are collegial or referent and expert power.

12.12.2 Behavior Modification Techniques

The other way of understanding the process of influence is to examine the different techniques used by the R&D manager. Some of them are as follows:

Reinforcement: Managers can "shape" or modify inappropriate behavior. This technique is based on the view that behavior is purposeful, and by controlling the purpose or reward, one can influence and generate the required behavior.

Modeling: Modeling involves providing an acceptable behavior mode and allowing people to practice the same. This technique is based on social learning theories. The behavior of one individual is largely influenced by the behavior models around him. It could be the parent, teacher, friends, different groups, and so on. The manager helps the researcher to identify the model and encourages the required behavior. The effectiveness of this method of influence depends on the strength of the identification with the "model." Sometimes, managers may also act as a model and may encourage people to model his behavior.

Persuasion: The process of persuasion involves influencing the individual through changing. It is comparable to friendly use of force. In the process, an individual may adopt a new behavior. The effectiveness of persuasion depends on the "estimation or opinion of the individual about the manager." If the manager is seen as benevolent, the parental persuasion method may be an effective method.

Coercion and manipulation: Coercion and manipulation involves the use of force and suppression and taking advantage of certain conditions. If a manager indulges in this method of influence, then the results are likely to be short term. In due course, scientists and engineers may resist the influence attempt secretly as well as in open. They may act negatively in the achievement of the task. Often, it triggers the feelings of hostility, insecurity, and resentment.

12.12.3 Lewinian Approach: Three-Stage Change Process

The conceptualization of Lewin as elaborated by Schein (1969a, b) of the process of change is particularly useful at the group level. Lewin suggests three stages in the change process:

- *Unfreezing, creating motivation to change*: The creation of motivation to change involves the following:
  Present behavior or attitudes must actually be disconfirmed or must fail to be confirmed over a period of time. In other words, the individual discovers that his/

her assumptions about the world are not validated or that some behavior does not lead to expected outcomes and may even lead to undesirable outcomes. Such disconfirmation can arise from any of a wide variety of sources, and it is a primary source of pain or discomfort that initiates a change process. The disconfirmation must set up sufficient guilt or anxiety to motivate change. The creation of psychological safety, either by reducing barriers to change or by reducing the threat inherent in the recognition of post failures, is the critical third ingredient.

- *Changing, Developing New Responses*: Changing and developing new attitudes and behaviors on the basis of new information and cognitive redefinition is the next stage. The effect of creating a motivation to change is to open the person up to new sources of information and new concepts or new ways of looking at old information (cognitive redefinition). Identification with a rare model, mentor, friends, or some other persons and learning to see things from that other person's point of view would facilitate this process. Scanning the environment for information specifically relevant to one's particular problem and the selection of information from multiple sources is more difficult but produces more valid change. If motivation to change is not present, the change program must move to the more difficult emotional level of attempting to create circumstances which will induce motivation.
- *Refreezing, stabilizing, and integrating the change*: Stabilizing the changes is the third stage. It has been found that programs designed to induce attitudinal changes do have observable effects during the training period but do not last once the person is back in normal routine. The person should have an opportunity to test whether the new attitudes or behaviors really fit his self-concept, are congruent with other parts of the personality, and can be integrated comfortably. The person should have an opportunity to test whether "significant others" will accept and confirm the new attitudes and behavior patterns. Alternatively, the change program should be targeted at sets of people or groups who will be able to reinforce the new behaviors in each other.

Within this framework, the manager has to employ various tactics to ensure that each stage and/or mechanism will be properly negotiated.

12.13 Communication

Communication between humans is clearly an essential element for all levels of human activity. Communication processes, communication successes, and communication failures can be detected in all walks of life. Persons in organizations interact with others in their groups, across groups, and across levels. Communication, to be effective, should be a two-way process and especially so in the R&D context because it has to be an innovative/creative climate.

Interpersonal communication can be defined as the process of sharing messages between two persons through a medium or media. Basically, communication according to static models involves a source (a sender), a message (transmitted), a message (received), a goal of the message, and the medium. The extent to which the sent message and the received message differ will show the distortion angle of communication. The credibility of the source or the sender contributes a lot to the effectiveness of communication, so too the readiness and receptivity of the target; there is no guarantee that transmitted and received messages will be the same. In many cases, they turn out to be different, and this distortion causes communication problems.

12.13.1 Need for Communication in R&D

The interpersonal communication situations arise because of incomplete specification of organizational structure. The interdependence of activities of individuals in the organization makes it necessary for people to communicate interpersonally.

The need for communication in an R&D setup illustratively includes the following:

- To know about the overall organizational goal and to select areas of relevant science
- To determine the economic manufacturability of their designs, to make trade-offs between design and process or balance performance, cost, and reliability
- To use innovations in manufacturing technology

12.13.2 Types of Communication

R&D managers may be involved in many types of interpersonal communication situations which are related to the external system. The direction of communication can be downward communication (situations involving subordinates), upward communication (situations involving superiors), and lateral communication (situations involving peers). In addition, communication may be formal (part of the organizational chain of command) or informal (arising to meet a need, either external or internal) (Table 12.4).

Communication is an integral process of the innovation process. During the entire six stages of the innovation process, effective communication cannot be avoided. During preproject, for example, scientists and engineers find themselves interacting with their workgroup, discussing or communicating rough-cut ideas and broad parameters of innovative interest. In the project possibilities stage, their ideas have to be communicated to the customer so as to perceive possible customers interested in product or process changes. Finally, project outcome has to be communicated and intense evaluation done to see how the results compare with prior expectations and current market perception.

Table 12.4 Purposes and mechanism of different direction of communication

Downward communication	**Purpose**	**Mechanism**
	Diffusion of routine information	Circulars, bulletin boards, wall magazines
	Diffusion of procedural information	Circulars, handbooks, manuals
	Socialization	Special publication lectures, meetings
	Providing job-related information	Conversation
	Feedback	Conversation, memos
	Employee development	Conversations, group meeting
Upward communication	Control	Periodical information
	Feedback	Questionnaires, exit interviews
	Problem solving	Periodical meeting, grievances, procedures
	Ideas for improvement	Suggestion box, exit interviews
	Catharsis and group building	Review meeting (MECOM)
Lateral communication	Experience sharing	Joining forum
	Problem solving	Task force, problem clinics
	Coordination	Periodical meeting

Source: Paree et al. (1981)

Among the various roles required in an R&D process, it is that of the gatekeeper, requiring collecting and channeling information about important changes in the internal and external environments, which is most critical. The information gatekeeper is a communicative individual. The gatekeeper provides links to sources of the technical information that flows into and within an R&D organization and that can enhance new product development as well as process improvement. Engineers and scientists may have to be market gatekeepers as they need market information as well as technical information and to communicate this effectively to their technical colleagues.

The project leader or project manager is an organized individual sensitive to the needs of the different people who are being coordinated. His effective interaction with these people differentiates him from the idea generator, who is basically a "loner."

The role of sponsoring or coaching requires the skills of a good listener; he provides encouragement and guidance and acts as a sounding board for the project leader and others. Listening with the "inner ear" has become the target of many training programs. All levels of management and technical professionals need to improve their listening skills. In most studies dealing with executive appraisal, managers who are rated most efficient by their subordinates invariably are good listeners. Good listeners, even when they judge a talk to be uninteresting (but cannot

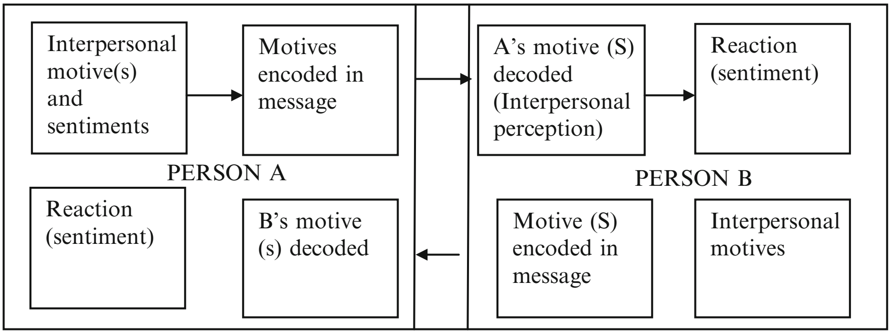


Fig. 12.4 Model of communication

leave without offending the speaker), make up their minds to learn if anything is said that they could use later.

12.13.3 General Communication Problem

In order to see how communication breakdown occurs, it is important to examine a model of communication (Fig. 12.4).

We assume that any interpersonal communication contains an interpersonal motive. First, a person may be unaware of his/her motives. The second area in which communication breakdown originates is in the encoding of motives. The third area of breakdown often occurs as a result of failure to recognize and deal with the interpersonal factor of emotion. The basic problem of communication is always the same regardless of the type of communication situation we are dealing with. Weaver (Shannon and Weaver 1949) generalized that there are three levels of the communication problem:

LEVEL A: The technical problem of achieving accuracy in the transmission of signals
LEVEL B: The semantic problem of assuring that the transmitted signals convey the desired meaning
LEVEL C: The effectiveness problem of assuring that the received meaning affects behavior in the desired way

If communication must be effective, each level of the problem must be solved or its effects minimized.

Further, in the R&D context, specialization in a particular area causes communication gaps with other specialized groups. If the leader belongs to a specialized group, his interpersonal relationship will be maximum with that group. This will hinder effective communication. The resources the leader will have to distribute will determine with whom he has to interact most. Power and status differences block communication. Overemphasis on conformity restricts the flow of communication and hinders creativity. Language barriers as well as specialized knowledge especially in the context of the interdisciplinary groups impede communication. Such communication problems must be overcome for the effective functioning of the R&D department.

The research of Likert (1961) indicated that 80 % of the managers surveyed felt that downward communication was the major communication problem and effective communication is crucial to organization success. There is some evidence that message distortion filtering and perhaps even omission occurs as an attempt to communicate downward through the hierarchy. Brenner and Sigband (1973) found indications of such dysfunctional effects when they surveyed the opinions of more than 500 executives and managers in personal interviews and questionnaires. Results showed that managers at a higher level in a structural hierarchy tend to be better informed than those who are at a lower level.

However, Likert (1961) commented that upward communication is as inadequate as downward communication and probably less accurate because of the selective filtering of information which subordinates feed to their superiors. Athanassiades (1973a, b), on studying a university faculty, suggested that distortion of upward communication by subordinates is influenced by the subordinator's ascendance device and his level of security.

12.13.4 Trust and Communication Cycles

Interpersonal trust is a gateway to communication. The subordinates must trust that the supervisor will not use the information the subordinates send to their detriment. They must believe that the information will not be inappropriately or inaccurately transferred to others. The subordinates must believe that the supervisor is on their side and can be depended upon. The relationship between trust and communication can be demonstrated as follows (Table 12.5).

Trust is a key ingredient of communication effectiveness and ultimately of organizational effectiveness.

Listening skills should be developed by careful attentive practice. There are some basic responsibilities of the listener and the sender if effective two-way communications are to take place. Some of them, he says, are by one's action: "show interest in the sender you are listening to, take time to listen, be ready to listen, try learn something if not the whole massage, make the sender repeat for clarity, do not interrupt the sender, concentrate on listening." The sender too has responsibilities:

Table 12.5 Comparison between trust cycles

	Constructive trust cycle	Destructive trust cycle
Person A	High trust	Low trust
Person B	Effective communication	Ineffective communication

"He must show the receiver that he wants him to listen, must make that the receiver is ready to listen, avoid distracting personal habits, look at the receiver and evaluate his interpretation."

Further, feedback is essential in communication as it allows the sender to evaluate the effects of his/her own communication on the receiver. Borman et al. (1969) suggest steps to encourage feedback: "tell people you want feedback, identify areas in which you want feedback, set aside time for regularly scheduled feedback sessions, use silence to encourage feedback and watch for nonverbal responses."

12.14 Conflicts in R&D Contexts

Conflicts are a part of any interpersonal relationship and arise due to different reasons such as limitation or scarcity of resources, competition, and differences in values, goals, attitudes, expectations, and so on; whatever the reason, if conflicts are not managed well, they may adversely affect R&D staff functioning and the health of the organization. Conflict management involves predicting conflicts, devising means by which dysfunctional conflicts can be avoided, and, besides, overcoming them without creating problems for the organization. Like in any other situation within any department of an organization, conflicts arise in R&D departments too.

12.14.1 Levels of Conflict

Conflicts can be examined at four levels:

- Intrapersonal
- Interpersonal
- Intragroup
- Intergroup

Intrapersonal conflict is that which the individual faces within himself. It is commonly seen when the individual has to do different jobs between conformity and creativity. Some people develop internal systems or mechanisms to solve their own problem systematically. Some people have a knack of coping with these internal conflicts by not getting agitated and taking the advice of friends, colleagues, or superior managers or taking concrete steps to sort out the conflicts. The extent to which a person experiences a conflict depends on the person himself.

Interpersonal conflicts are characterized by people not getting along with one another. They seek an outcome that is most beneficial to themselves and most detrimental to other participants, unlike a person with cooperative motives who seeks outcomes that are most beneficial to all participants. Cooperation involves a nonzero-sum approach. The strategy in zero-sum situations is to maximize payoffs for one and minimize payoffs for the other as the payoff is perceived as limited, whereas in a nonzero-sum game, the payoffs are perceived as unlimited, and the amount of payoffs one can get is more or less equal to what the other gets. One of the most popularly used zero-sum games is the prisoner's dilemma game (PDG) (Rapoport and Chammah 1965; Schelling 1960).

Walton (1987) suggests that there are two basic types of interpersonal conflict: substantive conflict and emotional conflict. Substantive conflict involves disagreement with policies or actions, differing concepts of areas of responsibility and roles, and direct competition for the same personal objective. To resolve substantive issues, the third party needs to set the stage and mediate a bargaining and/or problem-solving meeting. Emotional issues generally cannot be resolved through negotiation or problem solving. Generally, the third party must facilitate a "working through" of the feelings and perceptions involved; that is, resolution of emotional issues involves dealing with emotions, whereas resolution of substantive issues can be more "intellectual" or cognitive.

Parsons and Bales (1955) speak of two types of conflicts in project groups, namely, technical conflict and interpersonal conflict. They say technical conflict or task conflict pertains to the environmental demands of the social system, while problems concerned with social–emotional factors may involve interpersonal conflicts.

12.14.2 Types of Conflict in Project Groups

They add that conflicts arise among peers or between one or more of the subordinates and supervisors in the project group. This cross-classification of the two dimensions of conflict, technical vs. interpersonal conflict on the one hand and peer conflict vs. supervisor–subordinate conflict on the other, yields four types of conflicts (see Table 12.6).

12.14.3 Intragroup and Intergroup

Intragroup and intergroup conflicts arise out of differences on how to share the available resources and who should take the major portion. And when the resources are perceived as expandable, much of the effort of the members is spent on how to

Table 12.6 Types of conflicts

Issues in conflict	Parties to the conflict	
	Peers	Supervisor–subordinates
Technical conflict (TC)	TC peers	TC sup–sub
Interpersonal conflict (IC)	IC peers	IC sup–sub

increase them rather than on how to share them. For example, in a group, the chairman's position may be very important, and he may exercise most of the power. Then, there may be a conflict among members on who should become the chairman. An alternative arrangement may be to divide the chairman's responsibility into some major areas, and several people may then share these tasks. In fact, the more the power is shared in this way, the more it increases in the group.

Expectations of uniformity may lead to conflicts, but tolerance of uniform norms and standards should help groups to accommodate each other. Variations may be tolerated as long as they do not conflict with the main goals. This is especially relevant to an intragroup situation. In an intergroup situation, if groups have narrow concerns or do not perceive or create a superordinate goal, the resources and power are seen as limited or the ideologies of the group are in conflict. On the other hand, if the concerns are wider, the groups perceive a superordinate goal; they feel that resources and power can both be shared and expanded; they realize that groups with different ideologies can work together and collaborate; the groups will tend to minimize their conflicts and manage their resources and power effectively.

Blake et al. (1964) suggest that if conflict is seen as inevitable and a solution is not possible, a situation of helplessness may lead either to resignation to fate or to power struggle. The general orientation of a group may be an avoidance orientation or an approach orientation. Avoidance modes or styles of conflict management include resignation, withdrawal, appeasement, and diffusion, whereas approach modes or styles include confrontation, compromise, arbitration, and negotiation.

Filley (1978), similar to Blake et al. (1964), calls the functional method of conflict resolution a problem-solving method. According to him, problem-solving methods evolve intellectual intensity rather than emotional intensity or power.

Derr (1978) supports the contingency approach of conflict management. He supports three main strategies of conflict resolution, namely,

Collaboration: Collaboration may be used when parties in conflict openly face their differences or their excess power parity and when the organization itself supports the open surfacing and working of disagreements.

Bargaining: This works best between competing people or groups to establish power parity. Often, they are unable to reach a common solution due to the disparity between them. Bargaining is often a midway or a "bridge" strategy.

Power play: The third strategy suggested is an important way to cope with conflicts for the autonomous; it is advantageous for those who are most adept at this mode; it is a means for achieving a dynamic balance of competing forces and is often the only feasible way to resolve ideological disputes.

In the R&D context, the collaboration mode may be most useful in dealing with conflicts within the group. Bargaining may be most effective in dealing with intergroup conflicts, and power play may be needed to deal with the issues relating to interfunctional conflicts.

Questions

1. Define a team and various types of teams based on their functionalities.
2. Write a short note on the role of interdisciplinary teams and cross-functional teams in an R&D setup and organizational silos.
3. Briefly explain the stages of a team development model.
4. Discuss the team member roles for a successful team.
5. Explain with a diagram the Johari window model.

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Chapter 13
Innovation Management

Abstract Innovation management is a complex process and requires additional skills when compared with traditional management processes. To understand the complexity of innovation management, the process of innovation is studied in detail. In the present chapter, an innovation management framework is discussed to give a clear view of the management process. All the influential factors are discussed, and the ways to manage them effectively are highlighted. Uncertainties in the innovation process and its implications on managerial decisions are discussed in brief in this chapter. Further, we have provided an insight on the degree of complexity involved in an innovation process. The importance of people management in innovation is also dealt with elaborately in the current chapter. The process of a virtuous innovation cycle and its managerial impact on the process of evolution of innovative organization with high reputation are discussed in detail. From the chapter, it is clearly understood that R&D management needs to be optimistic and continuously motivate the team members to improve their creativity and generate new ideas. These potential ideas are converted into innovative products, which are commercialized. To conclude, it requires a combination of managers, leaders, and entrepreneurs to manage innovation.

Learning Objectives: To provide a brief understanding of the terms *innovation* and *innovation management* and an overview on the various concepts and models of innovation management; to provide an outline on various aspects of innovation management such as innovation uncertainty and its impact on innovation management, breeding innovation in an organization, innovation management, and people and measuring innovation.

Keywords Innovation management in R&D • Innovation models and concepts • Degree of Innovation • Innovation management framework • Innovation strategies in R&D organization • Market research and high-tech customers • Knowledge is the source of innovation • Impact on innovation management • Evolution of a successful innovative organization • Innovation management and talent

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_13

13.1 Introduction

Starting an organization is an easy task when compared to the task of sustaining it in market due to changing market dynamics. An organization has to constantly produce and launch new products or improve customer service better than its competitor to be remembered by its customers. New products are released by processing innovation either by solving existing problems or by new inventions. Innovation can be in technology, management, process, or production. "Innovation" thus becomes part of the business tactics to sustain and gain reputation in the market.

Innovation is a process that consists of various stages, starting from idea generation to marketing of new products. In this sense, innovation management is viewed as managing innovation itself. Therefore, complete understanding of the innovation process is important for effectively managing innovation in the organization. To understand the process, definitions of innovation from different perspectives of leading scholars are highlighted with their reference source. In this section, various generations of innovation models are presented. Technology push, demand pull, coupling model, and interactive innovation models are discussed in brief. The process of open and closed innovation is represented by an "innovation funnel." Various processes involved in an innovation funnel are discussed with the support of the literature resource. This part is aimed at gaining insight and in-depth knowledge of the process of innovation. Bottom-up and top-down approaches are also discussed. Degrees of innovation such as radical and incremental innovations are explained, and its implications on market dynamics are also studied.

Research and development function acts as the source of major innovations. In technology-intense organizations, R&D group members are idea generators. R&D function needs to continuously involve in basic research and identify the core competency of the organization. A constant interaction with universities and research institutes updates the knowledge base of the organization. In addition to the external interactions, R&D should interact with groups in organization at every step of the innovation process. Management should arrange formal meetings and continuous dialogs throughout the process. This will lead to the development of superior final products with less complexity.

With innovation management framework as the basis, this chapter attempts to capture the influence of various aspects relevant to innovation management. For effectively managing the innovation process, various influential factors highlighted in the innovation management framework need to be addressed. These influential factors are discussed in brief to gain insight into the management framework.

Innovations are always accompanied by uncertainties. Innovative products launched in the market may or may not succeed due to market uncertainties. Due to uncertainties involved in the innovation process, innovation management is always challenging and complex. Uncertainties related to innovation have to be understood to enhance the decision-making skills and help the management to take calculated risk. Pearson's uncertainty map is discussed, which gives a clear picture of uncertainties in different situations in the innovation process. Competitive advantage of the organization is explained using a virtuous innovation cycle. Knowledge base, individuals, and team role in the process of innovation are briefly explained, and managerial impacts on these factors are also discussed. Finally, innovation performance metrics are indicated. A case study of Tata Nano innovation is included to understand the process of innovation and the management process.

13.2 Innovation

Innovation management forms an important part in R&D function in the organization. It is viewed as the activity of managing innovation. For effectively managing innovation, the process of innovation needs to be understood in a broad sense. There are numerous definitions given in literature for innovation. Few of them are listed below.

Innovation management is defined as the managerial activity that attempts to control the innovation process (Jukka Ojasalo 2003). It describes the decision practices and activities that lead to the realization of an idea. Also, Jukka Ojasalo (2003) defines innovation management as a term that captures the complete management process of innovation, which includes idea generation and product development stages to launch the product in the market. In other words, the product development process includes three phases: idea generation, technical development, and commercializing. According to Quinn (1985) (cited in Jukka Ojasalo 2003), management of innovation is called "controlled chaos"; it includes surprises and unexpected changes but is still controlled to an extent. Jay Paap and Ralph Katz (2004) stated that "Innovation begins with the connection between a need and the technology to address that need. Innovation in a broad sense can be the management of all the activities involved in the process of idea generation, technology development, manufacturing and marketing of new or improved product or manufacturing process or equipment" (Trott 2002a, b).

The above words clearly identify innovation as the management process. Roger and Shoemaker in 1972 (cited in Trott 2002a, b) termed innovation as "newness." Innovation in the organization may be in terms of new product, new service, new method of production, opening new markets, and new ways of managing. To study the various aspects of innovation management, a clear understanding of the term "innovation" is vital.

13.3 Concepts and Models

Innovation models and the process involved, discussed in this section, focus on new product development. Models are discussed with literature support (Table 13.1).

Technology push and market pull (first and second generation) are linear models (Trott 2002a, b), which are represented in Fig. 13.1. In the technology push model, product innovation is triggered by technology breakthrough, and then the product is

Table 13.1 Innovation models

Model	Generation	Characteristics
Technology push	First	Simple linear sequential process, emphasis on R&D
Market pull	Second	Simple linear sequential process, emphasis on marketing, the market is the source of new ideas for R&D
Coupling model	Third	Recognizing interaction between different elements and feedback loops between them, emphasis on integrating R&D and marketing
Iterative model	Fourth	Combinations of push and pull models, integration within firm, emphasis on external linkages
Network model	Fifth	Emphasis on knowledge accumulation and external linkages, systems integration and extensive networking
Open innovation	Sixth	Internal and external ideas as well as internal and external paths to market can be combined to advance the development of new technologies

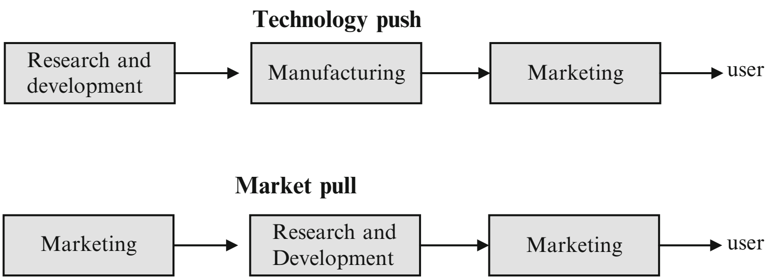
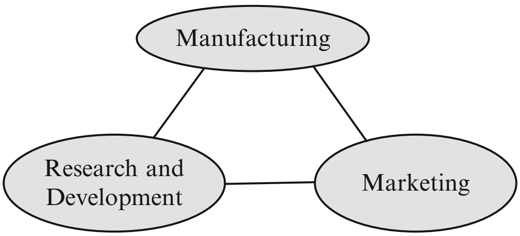


Fig. 13.1 Linear model

Fig. 13.2 Coupling model



developed and launched in the market. Exactly the opposite process happens in the market pull innovation process, where a product is innovated based on customer needs.

Third-generation coupling model is shown in Fig. 13.2. In this process, simultaneous coupling occurs between the three functions. Here, the stimulus of innovation is unknown.

Interactive model of Rothwell and Zegveld (1982) cited in Trott (2002a, b) shown in Fig. 13.3 explains how the process occurs.

Closed innovation is the innovation process which occurs within the organization. Knowledge flow happens within the boundary of the organization and between the

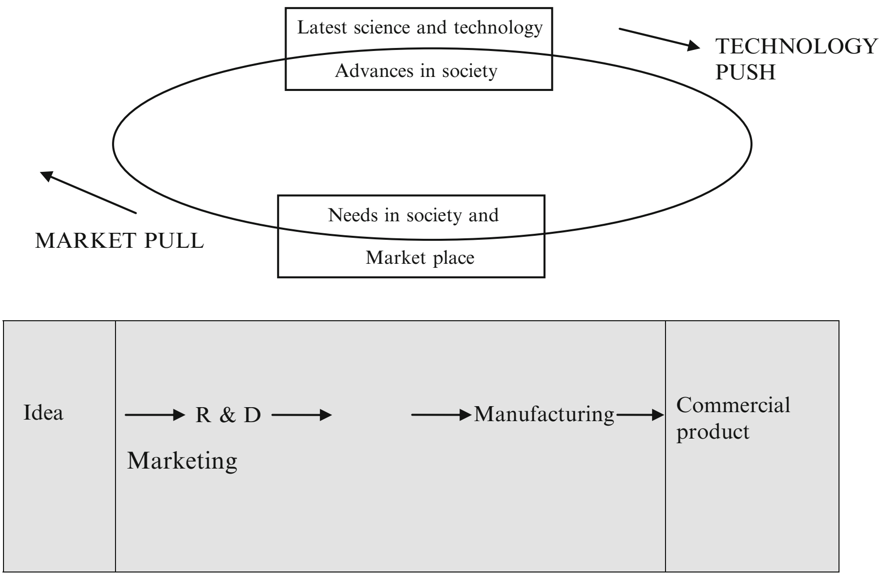


Fig. 13.3 Interactive model

groups. Organizations own the product through patent rights. Research and development activity required for the closed innovation in products is less when compared with open innovation products. In an open innovation process, knowledge flow occurs between intra- (within the organization) and interfunctional (outside the organization) groups. Closed and open innovation models are shown in Fig. 13.4.

Innovation funnel is a simple linear model, which gives a clear view of the functions involved in the process. This process is the base for the current innovation process and managing innovation. Figure 13.4 depicts the stage-gate innovation funnel. Depending on the organization and complexity of the product and its development cost, the number of gates in the funnel may vary. At each step of the gating process, managerial decisions filter the output of each process based on reviews at each stage. Decision points in the innovation funnel are at the end of every process as indicated in Fig. 13.4. Innovation process starts with an inflow of many ideas. Ideas are filtered at the first gate, and then a feasibility study is conducted to identify the potential ideas which can be transformed into new products. At the end of the funnel, only one or two products come out successfully and are launched at the right time after extensive market research. Lindblom (1959) argued that it is unrealistic to say that managers can manage all the things they have to deal with logical and sequential planning mechanisms. This leads to an important management theory, which says that the process of management involves continual iteration between various parts of the organization until a strategy arises. In this context, decision-making at every level in the innovation funnel becomes an important criterion for managing innovation. The above school of thought is also reflected in the statement “decisions are taken via logical incrementalism” (Quinn 1978).

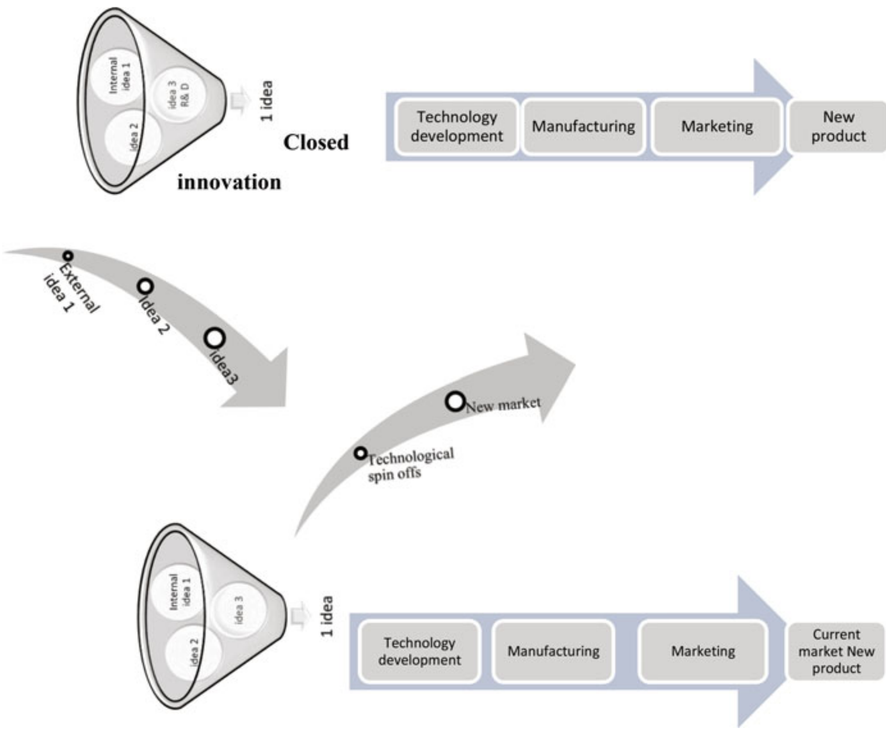


Fig. 13.4 Innovation funnel

13.4 Degree of Innovation

Innovation is characterized by its uniqueness. It may be highly radical, radical, intermediate, or incremental (Abetti 2000; Ojasalo 2008). These are called degrees of innovation. Highly radical innovations are unique and are original products. Radical innovations originate from beyond state-of-the-art technologies and have the capability to expand in future. Intermediate innovations are from proprietary technology with special features. Incremental innovation is a product with state-of-the-art technology with additional features. Minor incremental innovation refers to products with little incremental improvement in existing features. Incremental innovations can be disruptive. "Disruptive innovation" products may wash away the existing products due to some incremental change. Understanding when and how new technologies are adopted can help us anticipate future technology introductions, some of which may represent potentially disruptive technologies. An example of disruptive innovation in India is the launch of rural exchanges innovated by C-DOT (Center for Development of Telematics).

13.5 Top-Down or Bottom-Up Approach

Innovation in an organization comes from a top-down or bottom-up approach. Top-down innovation is the best approach for open innovation. When an organization decides to approach a partner organization to develop new technologies and produce an innovative product, it is best to approach the top-level team of the potential partner organization. The top-level team requires strategic insights and good decision-making skills. Hence, a top-down approach is good for open innovations. For incremental innovations, a bottom-up approach fetches good results, while a top-down approach gives best results for radical or breakthrough innovations (Govindarajan and Trimble 2012). A new concept called "reverse innovation" has been introduced by Vijay Govindarajan. Reverse innovation refers to innovating in developing nations (BRIC nations) and marketing in the developed countries.

13.6 Innovation Management Framework

Innovation management requires effective management of various activities involved in the innovation process. Innovation management is precise in managing innovation. Innovation management framework in the organization is shown in Fig. 13.5.

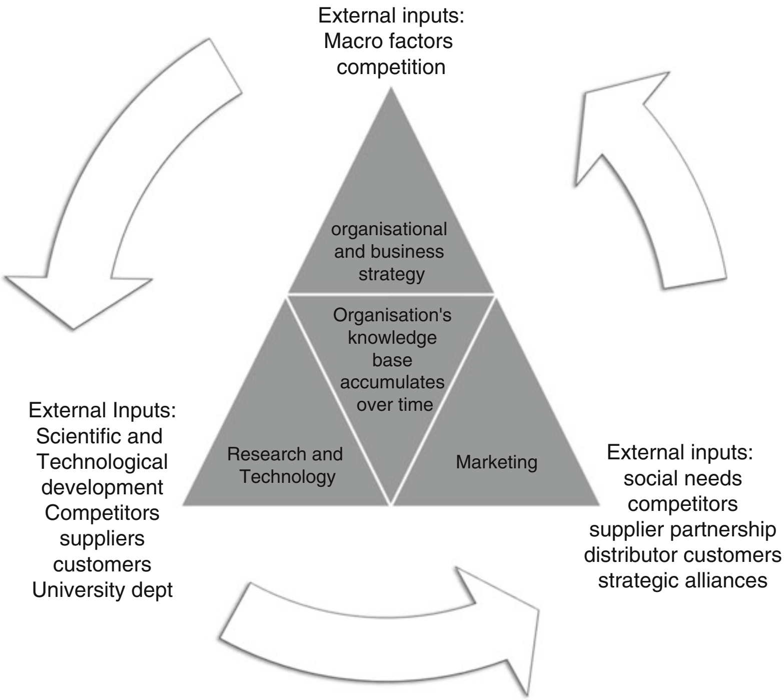


Fig. 13.5 Innovation management framework

The model (Fig. 13.5) depicts innovation as a management process. From the figure, it is evident that three influential functions in an innovation management process are research and development, marketing, and business strategy. For effective innovation management, these functions must constantly interact with the external inputs shown in Fig. 13.5. For example, organization and business strategy function need to constantly interact with other firms to keep track of the competitors. Innovation management should be aware of the current R&D activities going on in other organizations and their new products. Similarly, R&D function needs to be constantly interacting with external scientific firms and universities and updating the knowledge base of the organization. Marketing function should involve continuous market research. Knowledge base gets accumulated by the abovementioned activities of the three functional groups of innovation management. In addition to interacting with external interactions, the three functional groups constantly interact within the group and also among other active functional groups within the organization. The major influential functions and the managerial impacts are discussed in detail.

13.7 Innovation Strategies Employed in an Organization

For effective management of innovation, the innovation strategy must be clearly defined and understood. Innovation strategies must be in line with the organizational strategy. Innovation strategies are based mainly on the technology position of the firms. Management has to arrive at an innovation strategy before venturing into new projects.

There are four broad innovation strategies followed by technology-intense organizations:

- Leader/offensive
- Fast follower/defensive
- Cost minimization/limitative
- Market segmentation/traditional

Leadership strategy aims at acquiring the market by launching a new product (new technology breakthrough). These are monopoly organizations and do not have competitors. Fast followers of defensive strategy have a substantial technology base and produce improved versions of the product such as additional features at low cost. Cost minimization or limitative strategy is about manufacturing licensed products. Technology is licensed from other companies. Market segmentation specialist or traditional strategy is about producing only certain products and targeting only a certain group of customers in the market.

13.8 Market Research and Understanding High-Tech Customers

Customers are the heart of innovation. Management identifies market analysts and motivates them to involve in continuous market research and conduct periodic surveys to understand the changing market conditions and customer expectations. Understanding the customers refers to two important attributes: purchase decision and postpurchase evaluation. Management has to review the outcomes of market research and insist the team members to conduct periodic surveys to understand the customer's needs.

Also, there is a need to recognize high-tech customers in the process of innovation. Need for recognition for high-tech customers (Mohr et al. 2011) can be simulated by factors internal to the customer or by external factors in the environment. Internal factors can be the fact when the customer recognizes that an exceptional way exists in its order of fulfillment process. An external factor is an advertisement that creates awareness of the new type of technology offering or observation of other customers' purchase behaviors.

Demographic changes have to be studied to understand newly evolving markets. Continuous monitoring (*vigilance*) of new products launched in the market by its competitors helps the management in taking strategic decisions and guides the organization to venture into new innovative projects. Sales and advertising groups need to be equally active during the new product launch. Marketing functions need to constantly interact with suppliers and distributors. Technological shortcomings of existing products can be identified, and a new line of research based on market pull can be initiated in the organization.

13.9 Knowledge Base of Organization and Management

Knowledge is the key source of innovation. Well-defined knowledge management strategy is required for the innovation management process. According to Cantner et al. (2009), an organization with knowledge management ensures the right flow of knowledge at the right time in the right place (cited in Dick and Wehner 2002). Knowledge base of the organization can be viewed in the following four dimensions:

- *Individual assets*—skills and knowledge of individuals known as tacit knowledge
- *Technological assets*—technological base for product and process
- *Administrative assets*—contains individual profile and their skill sets
- *External assets*—resources about joint ventures and distribution channels

(a) According to Borghini (2005), a knowledge management strategy in an organization is about codification (explicit knowledge) and personalization (tacit knowledge). Codification is done using IT tools, which is supply driven, and personification is about an individual's tacit knowledge and is a demand-driven approach. Tacit knowledge can be obtained only through practice and experience. Tacit knowledge of the individual must be shared among team members by informal discussions and debates (UweCantner 2009).

It is the responsibility of the innovation managers to make knowledge resources available among innovators at all times. Members of technological teams must be motivated to use the knowledge resource in the organization. *Knowledge drain* in the innovative organization is likely to happen whenever a highly knowledgeable person leaves the organization. Highly knowledgeable or skilled persons always have good offers outside the organization. The loss of key personnel is consequently one of the most important reasons to implement or to increase the use of knowledge management (Earl and Gault 2003 cited in UweCantner 2009). Knowledge transfer must have high priority in an organization when there is high-frequency fluctuation of key personnel of the innovative team. Accumulation of knowledge over a period of time forms the base for sustained growth of innovative organization.

13.10 Innovation Uncertainties and Impact on Innovation Management

Research and development manager in a knowledge-based organization is required to manage uncertainties. Managing uncertainties is the major task in the management of innovation. Figure 13.6 is Pearson's uncertainty map.

Pearson's uncertainty map is divided into two major aspects: uncertainty about ends and uncertainty about means. Figure 13.6 is self-explanatory. Quadrant 1 is

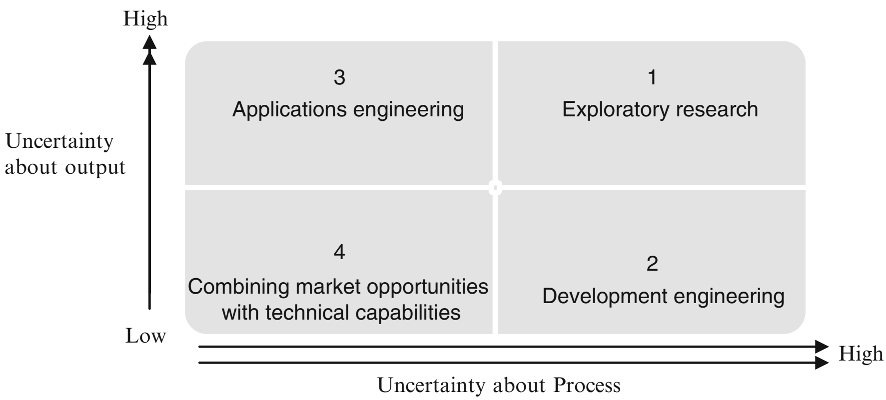


Fig. 13.6 Pearson's uncertainty map

highly uncertain as there is a high degree of uncertainty in process and output. This is termed *blue sky research*. Quadrant 2 in process means that it is highly uncertain but the target is known (uncertainty is low). Quadrant 3 is certain in process but highly uncertain about the output. Quadrant 4 is certain in both process and output. Understanding of this map gives a clear picture of innovation process and the uncertainties involved in the process. A clear understanding of uncertainties helps the managers to handle stress, which accompanies every innovation process. This helps the managers to take critical decisions under calculated risk. By knowing the level of uncertainties in a new product development process, management can decide to have strategic alliances and share the risk involved in the project.

13.11 Evolution of a Successful Innovative Organization

Any organization that focuses on sustenance of growth must innovate. Any successful organization till date should have had a high impetus on innovation and its management. *Creating innovative environments* in the organization is the foremost priority in emerging as an innovative organization. The factors that influence this environment are depicted in the concept of *virtuous cycle of innovation* (Fig. 13.7) as identified by Michael Porter (1985).

Fig. 13.7 Virtuous cycle of innovation

Innovation management has to address influential factors indicated in the innovative cycle to create an environment which leads to constant inflow of ideas and development of innovative products. The first factor is reputation for innovation in organizations. Organizations gain reputation for innovation based on the following factors: investment in R&D, recent new product launch, recent technological breakthrough, and so on. Highly skilled people and leading scientists seek opportunities in organizations that have a reputation in innovation and sustained research excellence. Organizations should absorb these scientists and skilled engineers from reputed institutes and other organizations. Organizations should also build an environment of forgiveness. There must be a willingness within the organization to accept the new idea termed *adaptability*. New potential ideas should not be overlooked. If potential ideas are not accepted, then it may lead to frustration. If all factors in the virtuous cycle of innovations are fulfilled, then this will increase the morale within the organization. Innovation management has to constantly address these factors to build a healthy innovative environment.

13.12 Innovation Management and People

Innovation management is challenging and hence requires high-potential managers. The main task of the manager is to identify the key role players within the innovation process and provide them with available resources in the organization. Problem-solving experimentation and risk-taking behaviors need to be encouraged to convert ideas into useful technologies and products. Market acceptances of ideas are important to consider any initiative as "innovation" at the organizational level. It becomes necessary that the scientists continuously understand customer needs as well as business needs from their senior managers and business heads.

13.12.1 Role of Individual in Innovation and Managerial Responsibilities

Two main contributors of the innovation process are technical innovators (scientist/engineer) and technological gatekeepers. Technical innovators generate ideas in the organization. They are the initiators of the innovation process. Technical innovators or idea generators generally get frustrated if their ideas are constantly overlooked. To avoid this, management should be able to identify potential ideas which have the capability to get transformed into innovative products and should approve them. In this context, an elaborate approval system must be avoided as this may hinder progress in innovation (Pearson 1988).

Technological gatekeepers transfer knowledge between groups within the organization by acquiring knowledge from outside (from firms or journals). Innovation managers should nurture technological gatekeepers who maintain inter- and intradepartmental information flows and must determine the appropriate managerial approach to achieve the desired information exchanges (Behrman and Fischer 1980). The managers should identify the characteristics of the information channels, and methods for information processing within R&D groups need to be determined, particularly from the point of view of the role of the technological gatekeeper.

13.12.2 Creating Sustainable Performance

> if you give employees the chance to learn and grow, they'll thrive and so will your organisation (Spreitzer and Porath 2012).

It is evident from this statement that managers who overcome the organizational inertia and start a culture that encourages employees to thrive will lead the organization to sustained growth. According to one of the HBR research analysis, employees are encouraged to thrive in organizations by providing decision-making discretion and performance feedback. The following factors and their managerial impact create sustainable performance for the individual and a team.

- Innovative project teams must be given autonomy in decision-making. Autonomy can be defined as the extent to which an organization allows individuals to work in their greatest degree of freedom possible, controlling their own work and their ideas (Amabile 1996). Empowering them with autonomy in decision-making gives them a sense of control and more learning opportunities. This is an intrinsic factor that motivates to innovate (Amabile 1997; Camelo-Ordaz et al. 2005). Autonomy thus motivates individuals in the generation of ideas and thereby promotes innovative activities.
- Informal communications and meetings have to be encouraged to enhance their knowledge and to maintain a flow of ideas. Informal debates and discussions can be arranged within the work teams (Thamhain 2003; Camelo-Ordaz et al. 2005). Informal meetings and discussions promote sharing of knowledge of different domains and concepts in different perspectives. This act helps in widening individuals' perspective (Fogarty 2002). Great ideas generate in a casual meeting.
- Performance appraisal must be ethical, and the performance of the individual has to be assessed based on his commitment to the assigned objective. Uncertainties are unavoidable in the process of innovation. Hence, management should develop a culture to forgive mistakes done by an individual or a team and learn from mistakes and judge them fairly.
- Performance feedbacks are helpful in creating opportunities for learning and help employees to correct their weakness and align with organizational goals.
- Obtaining employee feedback during performance appraisals should be brought into practice. This will help the management to unearth the difficulties faced by its employees in organization.

- Rewards are motivating factors for highly skilled scientists. It could be in terms of incentives, promotions, or holidays. Idea generators generally have a feeling that they are not rewarded. Hence, rewarding systems for idea origination and idea evaluation must be encouraged.
- Innovation group, which is always dynamic in nature, has people inflow and outflow due to prevailing opportunities outside the organization. Hence, it is important for the managers to make maximum effort to retain skilled and knowledgeable persons by providing them with necessary resources, time, and space to come up with innovative ideas and transform them into products.
- Employing people with diverse knowledge and skill sets drives the organization to become more innovative. Recruiting highly skilled people whenever identified is important. People with required expertise and problem-solving skills are to be tested during a recruitment process.

13.13 Measuring Innovation

Innovation has to be measured to know the organization's overall performance. Innovation performance metrics can be measured under the following indicators (Kuczmarski and Shapiro 2000):

- *Knowledge creation*: The ability to generate new ideas and technologies.
- *Human resources*: The capacity of the employee force to transform these ideas and technologies into tangible economic outcomes.
- *Venture capital*: Funds are available to commercialize ideas and technologies.
- *Technology diffusion*: The capacity of the economy to transfer new ideas and technologies to other firms.
- *Collaboration*: The international linkage innovation system.
- *Market outcomes*: Economic return on investment in innovation.

Questions

1. Explain in detail the major innovation management framework depicting influential functions and managerial impacts in innovation management.
2. List the various indicators to measure innovation performance in an organization.
3. Discuss the two main contributors in the innovation process.

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Chapter 14
Portfolio Management

Abstract When it comes to describing actions, situations, and organizations, moments play an important role. To capture these moments in each step, actions and strategy portfolio management provides a holistic view to govern project of activity in R&D organization. This chapter gives a brief introduction, objective, scope, and different methods of portfolio management.

Learning Objectives: To understand portfolio management and its importance in an organization; to present a holistic picture on various features of portfolio management.

Keywords Portfolio management • Portfolio alignment and balance • Objectives of portfolio management • Balancing portfolio • Methods of portfolio management

14.1 Introduction

An organization can have several projects of different nature at the same time. The uncertainty surrounding individual projects leads them to find out some of the tools or methodologies to balance risk and reward in such a way as to reduce the overall uncertainty. Portfolio management is one such kind of methodology/tool adapted across all the sectors of the industry. The practices of portfolio management differ across the different continents.

Portfolio management technique is a process for a project or activity or even business unit to acquire a balance between risks and returns, stability and growth, attractions and drawbacks, by making the best use of limited resources.

The objective is to establish priorities and allocate resources to deliver business strategy.

From Fig. 14.1, it can be understood that portfolio management can be implemented in a project, that is, if a project is in pipeline or even if any idea/strategy is pitching up in the market. It helps an organization to allocate the resources as per the need of the hour and predicts when to expand and when to diversify.

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_14

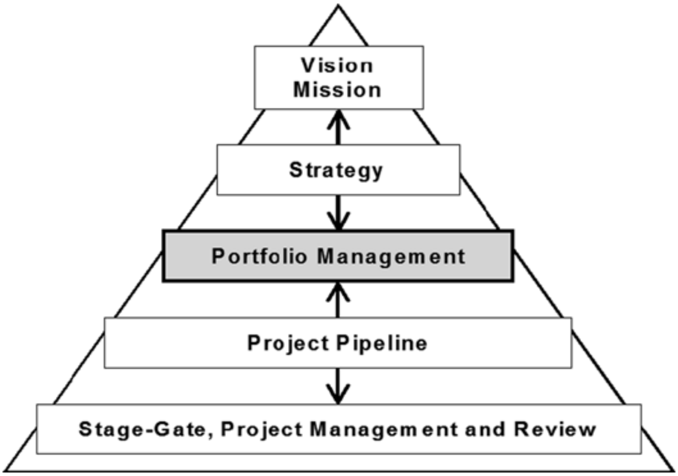


Fig. 14.1 Implementation of portfolio management

14.2 Portfolio Alignment and Balance

Portfolio alignment and balance is required in an R&D organization. The mission and vision of an organization must be known and well understood down the line of workflow. The management must identify the company's strategic business driver to sustain in the market. The Research and development organization has to be on its toes always. The skilled multidisciplinary teams must be working together to bring out new changes in the ongoing products as well as development of new products. The technical team must work in close association with the marketing team and customer relation team so that monitoring of the business performance is up to date, and based on evolution of technology and customer taste/response, ongoing projects can be terminated or new projects can be launched well within the time. For this to happen, the capability of an organization in all departments must be up to date. There should be no hindrances in transfer of technology from one group to another. This policy has to be well defined because it will help management to create short- and long-term road map for an organization. In short, project portfolio management must remain strategically balanced and well supported by the organization capabilities, such as its knowledge base, technology base, marketing base, and customer relation base.

14.3 Portfolio Alignment Model

Research and development activities can prioritize projects involving a challenging activity. The starting point of portfolio management is the role of the business heads (Fig. 14.2). The business heads need to critically understand vision and mission of

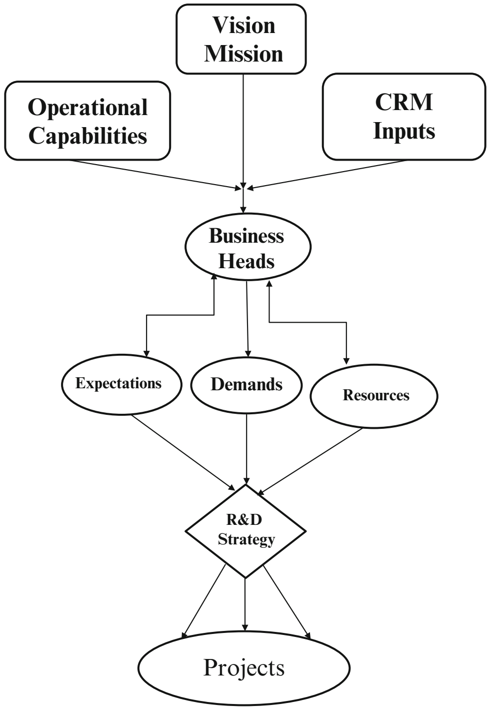


Fig. 14.2 Portfolio alignment model

the organization, operations capabilities of the organization, and assess inputs from customer relationship management. Vision and mission help analyzing both short- and long-term goals. They clearly define the business model, which helps in clarifying the value creation process. Value is what the customers are ready to pay for, that is, the organizational products and services. Business heads need to review the capabilities of the operations. They should analyze the capacity constraints, quality of the performance, and also delivery capabilities. Such an assessment would help them to critically see the new product and visualize its specifications. Customer relationship management is driven by the feedback obtained by both the internal and external customers about the products and services. Deviations and defects are important points for learning and development. Systematic methods need to be deployed to gather customer experiences. Business heads need to convert these experiences into new product definitions and enhanced product support activities.

Research and development strategy gets defined around the continuous interaction of the scientists and engineers with business heads as well as through clear articulation of the requirements, and improvements and features will help scientists and engineers to come up with ideas and proposals. Proposals contain scope of the project, specific objectives, timelines, and deliverables. Portfolio management involves a joint decision making about various proposals to commit resources and provides support.

14.4 Objectives of Portfolio Management

Portfolio management focuses on continuously assessing the changes in customer demands, critically evaluating technology developments, and use of resources. Hence, the goals of portfolio management would involve three main objectives. The first objective is to identify, assess, and evaluate technology life cycle. Every technology will follow an s-curve; it has a birth, growth, maturity, and decline phases. Portfolio managers should qualitatively and quantitatively analyze every technology in relation to respective s-curves.

The second objective of portfolio management is to classify the existing activities and projects. They need to decide which projects require competent and better people, projects requiring capital resources and projects demanded by the customer, and projects relevant to organizational positioning and projects that need to be discontinued.

The third objective of portfolio management is to relate the existing technologies to the technology road maps. Research and developmental activities need to be prioritized. Based on the road maps drawn, one need to see which of the technologies and projects are being implemented within the time and resource constraints, which projects have different degrees of uncertainties and complexities, and which are those projects facing challenges of implementation. Effective stage-gate processes need to be evolved that detect problems early and continuously monitor resources and implementation.

14.5 Need of Portfolio Management

We know necessity is the mother of all invention. Once a product is developed or launched by a company, it goes under s-curve of business life cycle as shown in Fig. 14.3.

14.5.1 Balancing Portfolio According to Strategy

Figure 14.4 provides perspective on balancing project portfolio. In this project, status and their strategic comparatives need to be compared with strategic objectives of the organization. Go-or-kill decisions need to be made in order to keep a prioritized project on the fast track and the remaining ones in some slow tracks.

Balancing portfolio involves the following:

(a) Identifying and assessing critical technological advances
(b) Detecting discontinuities
(c) Recognizing new and emerging technologies

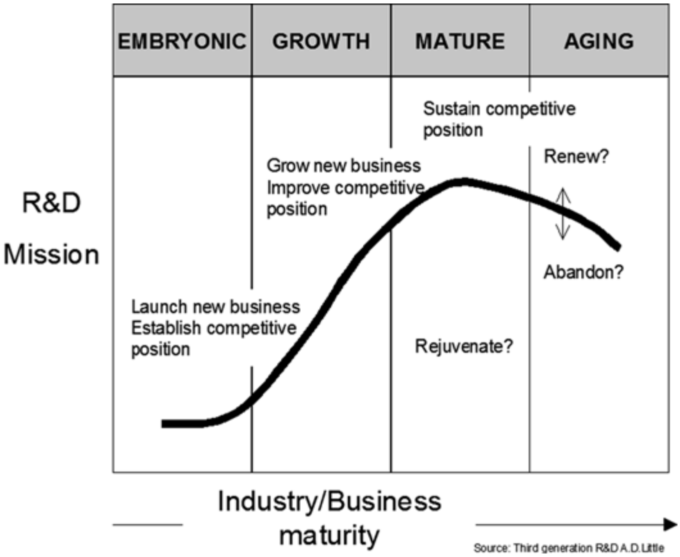


Fig. 14.3 S-curve of business life cycle

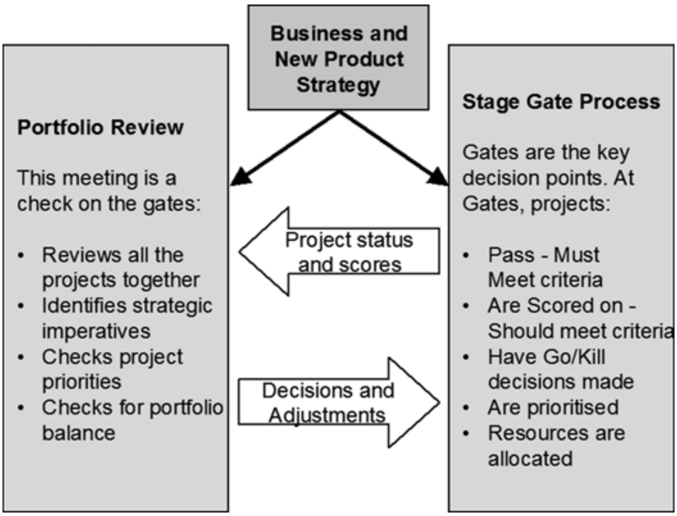


Fig. 14.4 Balancing portfolio

14.6 Methods of Portfolio Management

Portfolio management is a balancing act among the competing research activities, ideas, and proposals. Each of the projects needs to be compared with others which have minimum risk, maximum impact and returns. Organizational factors, such as ownership, philosophy, age of the organization, and other factors need to be considered while assessing the projects. Many of these methods have been discussed in the earlier chapters. In portfolio management, the focus is on comparisons. Comparisons are done between the projects as well as over a period of time. Good managers use process and methods of ranking, factor-by-factor comparison methods, as well as waited point's method.

14.6.1 Ranking Method

In the ranking methods, projects and proposals are compared as a whole from one to the other. Scientists and engineers as well as managers obtain consensuses on continuation or discontinuation and prioritization of the considered project.

14.6.2 Factor Comparison Method

In factor comparison method, certain attributes of the projects are identified (approximately 7). They include capabilities, resource intensity, requirement of time, usefulness to the team, usefulness to the division, relevance to the organizational short-term goals, relation to strategic goals, and so on. Each of the factors will be rated on a five-point scale; 1 being very low and 5 being very high. The high-rated projects based on the factor methods are further analyzed to keep or support and the low-factor rated activities will be dropped from the portfolio.

14.6.3 Weightage Point Method

In the factor comparison method, each of the identified factors was given equal weightage in practice; some factors are of more importance and hence should be given a better weightage. Different weightages are assigned among the considered factors to arrive at a value for each of the projects in the portfolio. Furthermore, decisions are made about continuity and discontinuity of the projects.

Portfolio management exercise should be done once in a year and should not be an ad hoc, impromptu, or emotional process. An objective-detached engagement is necessary to arrive at appropriate decisions. An undermanaged portfolio management will result in confusion, chaos, and conflicts. In other words, better-managed portfolio selection process will contribute toward individual effectiveness, better resource utilization, and enhanced team performance.

Questions

1. Explain the portfolio alignment model.
2. State and explain various methods of portfolio management.

Chapter 15
New Product Development

Abstract Developing and launching successful new products is a key marketing value driver of any R &D organizations. The chapter has featured the operational definition, role and scope of NPD. Developing and implementing a proven NPD process increases success rates, together with managing the other key factors that drive results. This has been clearly conveyed in this chapter how NPD as strategy adds a competitive advantage. At the end, chapter briefly accounts to the theoretical understanding of NPD, framework of NPD and models to explain the execution of NPD.

Learning Objectives: To understand the vital role of new product developments (NPD) for an organization and in turn the economic growth of the country; to explore how to evolve an NPD strategy, evolutionary theory behind NPD, and Brown and Eisenhardt framework; to provide a brief description of various models in NPD.

Keywords Role of new product development for R&D organizations • Innovation in NPD • How to Evolve an NPD Strategy • Abstracting understanding of NPD • Evolutionary theory • Execution of NPD

15.1 Introduction

One of the activities associated with R&D is new product development (NPD). Annacchino (2007) aptly refers to NPD as the *lifeblood of a company*. It would be more appropriate to extend this definition and introduce NPD as *lifeblood of both a company and a growing economy*. In case of a company, NPD plays a dominant role in its survival and growth phase. Although the degree of NPD is different for these phases (survival phase mostly requires evolution of existing products, while growth phase requires introduction of new products), nevertheless NPD can provide competitive advantage. This helps companies to penetrate deeper into existing markets or create new markets. The revenue accumulated by companies through the NPD activity eventually percolates to its stakeholders (shareholders, employees, and vendors), who in-turn use it to purchase various other products and services. This spurs economic activity and gives rise to cycles of revenue generation, resulting in economic prosperity of a nation.

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0_15

15.2 What Is New Product Development?

An NPD activity includes a wide range of activities—it begins with the identification of an opportunity (idea generation), transforming this idea into a product (design and development), and finally, commercialization of the product (production, sale, and delivery of a product) (Ulrich and Eppinger 2004). The reference to the word "process" in almost all definitions of NPD in the literature is an interesting one. The usage implies that NPD is not merely a chance activity but is an outcome of systematic management effort, resulting in a successful product (Turner 1985). Hence, organizations can institute and conduct NPD systematically and aim toward producing a successful product at lower development costs and at faster pace of development.

15.3 Understanding What Is "New" in NPD

The term "new" in NPD may create some confusion in the minds of the readers. The word new does not always refer to a product that is new in an absolute sense, but more so in a relative sense. Let us say a company introduces an exact replica of an already existing product to gain an entry into its competitor's market. Can such a product be termed as "New" especially since it is just a replica of an existing one? The answer is "Yes." Although such a product already exists in the market, but it is the first of its kind in the eyes of the company introducing it, that is, new with regard to the company? Thus, it is the *perception* that becomes an important consideration while attributing newness to a product (Trott 2008). So long as a company or the market perceives it to be new, a product can be termed as new. A majority of the products developed under the tag of NPD are variations, imitations, or repackaging of an already existing product (Griffin 1997). The share of the products that are new to both market and company is a mere 10 % of the total product introductions. This trend related in product portfolio has persisted over the decades with "modified products" overtaking the "new-to-company" and "new-to-market" products (Fig. 15.1).

From the above discussion, it implies clearly that newness is referred to in a relativistic sense. This relativistic aspect of newness can be exploited to classify the products based on the degree to which they are new. A product that is absolutely new is tagged with highest degree of newness and is classified as new-to-the-world product. The other possible classifications (along with the new-to-the-world category) are listed below.

- *New to the world (NTW)*
  These products are absolutely new, something that the world has not seen. They are usually the outcome of major developments in design and technology, and result in creation of new markets.
- *New to the company (NTC)*
  These products are new to the company, but not the markets they cater to. They provide an opportunity for companies to make in-roads into an already established market.

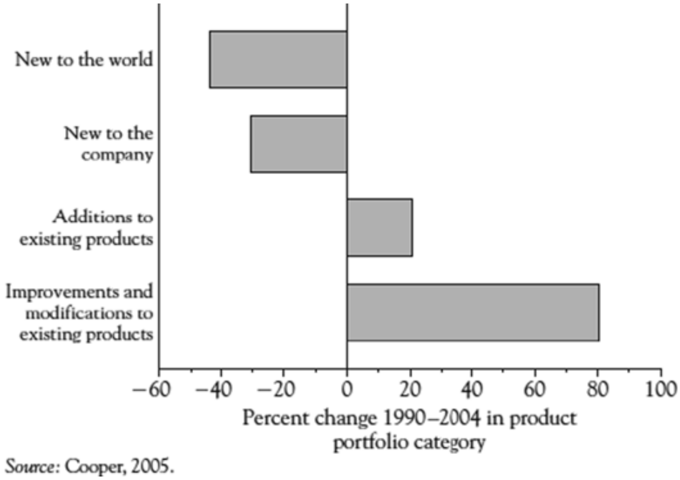
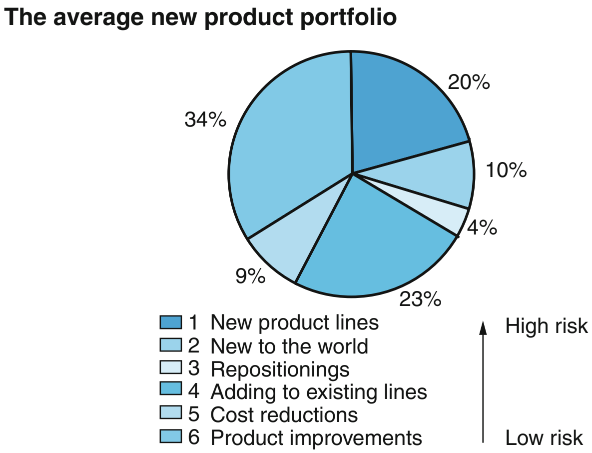


Fig. 15.1 Changes to the product portfolio between 1990 and 2004 (*Source*: Smith 2007)

Fig. 15.2 Break-up of product portfolio (*Source*: Trott 2008)



- *Additions to the existing lines (AEL)*
  These are the products which are new additions to an existing product line of the company. They are of lower degree of newness when compared to NTC products.
- *Improvements or revisions to existing products (IM)*
  These are the incremental versions of already existing products. They form the major portion of all new product introductions (see Fig. 15.2).
- *Repositioning (RP)*
  These products are a result of discovery of new applications for existing ones. They are the outcome of a new branding exercise rather than technology developments.
- *Cost reductions (CR)*
  These are the products already existing in market but offered by the company at much lower costs when compared to its competitors.

15.4 How to Evolve an NPD Strategy

Organizations undertake product development activity for its own reasons. In a market dominated by new products, organizations might choose to pursue NPD activity to prevent erosion of its current market. However, organizations might also choose to introduce a new product to increase their revenue (Griffin and Page 1996). In a simple scenario, an organization might pursue an NPD activity with a single goal in mind. But in reality, many a time organizations pursue multiple NPD activities with multiple goals (Crawford 1983). Devising and managing such complex scenarios requires some underlying framework for organizations. This underlying framework is provided by NPD strategy.

A Product development strategy tries to provide unifying direction to organizations bringing together people and resources. Crawford (1983) regards PD strategy as the "loose harness" that ties together the different aspects of organization (people and resources) and results in creating a synergy for a good development effort.

According to Crawford, "The basic purpose of a PD strategy is to provide a unifying direction. It specifically notes any tempting development areas that are off limits; it clearly specifies those areas where effort is to proceed; and it adds any other direction appropriate and relevant to the firm…".

A PD strategy, like any other strategy, is derived based on the organization's goals and objectives. Each organization chooses to pursue a particular strategy in the market and this strategy dictates all the other strategies adopted by that company including its NPD strategy. According to Miles et al. (1978), there are four broad types of organization based on the strategy they adopt:

15.4.1 Defenders

These types of organization occupy a narrow product market domain and define strategies to secure this domain completely. They usually do so through competitive pricing and high-quality products. They are more focused on market penetration within this domain through some limited product development. Hence, such companies pursue PD strategy aimed at introducing variation or improvements in existing products to ensure continuity of their market.

15.4.2 Prospectors

These companies are exactly opposite in nature to defenders. They operate in an environment that is highly dynamic. The strength of a prospector lies in finding and exploiting new product and market opportunities. They value the tag of being an "innovator" in product and market development. Thus, developing New-to-the-World and New-to-the-Company products from the core of their PD strategy.

15.4.3 Analyzers

The analyzers have a balanced mix of characteristics of both defenders and prospectors. They pursue a host of PD strategies to maximize their opportunities for profit, while at the same time minimize the risk. The analyzers are usually not the first ones to enter new markets or produce a new product. They first establish the viability by imitation of existing products and then make a full-scale entry. A majority of their product portfolio is about producing stable products to a targeted customer segment.

15.4.4 Reactors

These organizations operate in a highly stable and uncompetitive market space. They lack mechanisms to cope with changing environment. They do not aggressively pursue product or market development activities but sometimes respond when the situation forces them to.

The process of formulating a PD strategy takes into account the current position of the company and the future opportunities that business can exploit. Trott (2008) has provided a framework which explains the decision-making process in developing a PD strategy. The main inputs to decision making is provided from four major sources: (1) ongoing corporate strategy, (2) ongoing market planning, (3) ongoing technology management, and (4) opportunity analysis. This is illustrated in the Fig. 15.3. The ongoing corporate plan is performed by senior management in a large organization and usually has a long-term impact on an organization. It provides the direction the business is headed toward. The input

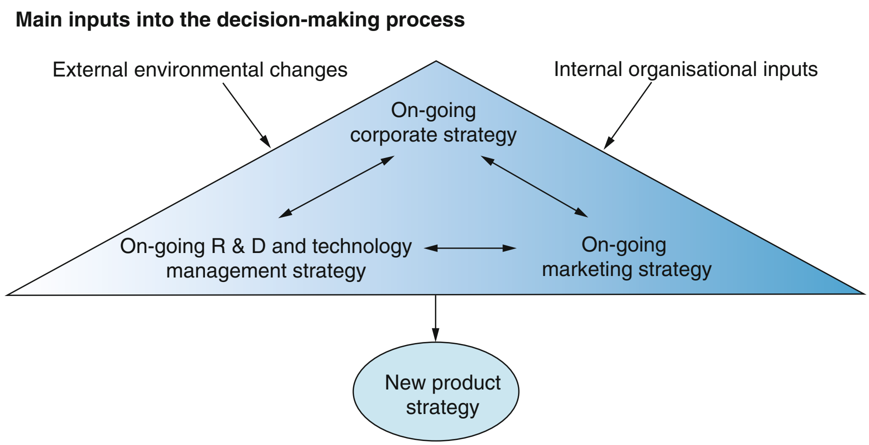


Fig. 15.3 Main inputs to PD strategy (*Source*: Trott 2008)

Table 15.1 NPD strategy

		Technology newness		
Market newness		**No technology change**	**Improved technology**	**New technology**
	No market change	No activity	Reformulation	Replacement
	Strengthened market	Remerchandizing	Improved product	Line extension
	New market	New use	Market extension	Diversification

Source: Johnson and Jones (1957)

from ongoing corporate plan is supplemented with input from market planners (i.e., ongoing market plan). The ongoing market plan takes into account the competition prevailing in the environment and strategies to overcome them. Additionally, in a technology-intensive company the role of technology awareness becomes very crucial. The lag between in-house R&D projects and external technology must be factored-in to create adequate business opportunities. Finally, in addition to the above sources there may be inputs related to several opportunities that were identified as a result of "serendipity." The inputs from all these sources are collated and analyzed to define a PD strategy.

In addition to the above framework, organizations commonly refer to the classical framework provided by Johnson and Jones (1957) to choose their NPD strategy. This framework suggests the possible strategy an organization can adopt based on the market and technology aspects confronting organization. It is organized as a 3×3 matrix of possible strategy for a given market and technology mix. In the Table 15.1, the row elements represent the newness of technology and column elements the newness to market. For example, a company when faced with no newness in market and some improvements in technology could possibly explore the "Reformulation" strategy. This strategy can be achieved by looking at producing the "Repositioning (RP)" kind of products.

15.5 Theoretical Understanding of NPD

A theory or theoretical framework helps to consolidate the findings of research in a given area. The macro-level theories at the system level help in getting a broader perspective and have wider level of applicability, and hence are of more interest compared to micro ones. With PD being a vast area and highly context dependent, macro-level theories are hard to come by. In this section, two important macro-level theories are presented—Evolutionary theory and Brown and Eisenhardt framework. The evolutionary theory provides insights about how NPD evolves over a period of time, and Brown and Eisenhardt framework presents a classification of PD literature.

15.5.1 Evolutionary Theory

Loch and Kavadias (2007) provide an overarching theory that explains the phenomenon of *evolution of NPD*. Through this theory, they attempt at capturing large parts of NPD phenomenon in a causal framework. This theory is analogous to Darwin's theory of evolution and views NPD as an evolutionary activity; *a slow, cumulative, one step-at-a-time, non-random survival process*es, and being nested across several levels.

The NPD theory of evolution is associated with two major concepts. First, the levels of evolution. The theory treats evolution as nested in three distinct levels—process, firm, and industry. A process consists of procedures, rules, and norms and represents how an NPD activity is performed. It is analogous to the concept of a gene. In the biological framework, a gene is the fundamental unit, followed by an individual (which is a collection of genes) and finally the population (a collection of individuals). Similarly, a collection of process represents a firm and a population of firms forms the industry. Thus, the industry forms the outermost layer encompassing firms, which in turn encompasses the processes. This is pictorially represented in Fig. 15.4. There is an interaction between these levels with the aggregate effect of one level influencing the next level (both high and low level). The effects may be negative or additive at the next level depending on the context. To quote an example

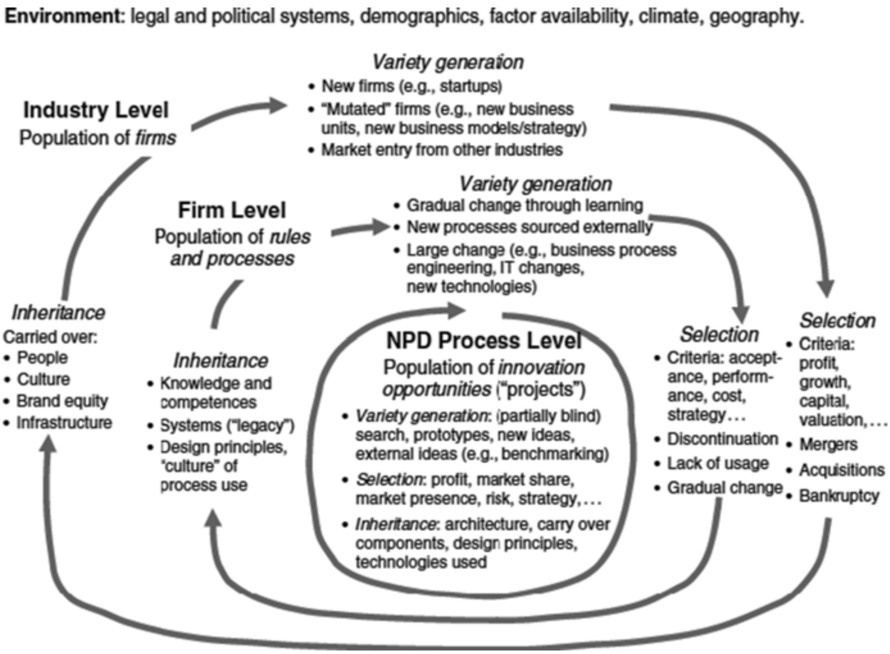


Fig. 15.4 Evolutionary framework (*Source*: Loch and Kavadias 2007)

from Loch and Kavadias (2007), pursuing short-term profit maximization goal by NPD firms may reduce the growth of the industry because of the narrowed focus only on cash projects.

The second major constituent of the theory is the process of NPD evolution. This process consists of a series of steps that describes the aspect of evolution. It starts with "variant generation processes." The variant generation process identifies new combination of technologies and market opportunities which have the potential to create economic value. This process is followed by "Selection" of most promising combinations for future investment. A "transformation" process develops opportunities into products and finally a "coordination process" representing the sharing of knowledge and collaboration among multiple parties. These processes are comparable to the generation, selection, and inheritance among all level of living being. These processes occur at all the levels (process, firm, and industry) and result in the evolution of NPD industry as a whole.

The evolutionary cycle (Fig. 15.4) works as follows. At the highest level, an industry represents a population of firms that were created, selected, and developed over a period of time. The industry as a whole creates a structure in which firms operate. They also influence the criteria for selection at the firm level, that is, they influence the subsequent level in the evolutionary cycle. In response, an individual firm chooses a certain strategy for survival to outperform in the competition. Only those internal NPD process and activities that helps a firm achieve its strategic goal survive, whereas the others are slowly eliminated. Thus, there is an interaction effect across all levels of evolution. This cycle of evolution continues in perpetuity.

15.5.2 Brown and Eisenhardt Framework

- The research work by Brown and Eisenhardt (1995) is an important one in the area of PD, especially their classification framework. The classification framework provides a fresh perspective of the PD literature by organizing a vast number of empirical studies in the area of PD into three major streams—product development as a rational plan, communication web, and disciplined problem solving. They identify the key dimensions that separate one stream from the other.

Rational planning approach takes a broad perspective of NPD. According to this approach, success in NPD is achieved through rational planning and execution. The planning aspect includes identifying a product that has an attractive market and is likely to provide a competitive advantage. The execution aspect can be achieved through effective internal organization by using well-coordinated cross-functional teams blessed with support from senior management. Thus, this perspective lays equal emphasis on planning of products, internal organization, and market aspects of NPD.

15.5.3 Communication Web

This stream of research highlights the central role played by communication in stimulating performance of PD teams. This stream focuses exclusively on the communication and information processing aspect of PD. In contrast, rational planning perspective provides a broader focus on PD. The theory identifies two types of communication, namely external and internal. External communication can be enhanced by using "gatekeepers" and internal communication through promoting task-based communication inside the cross-functional teams. Promoting external and internal communication improves the quality of information flow between team members, and thus results in higher performance. From a resource-based view, frequent political communication also helps in improving performance by increasing the probability of securing additional resources for the team.

15.5.4 Disciplined Problem Solving

These stream of research prophesizes a disciplined problem-solving approach leading to PD success. This approach has two aspects to it: autonomous problem solving by the teams, at the same time having a specific "product vision" which helps to create discipline. The senior management has the dual responsibility of enforcing the "product vision" and providing autonomy to teams. In terms of focus, this perspective is broader than the "communication web" approach and narrower compared to "rational planning" approach.

15.6 Execution of NPD

A PD activity involves a series of steps related to conceiving, designing, and commercializing a product. Typical list of activities include idea generation, idea screening, concept testing, business analysis, development, test marketing, commercialization, and monitoring and evaluation (Trott 2008). Organizations, in general, employ these steps with a slight variation depending on the context for executing NPD. There are many "models" which offer insights on planning and executing an NPD activity. This section describes seven models of NPD. A major portion of the text in this section refers to the work of Trott (2008).

The various models of NPD are:

- Departmental-stage models
- Activity-stage models and concurrent engineering
- Cross-functional models (teams)
- Decision-stage model

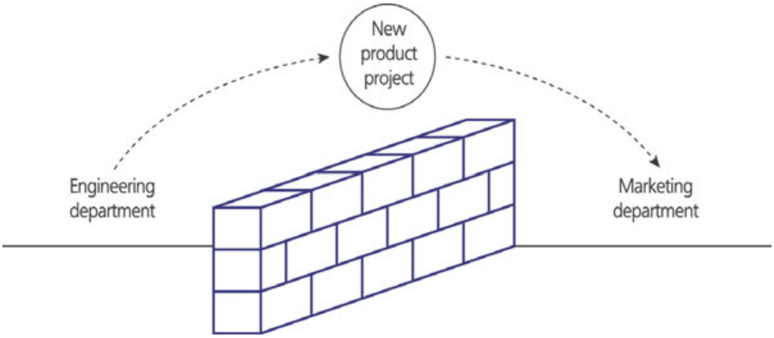


Fig. 15.5 Departmental-stage model (*Source*: Trott 2008)

- Conversion-process models
- Response models
- Network models

15.6.1 Departmental-Stage Models

This model is based on the linear model of innovation. Each department has a specific task assigned to it and holds the responsibility for carrying out that particular task. Upon completion of the task, the project is handed over to the next department. This approach is referred to as *pass-the-parcel* or *over-the-wall* approach (Fig. 15.5).

This approach is associated with some major drawbacks:

- Control of process is lost as the project moves from one department to another. It does not foster ownership of new products.
- Time consuming as it involves greater deal of reworking and passing to and fro between departments.

15.6.2 Activity-Stage Model (Fig. 15.6)

Activity-stage models are similar to department stage model except that they focus on individual activities. Unlike the department models, they provide for iteration and feedback mechanisms between activities. The recent development in activity-stage models recognizes the simultaneous execution of activities at any given point in a product development process. This has led to the development of the concept of "concurrent engineering," wherein the emphasis is on involving stakeholders from both upstream and downstream activities to obtain an integrated view of the entire project. This approach has also been criticized for continuing with the "pass-the-parcel" method of NPD.

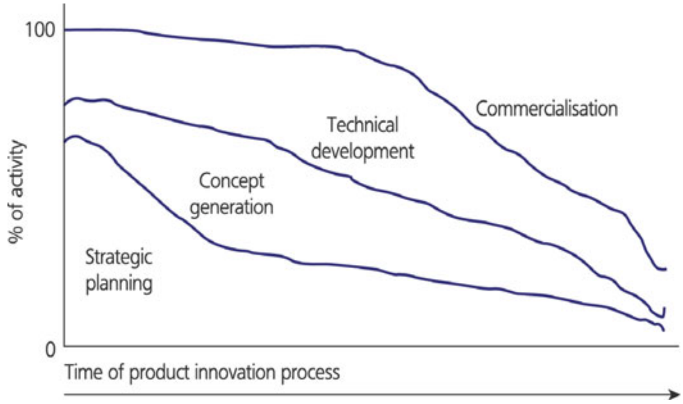


Fig. 15.6 Activity-stage model (*Source*: Trott 2008)

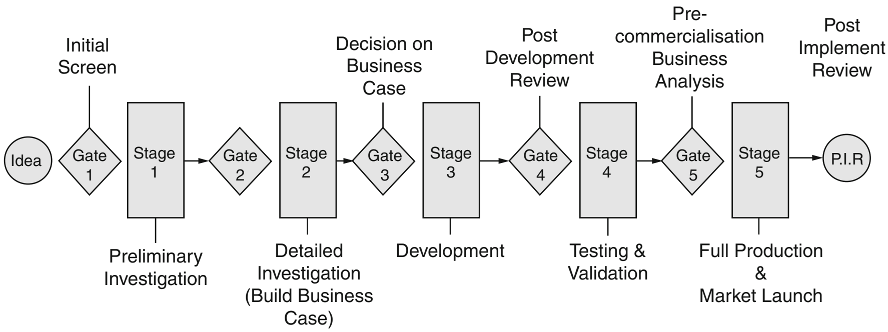


Fig. 15.7 Decision-stage model (*Source*: Cooper 1994)

15.6.3 Cross-Functional Teams

This approach was proposed to overcome the drawbacks of the previous two models. Instead of the functional or the department orientation followed by the previous two approaches, the focus is on project management through the usage of cross-functional teams. These teams are formed with individuals from variety of functions involved in developing the product. The responsibility of the PD stays with this team. This approach improves information exchange, and reduces the overall time taken for NPD by avoiding unnecessary back and forth movement of the project.

15.6.4 Decision-Stage Model

Decision-stage models (Fig. 15.7) view NPD as a series of evaluation points. At each of these evaluation points, decisions are taken about whether to proceed or abandon the project. A popular decision-stage model is the "Stage-gate" model.

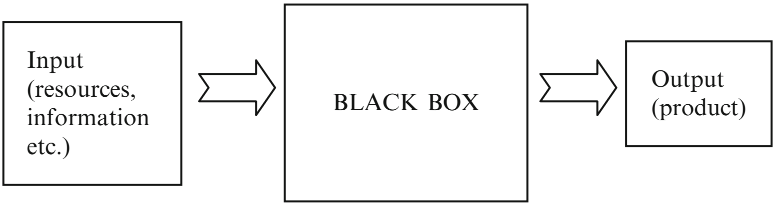


Fig. 15.8 A conversion model of NPD

The activities starting from idea generation to commercialization is grouped into what are known as "stages." A project typically has around four to five stages. Between two stages, decision points called "gates" are positioned for evaluating the outcome of the respective stage with the set criteria. These gates also serve as quality control mechanisms. At each gate decision is taken regarding proceeding, redoing, or killing the product. These models help in progressive evaluation of the product and reduce the risk of ending up with a wrong product after a lengthy development cycle.

15.6.5 Conversion Process Models

Conversion process models (Fig. 15.8) are based on the assumption that innovation process, including NPD, is irrational. This scenario is figuratively represented with the help of a *black box*. The inputs are converted to an output (product) inside this black box. These models try to provide a holistic view of PD and ignore the details associated with NPD.

15.6.6 Response Models

These models view NPD as an outcome of innovative behavior. Becker and Whistler (1967) describe innovative behavior as a four-stage process: stimulus, conception, proposal, and adoption. Stimulus for an organization to innovate comes through individual action. An individual is motivated to act because of his increased awareness or a desire to achieve. This motivation further drives an individual to conceive a plan of action, which he perceives to be the most effective for the organization. In the third stage, a formal proposal is placed by the individual in front of the organization. The final stage is the adoption phase which is a group process for either accepting or rejecting the proposal. Until the fourth stage, the driver is the individual action. When many individuals get involved, an organization starts exhibiting innovative behavior.

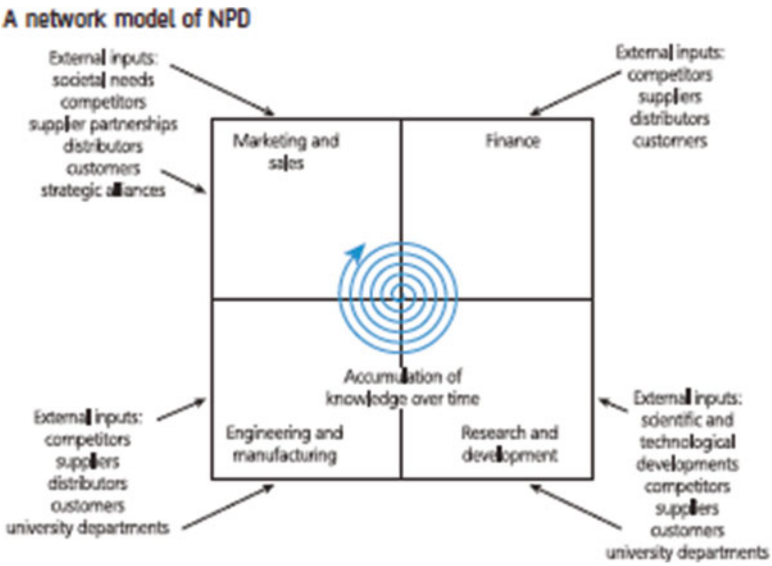


Fig. 15.9 A network model of NPD. Innovation management and new product development

15.6.7 Network Models

A network model (Fig. 15.9) views product development activity as a "knowledge-accumulation" process. A PD team starts with a certain set of assumptions related to product and over a period of time derives knowledge and insight about the product with the progress of the activity. The amount of knowledge progressively accumulates with the passage of PD process. The knowledge flows from both internal and external sources at each stage of PD activity and finally results in the development of product.

Questions

1. Define NPD and state its importance.
2. Briefly explain the various models related to planning and executing an NPD activity in an organization.
3. Discuss the four broad types of organization based on the strategy they adopt.

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Annexures

A.1 Annexure 1: History and Growth of R&D in India

A.1.1 Industrial Revolution and Industrialization in India

The eighteenth and nineteenth centuries marked the phase of industrialization in England, Europe, and the United States. India, which was under the British rule at that time, also entered the phase of industrialization. The industrial revolution brought with it a change in the system of production: from human labor to machines. With the invention of machines, new energy resources were tapped. The era saw the development of steam engines, textile mills, and so on. There were economic changes, such as increase in trade and the introduction of the factory system that brought about greater power to the industrialized nations. Social changes involved the creation of the modern working class, which brought in its fore the exploitation of people. The educational system also underwent several changes with a new mode of thinking and focus on technological changes.

Industrialization brought about many changes in India. Tata and other business houses contributed significantly in building a culture toward productivity; examples include the establishment of Tata Iron & Steel at Jamshedpur, Swadeshi Cotton Mills in Mumbai, and so on. The Indian cotton textile industry went through a mammoth change. India began capturing western markets by producing textile that was low in cost and high in quality. But with the tax tariffs in India during the late eighteenth century, India then became a producer and exporter of raw cotton along with other cash crops such as indigo, sugarcane, and jute.

Postindependence, there was a change that came about with the industrial policies, which was followed by the Nehru-Mahalanobis model and the 5-year plans falling into place. Research and development found a voice, resource, and greater vision.

K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0

A.1.1.1 The Nehru-Mahalanobis Model

The *Nehru-Mahalanobis* model laid the foundation of the classical Indian industrial policy framework. The policy that was laid out during post-World War II was with the purpose of controlling the investment flow in both the public and the private sectors. The idea was to bring certain strategic industries that would be the cornerstone of economic growth under the umbrella of the public sector. A socialist attitude was adopted with objectives laid out to achieve higher industrialization, increase per capita incomes, and ensure that the gains are equitably distributed. The economic progress was to reflect in all quarters and not just for a few privileged people. Industries were to be distributed across regions, giving them an equal opportunity to grow. This ideology brought with it a few salient features that impacted the Indian economy.

- The role of the heavy industries was emphasized and along with it the increase in the capital goods sector.
- As the structure of the economy transformed, the public sector played a pivotal role.
- The private sector industries that were planned and funded had to adhere to the national goal of equitable growth.
- The focus was on indigenous technology, processes, and manpower.

The changes above are reflected in the 5-year plans of the country and their industry focus.

A.1.2 Industrialization in the Five-Year Plans

Five-Year plans provided a framework for economic development through creating appropriate administration structure and resource mobilization and monitoring different contributors to the economic growth. Agriculture and manufacturing were considered as engines of growth.

In the following section, one can see the focus of the 5-year plan. All 11 5-year plans are presented in brief. This will illustrate how the focus on industrial development has changed over the years.

A.1.2.1 The First Five-Year Plan (1951–1956)

This plan aimed to improve agriculture, irrigation, and the power sector in the country. This was formulated with the idea of decreasing the reliance of the country on food grain imports. Focus was also on easing the raw material problem of jute and cotton, which increases the production of jute and cotton. The primary focus of this plan was the agriculture sector, with an understanding that increase in agricultural output would provide the momentum for industrial growth in the country. This plan was successful in increasing agricultural production, increasing the national income and the per capita income and consumption boundaries.

In the first 5-year plan, the focus was primarily on setting up national laboratories and other research institutions and developing them. The focus was on research into the development of new processes and the development of industries by using available local resources.

A.1.2.2 The Second Five-Year Plan (1956–1961)

The focus of this plan was primarily agriculture. However, the unfavorable monsoon during 1957–1958 and 1959–1960 affected agricultural production. In 1956, the Industrial Policy Resolution was adopted, which was socialist in nature. This meant that along with industrial growth and welfare, the progress of all segments of society would be the focus of the plan. The idea was to develop national resources and available talent to the optimum.

In the second 5-year plan, one of the primary objectives was also to develop the existing facilities in the country and ensure that scientists from national laboratories and researchers from universities work on problems of national importance. The Council of Scientific and Industrial Research expanded its scope post-1947. The Council has two standing advisory bodies, which are the Board of Scientific and Industrial Research and the Board of Engineering Research. The Board of Scientific and Industrial Research has the role of advising the governing body on proposals that relate to (1) specific research schemes, (2) scientific study in various institutions of problems affecting particular industries, (3) specific studies and surveys of indigenous resources, and (4) establishment of new research institutions. The board is assisted by several research committees; for example, there are various activities such as chemical research, physical research, metals research, radio research, statistics, standards and quality control, and so on. The research work under the Council is carried on at the Council laboratories and also universities and other centers. This involves teamwork and pilot plant investigation across national laboratories. In 1953, the Government of India set up the National Research Development Corporation, which is an organization that focuses on bridging the gap between research and development, ensuring that the results of research are made use of in practice by the industries, and securing maximum practical utilization by industries of the results of research. The corporation undertakes the trial production of completed processes, working in tandem with the industry, and licences patents and inventions held by it.

The Ministry of Education and the University Grants Commission helped the science departments of the Universities with setting up their laboratories and libraries and sourcing the equipment. The focus was on university research institutions as they would be the main source of supply of competent and trained scientific workers in the country. This plan also provided funds to some national research organizations for expanding their research facilities. They are Indian Institute of Science, Bangalore, the Tata Institute of Fundamental Research, Bombay, and The Indian Institute of Nuclear Physics, Calcutta, Bose Institute, Calcutta, Indian Association for the Cultivation of Science, Calcutta, the Birbal Sahni Institute of Paleobotany, Lucknow, and Shriram Institute for Industrial Research, Delhi.

A.1.2.3 The Third Five-Year Plan (1961–1966)

The main motive of this plan was to make the country self-reliant in both the agricultural and the industrial sectors. The focus was also on promoting economic development in backward areas. Subsidies were provided to unfeasible manufacturing units. However, this plan was affected by the wars in 1962 and 1965 along with bad monsoons.

The third 5-year plan focused on working toward improvement in agriculture, medical, and health facilities, improving the techniques of locating and processing raw materials, providing substitutes and evolving new materials, appliances, and techniques for the industry, improving transport, power, communications, and other essential utilities, and doing all this through a sustained research activity.

During the years 1961–1969, the Council of Scientific and Industrial Research (CSIR) set up various national-level institutes for research like the National Institute of Oceanography, Regional Research Laboratory at Bhubaneswar, the National Geophysical Research Institute, Structural Engineering Research Centre, and Industrial Toxicology Research Centre. Along with this, CSIR supported three cooperative research associations for textiles and one for tea. There were six national laboratories which were initiated during the second plan period. These were fully equipped and staffed during this phase. They are the National Aeronautical Laboratory, Central Scientific Instruments Organisation, the Central Mechanical Engineering Research Institute, Central Indian Medicinal Plants Organisation, the Indian Institute of Petroleum, and Central Public Health Engineering Research Institute.

The import substitution strategy that was implemented in 1961 ensured that materials were indigenously manufactured, which led to a saving of about 211 crores in foreign exchange during the period 1961–1967, as stated by the Directorate General of Technical Development (DGTD).

The activities of the Department of Atomic Energy (DAE) became part of the 5-year plan programs in the year 1961. Its primary objectives were to develop the use of atomic energy for the production of electric power and evolve new uses of stable and radioactive isotopes for agriculture, biology, medicine, and industry.

A.1.2.4 The Fourth Five-Year Plan (1969–1974)

The focus of this 5-year plan was to encourage education and create employment opportunities. The aim was to improve the condition of the marginalized segment of the society and in turn make the economy of the country self-reliant. This industrial plan however left a lot to be desired, with both agricultural and industrial growth rates being low in this tenure. It was in the year 1969 that the Monopolies and Restrictive Trade Practices Act (MRTP Act) was passed. According to this act, industrial groups with assets of 200 million and more would have to restrict their activities only to specific groups of industries. In 1973, the Foreign Exchange and Regulation Act (FERA) was passed, restricting the Indian activities of the companies which had more than 40 % foreign equity.

In the fourth 5-year plan, the focus was on developing research in industries such as chemical, electronics, instruments, drugs, and pharmaceutical . During this plan, it was decided that while the laboratories would provide experimental and pilot plant data to entrepreneurs, the consulting engineering firms could be engaged in design activities. This would ensure the integration of various departments and collaboration between various industries.

A.1.2.5 The Fifth Five-Year Plan (1974–1979)

The focus of this plan was on checking the rate of inflation to look at the nutritional requirements of the country and focus on health. However, the plan could not complete the tenure due to change in the political party ruling the country.

In the fifth 5-year plan, research priorities were in the fields of crop production and animal husbandry and to ensure new innovations in the farm technology sphere. This helped in the development of agricultural universities and related R&D work.

A.1.2.6 The Sixth Five-Year Plan (1980–1985)

This plan placed equal emphasis on infrastructure and agriculture, achieving a growth rate of 6 %. It was during the sixth 5-year plan that the Technology Policy Statement (TPS) was formulated, according to which there would be focus on technology assessment and forecasting and support to organizations and institutions would be provided for the development of indigenous technology. Along with it, through upscaling, use of design and consultancy, and engineering and establishing linkages and collaborative efforts between different sectors, the viability of the project would be proved. This would in turn mean and ensure that there was absorption, adaptation, and improvement of important technology, keeping in mind the environmental regulations.

A.1.2.7 The Seventh Five-Year Plan (1985–1989)

The focus of this plan was to increase employment opportunities, and with that, the Jawahar Rozgar Yojana was introduced. The plan also focused on other sectors such as welfare, education, and health. Despite a 3-year drought in the beginning of the tenure, the plan was successful in meeting its objectives.

In the seventh 5-year plan, it was stated that the guiding principle of the plan would continue to be growth, equity and social justice, self-reliance, improved efficiency, and productivity. There would also be an emphasis on policies and programs which would accelerate growth in food production, increase employment opportunities in the country, and raise productivity. Along with this, focus was given to education, particularly related to science and technology. In this plan, various research institutes were set up under the CSIR, for example, CCMB, CFB, 1MT, Palampur Complex, and RRL Bhopal.

A.1.2.8 The Period 1989–1991

During this period, there was immense political instability, due to which no 5-year plans were drafted. For the period 1990–1992, only annual plans were made, and the impact was seen economically, with the country facing a severe balance of payments crisis.

A.1.2.9 The Eighth Five-Year Plan (1992–1997)

The focus of the eighth 5-year plan was toward modernization of industries, strengthening infrastructure, and encouraging employment. The focus was also on reducing poverty and removing the license raj and bringing in an era of liberalization, privatization, and globalization. The idea was to do away with license prerequisites and decrease trade barriers. This plan helped to control inflation and achieved a growth rate of 5.6 % GDP.

It was in the eighth 5-year plan that industries received great support to help them establish a strong R&D base. This was done by providing them incentives through tax concessions. The eighth plan also saw the establishment of several institutes for scientific and industrial research.

The strategy for science and technology (S&T) development in the eighth plan was stated as follows:

- Laying greater emphasis on scientific and technological content of all programs in the socioeconomic sectors
- Identifying and implementing national technology missions and S&T projects in a mission mode in selected areas
- Aiming at improving the quality of S&T education and training at all levels
- Providing for a significant thrust in selected areas of advanced research to reach international levels
- Ensuring, through fiscal incentives, that research is carried out by, and within, the production and service sectors
- Accelerating the process of commercialization of research to induce a greater degree of purposiveness and better links between research and industry
- Taking appropriate steps, all round, for moving into the age of information/telematics

Encouraging research and innovation in the tools and techniques of traditional occupations (i.e., agriculture and rural artisanship) and inducing widespread adaptation

A.1.2.10 The Ninth Five-Year Plan (1997–2002)

The focus of the ninth 5-year plan was on increasing the income in the agricultural sector and also improving the conditions of the marginal farmer and landless laborers. The annual growth rate achieved during this period was 6.7 %.

In the ninth 5-year plan, the importance of R&D was further reiterated through the stated purpose of the plan:

- Need for mounting efforts to control the population and improve the levels of food security, economic growth, literacy, health, and so on apart from realizing technological strengths in the emerging global industrial/economic environment by optimal utilization of S&T systems in India.
- Scientists with exceptional capabilities should be nurtured and supported fully by offering them within the country facilities comparable with international standards.
- To be in the forefront in some of the chosen fields, research programs should be taken up on a mission mode through appropriate restructuring and reorientation.
- For the evaluation of S&T proposals, the criteria could be outputs/results, quality and timeliness (instead of quantity in terms of number of projects, expenditure incurred, etc.), ability to face global competition and to meet national needs, and ability to attract services or funds from the industry and financial institutions.
- There is need to establish links between the industry and research institutions/laboratories and encourage venture capital funds for the development and marketing of technology.
- There is need to develop core strengths and concentrate on areas where competitive strength can be built so that technological capabilities can be converted into commercial strengths.
- There should be greater emphasis on clean and ecofriendly technologies, and focus should be on the concept that one industry's pollutant is another industry's raw material.
- There is need to create a conducive environment in our educational institutions for developing creative skills and innovative capabilities with greater emphasis on modern management techniques, technology marketing, and IPR-related issues.
- Intensive efforts should be made to generate maximum resources for R&D from the production and service sectors.
- The academic community should gradually motivate the faculty to do research by giving them a sense of empowerment and autonomy of functioning within the university system.
- The interuniversity centers, which are providing very valuable services to the university research community, should be encouraged by earmarked support through the UGC.
- The operation of research funds both at the level of the individual research worker and at the institutional level needs to be reviewed so that subcritical support is avoided.
- The extramural research funding should be enhanced by carefully building up rigorous, objective, constructive, and credible peer review systems.
- Efforts should also be made to provide financial support to universities and related institutions for improving S&T infrastructure.
- Establishment of some regional science and engineering research libraries in chosen institutions with networking facilities.
- Need for building up national facilities in the area of accelerators by pooling technical and financial resources.

- Need for revival of the National Science Talent Scheme in its original form and introduction of some high-quality undergraduate science programs at selected institutions.
- To raise the national R&D expenditure to the desired level of 2 % of GNP, the industry should be made to come forward in a big way by putting in demands on the existing R&D infrastructure and by supporting innovative programs of technology development and refinement.
- To improve the technological competitiveness in the global market and enhance the technology export potential, attention has to be focused on areas such as university-corporate R&D spending, laboratory-to-industry conversion, indigenous innovation, IPR protection, and so on.
- A network of testing and evaluation facilities. The National Accreditation Board for Laboratories (NABL), set up in this direction, needs to be nurtured.
- While creating mechanisms for harnessing S&T, it is necessary to ensure that investment in technology development programs is governed by national needs.

A.1.2.11 The Tenth Five-Year Plan (2002–2007)

The purpose of the tenth 5-year plan was to increase the growth rate of the country, reduce the poverty rate, and increase the literacy rate. In this process, the aim was to make the Indian economy the fastest-growing economy. This plan gained success in several quarters, with the economic growth of the country crossing 8 %.

In the tenth 5-year plan, recognizing the global economic order, the focus was to strengthen application-oriented R&D for technology generation, promote human resource development especially in terms of encouraging bright students to pursue science as a career, encourage research and application of S&T for forecasting, prevention, and mitigation of natural hazards, integrate the developments in S&T with all spheres of national activities, and harness S&T for improving livelihood, employment generation, environment protection, and ecological security. The various activities in the tenth 5-year plan which were undertaken are

- Operationalization of National Natural Resource Management System (NNRMS) through application of remote-sensing technology in developmental programs.
- Technology development for future-generation launch vehicle for placing 4 ton class INSAT satellites in geosynchronous transfer orbit and also critical technologies required for reusable launch vehicles.
- Development of all-weather, remote-sensing technology by way of Radar Imaging Satellites (RISAT) with a multimode, multipolarization agile synthetic-aperture radar.
- Application of space technology in education and health for tele-education and telemedicine networks.
- Technology demonstration for water desalination for large-scale desalination of seawater and freshwater into fresh potable water.
- Development of technically feasible, economically viable, and ecofriendly irradiation technologies for farm products through linkage with state agricultural universities, seed corporations, ICAR, and other state and central agencies.

- Genomics research, which was especially for drug targeting against specific human pathogens like those responsible for peptic ulcer, tuberculosis, damage to kidney and heart, and the genes responsible for diabetes.
- Development of new-generation vaccines against diseases such as rabies, cholera, HIV/AIDS, tuberculosis, Japanese encephalitis, and malaria.
- Food and nutritional security through enhancement of crop productivity, value addition, and genetic engineering for enhanced nutritional status.
- Exploration and exploitation of microbial wealth of India for novel compounds and biotransformation processes.
- Development of pollution control and monitoring systems/devices for air, water, and solid waste.
- Carcass utilization and development of ecofriendly leather-processing technologies.
- Technologies for bamboo products for giving significant thrust to the usage of bamboo, promoting specialized products for commercialization, and generating good employment opportunities.
- Research in the area of nanoscience and technology for the development of nanosized ceramics, water purification, drug delivery systems, energy devices, and so on.
- The pharmaceutical R&D scheme is envisaged to encourage R&D in the pharmaceutical sector in a manner compatible with the country's needs and with particular focus on diseases endemic or relevant to India. A Drug and Pharmaceutical Research and Development Support Fund (PRDSF) was also proposed to be set up.
- Validation and testing of 10 new drugs and molecules from important medicinal plants.

A.1.2.12 The Eleventh Five-Year Plan (2007–2012)

The aim of the eleventh 5-year plan was to increase the GDP growth of the country to 10 %, work to reduce the unemployment level among the educated, and improve the health sector. Along with industrial growth, there is a change in the S&T policies in the country, the R&D developments across the plans, and the policy changes in R&D. In the annexure, we will look at science policies in India, how R&D has changed across the 5-year plans, what are the science policy benefits, and the growth of India as an R&D hub.

The eleventh 5-year plan laid out various strategies to develop R&D. They are

- Substantial stepping up of support to basic research
- Enlarging the pool of scientific manpower
- Strengthening S&T infrastructure
- Implementing selected national flagship programs which have a direct bearing on the technological competitiveness
- Establishing globally competitive research facilities and centers of excellence

The plan includes a fourfold increase for education over the previous plan. It also targets growth of R&D as a share of GDP from the current level of 0.9 % to 1.2 %

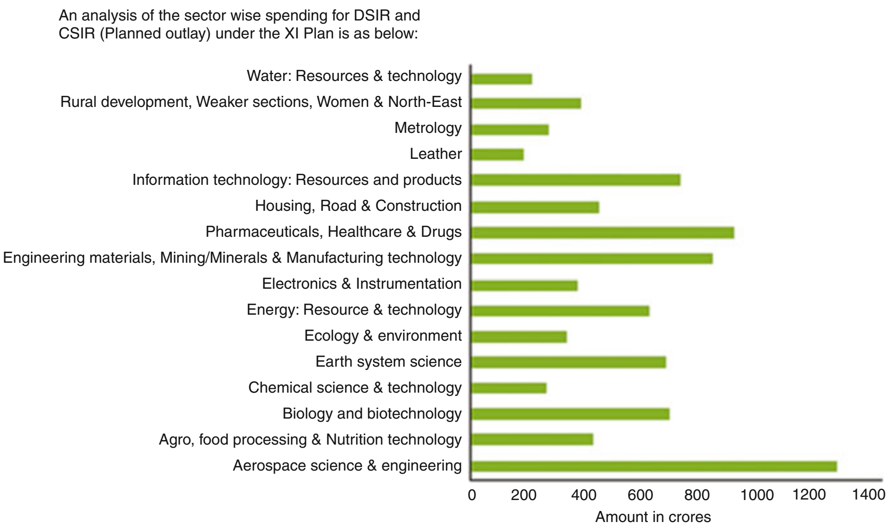

Fig. A.1 Outlays covering various sectors (*Source*: Deloitte 2011)

by 2012. Domestic R&D investment is considered to be one of the most critical inputs for innovation in any country. As the Indian innovation system is still in its nascent stage, 75–80 % of the domestic R&D is taken by the public sector, 20–25 % by private enterprises, and around 3 % by universities. On the contrary, the typical R&D expenditure break-up in countries belonging to OECD is as follows: 69 % by private enterprises, 18 % by universities, 10 % by government R&D laboratories, and 3 % by nonprofit institutions (Fig. A.1).

A.1.3 The Role of the Government in R&D

There are various reasons for which the government participates in R&D activities of a country. Some of them are

- The development of innovations, which would lead to cost reduction for all customers. While R&D activities of this nature are beneficial for a country, the industry may not be interested in pursuing it as they may not avail direct benefits from this R&D activity.
- The innovations that enhance the value of assets of a country, though not in direct financial terms, for example, the R&D involved in defence activities. This is a matter of national priority, and the government has to take interest in it and guide the entire process.

- Certain innovations have an impact on the environment. The adoption of these innovations by industry should be controlled by regulations, emission charges, and other mandatory policies. It takes a collaborative effort to encourage industries to focus on innovations that will lead to ecofriendly products/processes and also encourage the use of nonconventional energy. In such cases, the government has to play a very active role.
- The financial aspect involved in research may be a deterrent for some private industry practitioners, especially in cases where the technology is expensive and the chances of failure are high. This may be beneficial from a societal perspective and for the R&D portfolio of the country as success would translate to high gains for the country.
- Also, research activities that have a long gestation period may not find favor with the private players in the industry.

The above factors thus make it necessary for the government of a country to invest and carry out R&D activities. The technological progress and the innovation capacity of a country is also directly proportional to the effort that country is expending on its R&D activities (Deloitte report).

A.1.4 The Science Policy of India

Understanding the importance of R&D for a nation that had newly entered the threshold of independence, the Government of India assumed an active role in R&D activities in the country. This is evident through its focus on the science policy of the country and also the R&D focus that is seen across the 5-year plans. To define goals and objectives of R&D, in 1958 the government introduced a Science Policy Statement, with the following as its aims:

- To foster, promote, and sustain, by all appropriate means, the cultivation of science and scientific research in all its aspects—pure, applied, and educational
- To ensure an adequate supply, within the country, of research scientists of the highest quality and to recognize their work as an important component of the strength of the nation
- To encourage and initiate, with all possible speed, programs for the training of scientific and technical personnel on a scale adequate to fulfill the country's needs in science and education, agriculture and industry, and defense
- To ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity
- To encourage individual initiative for the acquisition and dissemination of knowledge and for the discovery of new knowledge in an atmosphere of academic freedom

In general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

It is very interesting, and perhaps also very strange, that a technology policy resolution was not issued simultaneously along with the Science Policy Resolution of 1958. In fact, a Technology Policy Resolution was formulated only in 1984, that is, more than a quarter of a century later. In the meantime, an Industrial Policy Resolution was formulated and operated for about three decades although industry's approach to innovation and the use of technology imports are crucial to the development of technology and technological capability. In keeping with the objectives spelt out in the Science Policy Resolution, the Government of India implemented various strategies for managing R&D at the national level. These strategies include

- Creation of institutions to foster research in the country
- Funding of research activities in educational institutions
- Legislation for the promotion of R&D
- Provision of incentives and disincentives for individuals and firms to innovate

Besides being directly involved in the creation and funding of R&D institutions, the Government of India has also implemented the strategies of enacting R&D-related legislation and of providing incentives for individuals and firms to innovate. Some of the policy instruments used to implement these strategies include

- Various awards, citations, and recognitions are offered to individuals who demonstrate scientific and technological mastery. Examples of these are the Independence Day Awards for the best innovation in various sectors given by NRDC, the Shanti Swarup Bhatnagar Award for scientists who have made outstanding contributions to the cause of science, etc..
- Financial assistance given by NRDC and IFCI in the form of seed capital to scientists and innovators to commercialize their innovations.
- Import ban on technologies that have been indigenously produced. This is effected by putting a CSIR nominee in the DGTD board, which approves foreign collaborations.
- Weighted income tax allowances up to 133 % on R&D expenditures directly incurred or incurred through sponsored projects in government laboratories.
- Recognizing private sector R&D laboratories for granting higher degrees to personnel employed there.
- Modifying patent laws by passing the Patents Act 1970 and thus removing barriers on various avenues for research hitherto blocked by patents of foreign firms and their Indian subsidiaries.
- Framing and implementing the technology policy statement of 1984 to rationalize government decisions on technological developments.

A.1.5 Implementation Over the Five-Year Plans

Research and development projects are a challenging task for any organization, considering the uncertainty it entails, with investments often being high and the anticipated returns picture not being too clear. To enable people and organizations

Table A.1 S&T expenditure across the 5-year plans (Rs. in crores)

Five year plan period	Plan	Non-plan	Total
First plan (1951–1956)	14	6	20
Second plan (1956–1961)	33	34	67
Third plan (1961–1966)	71	73	144
Plan holiday (1966–1969)	47	83	130
Fourth plan (1969–1974)	142	231	373
Fifth plan (1974–1979)	693	688	1,381
Annual plan (1979–1980)	208	222	430
Sixth plan (1980–1985)	2,016	1,652	3,668
Seventh plan (1985–1990)	5,087	3,158	8,245
Annual plans (1990–1992)			
Eighth plan (1992–1997)	–	–	–
Ninth plan (1997–2002)	–	–	–
Tenth plan (2002–2007)	–	–	–
Eleventh plan (2007–2012)	–	–	–

Source: Eighth 5 year plan, Planning Commission (1992)

to undertake R&D activities, the government provides an environment that can be an impetus for R&D growth. It involves the following:

- Ensuring that the economy is knowledge based and on a continual growth path and the government imposes fiscal policies, incentivises investments that organizations do in R&D, and also provides tax and other benefits
- Increasing the talent pool of the country and the quantum of knowledge workers
- Ensuring an environment of collaboration, cooperation, and interaction between the industry and academic institutions
- Ensuring that IPRs are protected and also working toward enhancing the sharing and transfer of knowledge

In India, it has been observed that the government contributes the majority of investment for R&D expenditure (Table A.1, Figs. A.2, A.3, A.4, A.5, A.6, and A.7).

India has progressed in S&T over the years and provided an overview of a substantial role of the government in creating R&D culture. Through funding, it has fostered the results, and the government has developed frameworks for an effective science-led technology development in the country. Government has also created institutional frameworks which are complimentary to each other. Scientific departments at the ministry level, state councils for S&T, public sector R&D promotion in all the strategic areas, systematic support for the private sector, protection and promotion of small and medium enterprises to sustain a manufacturing base, and establishment of technical institutions at different levels to supply educated technical manpower have all provided a substantial foundation and increase of R&D activities in the country. Research and development management has emerged as a need to fulfill effective growth of the economy on the one hand and promote strategic leadership of the organization through innovation on the other.

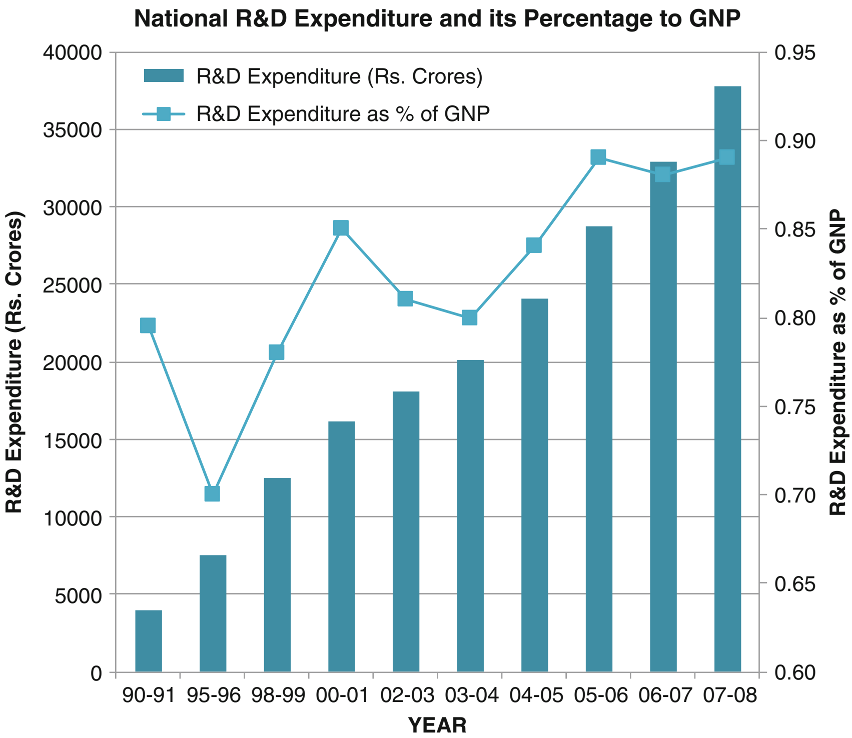

Fig. A.2 National R&D expenditure and its percentage to GNP (*Source*: Statistical Tables 2007–2008)

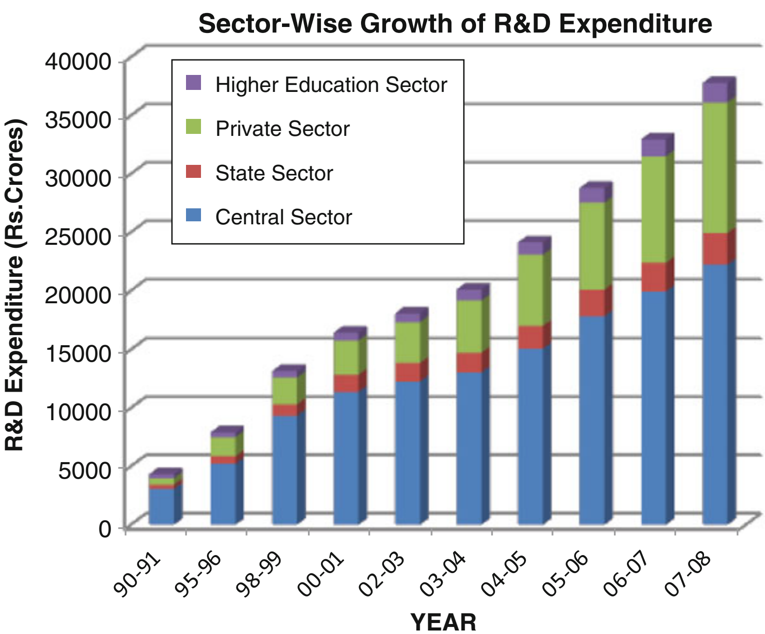

Fig. A.3 Sector-wise growth of R&D expenditure (*Source*: Ministry of Science and Technology 2008)

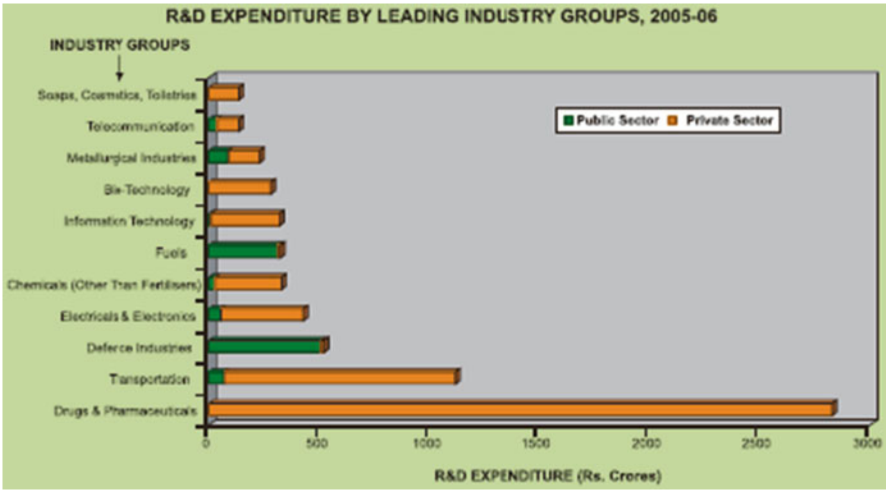

Fig. A.4 R&D expenditure by leading industry groups, 2005–2006 (*Source*: Ministry of Science and Technology 2008)

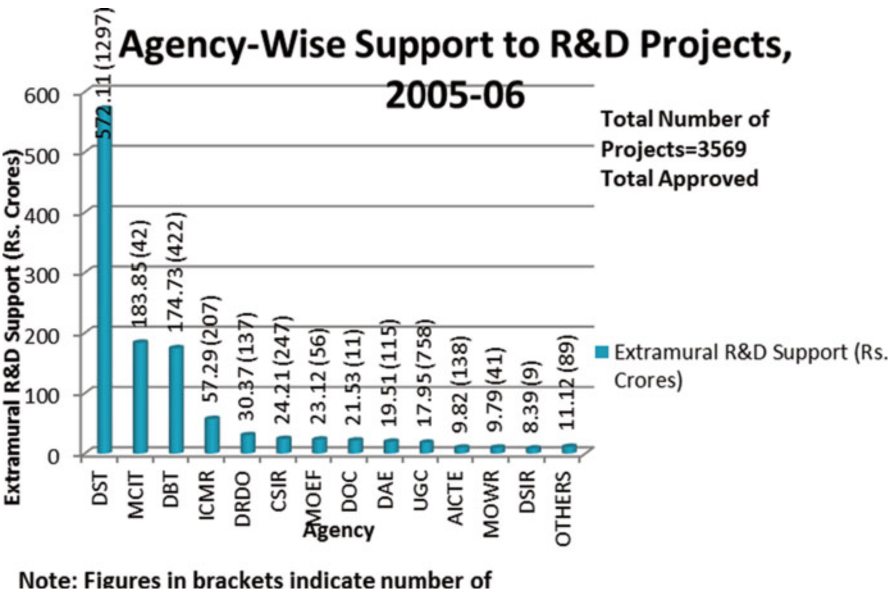

Fig. A.5 Agency-wise support to R&D projects, 2005–2006 (*Source*: Statistical Tables 2007–2008)

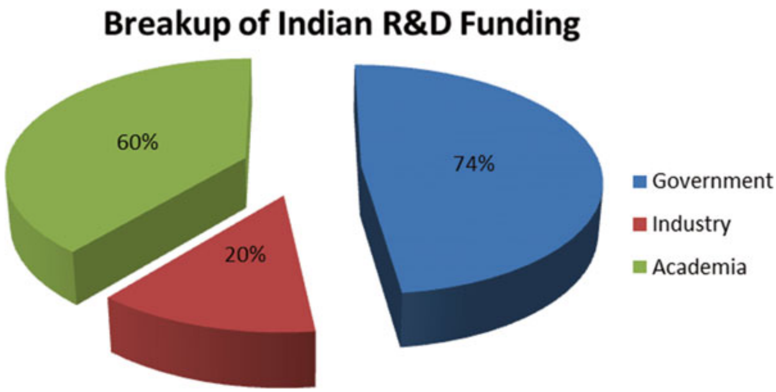

Fig. A.6 Breakup of Indian R&D funding (*Source*: Deloitte 2011)

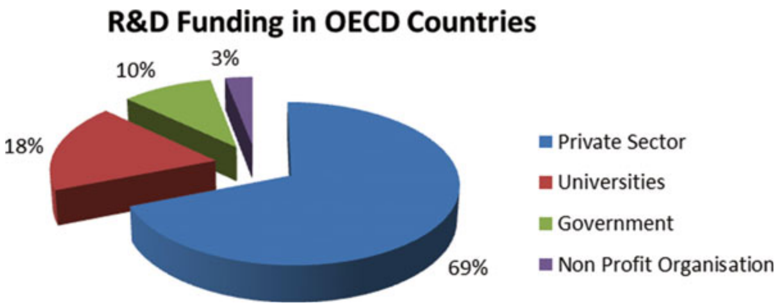

Fig. A.7 R&D funding in OECD countries (*Source*: Deloitte 2011)

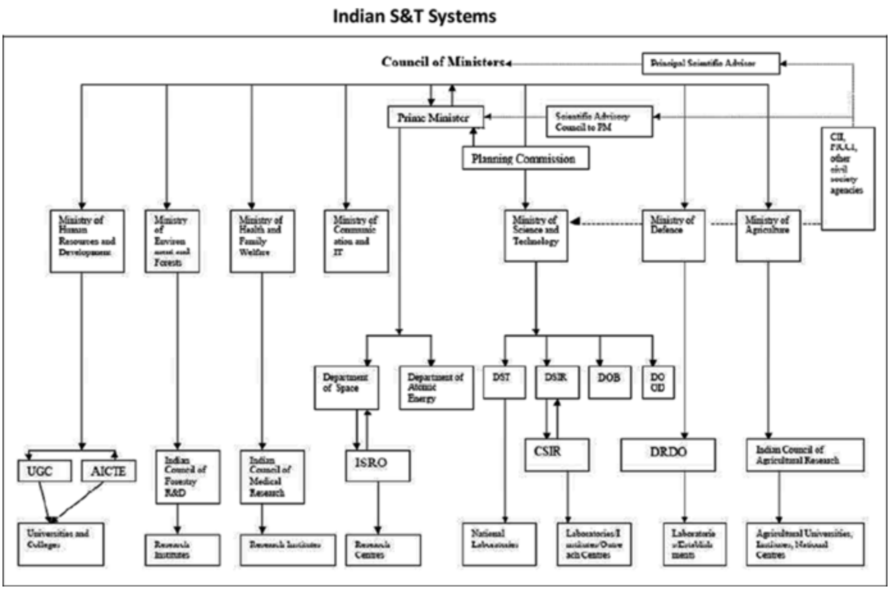

Fig. A.8 Indian S&T Systems (*Source*: CSIR 2010)

A.2 Annexure 2: Indian Science &Technology System

A.2.1 Introduction

Science and technology systems of a country are a reservoir of knowledge and the cauldron where more knowledge is created. To understand the technological potential of a country and its propensity to develop and innovate, it is essential to understand how the S&T system is working. Indian S&T can be viewed at federal as well as state levels, and scientific ministries under the Federal Government include seven ministries. The scientific ministries are classified accordingly:

1. Ministry of Human Resource and Development
2. Ministry of Environment and Forest
3. Ministry of Health and Family Welfare
4. Ministry of Communication and IT
5. Ministry of Science and Technology
6. Ministry of Defence
7. Ministry of Agriculture

This annexure provides an overview of these main ministries, which are called scientific ministries, and their role in promoting R&D activities in the country. They promote R&D activities through promoting appropriate policies, establishment of R&D laboratories, supporting centers of excellence, enabling knowledge centers, funding, and so on (Fig. A.8).

A.2.2 Ministry of Human Resource Development

With a mission to enhance and develop education in the country, the Ministry of Human Resource Development (MHRD) was created on September 26, 1985, through the 174th amendment to the Government of India (Allocation of Business) Rules, 1961. Currently, the MHRD works through two departments:

- Department of School Education and Literacy
- Department of Higher Education

While the Department of School Education and Literacy is responsible for the development of school education and literacy in the country, the Department of Higher Education takes care of what is one of the largest Higher Education systems of the world, after the United States and China.

The Department of School Education and Literacy (SE&L) has its eyes set on the “universalization of education” and making better citizens of our young brigade. For this, various new schemes and initiatives are introduced regularly, and recently those schemes and initiatives have also started paying dividends in the form of growing enrolment in schools.

The Department of Higher Education (HE), however, is engaged in bringing world-class opportunities of higher education and research into the country so that Indian students do not find themselves lacking when facing an international platform. For this, the government has launched joint ventures and signed MoUs to help the Indian student benefit from the world opinion.

The main objectives of the Ministry are

- Formulating the National Policy on Education and ensuring that it is implemented in letter and spirit
- Planned development, which includes expanding access and improving the quality of the educational institutions throughout the country, including the regions where people do not have easy access to education
- Paying special attention to the disadvantaged section of people such as the economically backward, women, and minorities
- Providing financial help in the form of scholarships, loan, subsidy, and so on to deserving students from deprived sections of society
- Encouraging international cooperation in the field of education, including working closely with the UNESCO and foreign governments as well as universities to enhance the educational opportunities in the country

A.2.2.1 Organizations

The department is divided into 8 bureaus, and most of the work is managed through more than 100 autonomous organizations under these bureaus.

- University and Higher Education; Minorities Education, which includes University Grants Commission (UGC), Indian Council of Social Science Research (ICSSR), Indian Council of Historical Research (ICHR), Indian Council of Philosophical Research (ICPR), 39 Central Universities (including 12 new Central Universities which have been established with effect from 15.01.2009 by an ordinance promulgated by the President of India), and Indian Institute of Advanced Studies (IIAS), Shimla.

Technical Education, which includes All India Council of Technical Education (AICTE), Council of Architecture (COA), 3 Schools of Planning and Architecture (SPAs), 16 Indian Institutes of Technology (IITs), 5 Indian Institutes of Science Education and Research (IISERs), 13 Indian Institutes of Management (IIMs), 30 National Institutes of Technology (NITs), 4 Indian Institutes of Information Technology (IIITs), Sant Longowal Institute of Engineering and Technology, 4 National Institutes of Technical Teachers' Training & Research (NITTTRs), 4 Regional Boards of Apprenticeship/Practical Training, and 2 BITS Pilani Institutes of Technology (Table A.2).

- Administration and Languages, which includes three deemed universities in the field of Sanskrit, viz., Rashtriya Sanskrit Sansthan (RSkS) (www.sanskrit.nic.in), New Delhi; Shri Lal Bahadur Shastri Rashtriya Sanskrit Vidyapeeth

Table A.2 Distribution of various institutions in India

Institutions in India	No. of institution in India
School of Planning and Architecture (SPAs)	**3**
Indian Institutes of Technology (IITs)	**16**
Indian Institutes of Science Education and Research (IISERs)	**5**
Indian Institutes of Management (IIMs)	**13**
National Institutes of Technology (NITs)	**30**
Indian Institutes of Information Technology (IIITs)	**4**
National Institutes of Technical Teachers' Training & Research (NITTTRs)	**4**
Regional Boards of Apprenticeship/Practical Training	**4**
Birla Institute of Technology and Science, Pilani (BITS)	**2**

(SLBSRSV) (www.slbsrsv.ac.in), New Delhi; Rashtriya Sanskrit Vidyapeeth (RSV) (www.rsvidyapeetha.ac.in), Tirupati; Kendriya Hindi Sansthan (KHS), Agra; English and Foreign Language University (EFLU), Hyderabad; National Council for Promotion of Urdu Language (NCPUL), National Council for Promotion of Sindhi Language (NCPSL), 3 subordinate offices: Central Hindi Directorate (CHD), New Delhi, Commission for Scientific & Technological Terminology (CSTT), New Delhi, and Central Institute of Indian Languages (CIIL), Mysore.

- Distance Education and Scholarships which includes Indira Gandhi National Open University (IGNOU).
- UNESCO, International Cooperation, Book Promotion and Copyrights, Education Policy, Planning and Monitoring.
- Integrated Finance Division.
- Statistics, Annual Plan and CMIS.
- Administrative Reform, North Eastern Region, SC/ST/OBC.

There are several other organizations under the Ministry of Human Resource Development such as National University of Educational Planning and Administration (NUEPA), National Book Trust (NBT), National Board of Accreditation (NBA), National Commission for Minority Educational Institutions (NCMEI), National Council of Educational Research and Training (NCERT), Central Board of Secondary Education (CBSE), Kendriya Vidyalaya Sangathan (KVS), Navodaya Vidyalaya Samiti (NVS), National Institute of Open Schooling (NIOS), Central Tibetan Administration (CTA), National Foundation for Teachers' Welfare, a public sector enterprise, Educational Consultants (India) Limited (EdCIL), and Central Tibetan Administration (Bureau of HH the Dalai Lama), (Lajpatnagar), Delhi.

Few Inter-university Centres (IUCs) in this ministry are Nuclear Science Centre, New Delhi; Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune; Inter-University Consortium for DAE Facilities, Indore; Information and Library Network (INFLIBNET), Ahmedabad; Consortium for Educational Communication (CEC), National Assessment and Accreditation Council (NAAC), Bangalore; and Central Tibetan Administration (Dharamshala).

A.2.3 Ministry of Environment and Forests

The Ministry of Environment and Forests (MoEF) is the nodal agency in the administrative structure of the Central Government for the planning, promotion, coordination, and overseeing of the implementation of India's environmental and forestry policies and programs.

The primary concerns of the Ministry are implementation of policies and programs relating to conservation of the country's natural resources including its lakes and rivers, its biodiversity, forests and wildlife, ensuring the welfare of animals, and the prevention and abatement of pollution. While implementing these policies and programs, the Ministry is guided by the principle of sustainable development and enhancement of human well-being.

The Ministry also serves as the nodal agency in the country for the United Nations Environment Programme (UNEP), South Asia Cooperative Environment Programme (SACEP), and International Centre for Integrated Mountain Development (ICIMOD) and for the follow-up of the United Nations Conference on Environment and Development (UNCED). The Ministry is also entrusted with issues relating to multilateral bodies such as the Commission on Sustainable Development (CSD) and Global Environment Facility (GEF) and of regional bodies such as Economic and Social Council for Asia and Pacific (ESCAP) and South Asian Association for Regional Cooperation (SAARC) on matters pertaining to the environment.

The core objectives of the Ministry are as follows:

- Conservation and survey of flora, fauna, forests, and wildlife
- Prevention and control of pollution
- Afforestation and regeneration of degraded areas
- Protection of the environment
- Ensuring the welfare of animals

These objectives are well supported by a set of legislative and regulatory measures, aimed at the preservation, conservation, and protection of the environment. Besides the legislative measures, the National Conservation Strategy and Policy Statement on Environment and Development, 1992; National Forest Policy, 1988; Policy Statement on Abatement of Pollution, 1992; and the National Environment Policy, 2006 also guide the Ministry's work.

A.2.3.1 Organizations

Various subordinate offices under the Ministry of Environment and Forest are Andaman & Nicobar Islands Forest and Plantation Development Corporation (Public Sector Undertaking), Animal Welfare Board of India, Botanical Survey of India (BSI), Kolkata; Central Pollution Control Board; Central Zoo Authority; Directorate of Forest Education (DFE), Dehradun; Forest Survey of India (FSI), Dehradun; Indira Gandhi National Forest Academy (IGNFA), Dehradun; National Afforestation and Eco-Development Board; National Biodiversity Authority; National Board of Wildlife, National Ganga River Basin Authority; National Institute of Animal Welfare; National Museum of Natural History (NMNH), New Delhi; National Tiger Conservation Authority; National Zoological Park (NZP), New Delhi; and Zoological Survey of India (ZSI), Kolkata.

Furthermore, there are many autonomous institutions under this ministry, namely, Govind Ballabh Pant Institute of Himalayan Environment and Development, Indian Council of Forestry Research and Education, Indian Institute of Forest Management, Indian Plywood Industries Research and Training Institute, Wildlife Institute of India, Central Zoo Authority, National Biodiversity Authority, National Ganga River Basin Authority, National Tiger Conservation Authority, Animal Welfare Board of India, Central Pollution Control Board, National Afforestation and Eco-development Board, and Andaman & Nicobar Islands Forest & Plantation Development Corporation Ltd.

A.2.4 Ministry of Health and Family Welfare

The Ministry of Health and Family Welfare comprises the following departments, each of which is headed by a secretary to the Government of India:

- Department of Health & Family Welfare
- Department of Ayush
- Department of Health Research
- Department of AIDS Control

Directorate General of Health Services (Dte.GHS) is the attached office of the Department of Health & Family Welfare and has subordinate offices spread across the country. The DGHS renders technical advice on all medical and public health matters and is involved in the implementation of various health services.

The Department of Health deals with health care, including awareness campaigns, immunization campaigns, preventive medicine, and public health. Bodies under the administrative control of this department are as follows:

- National AIDS Control Organization (NACO) (see HIV/AIDS in India)
- Thirteen National Health Programmes, namely, National AIDS Control Programme (AIDS), National Cancer Control Programme (cancer), National Filaria Control Programme (filariasis), National Iodine Deficiency Disorders Control Programme (iodine deficiency), National Leprosy Eradication Programme (leprosy), National Mental Health Programme (mental health), National Programme for Control of Blindness (blindness), National Programme for Prevention and Control of Deafness (deafness), National Tobacco Control Programme (tobacco control), National Vector Borne Disease Control Programme (NVBDCP) (vector-borne disease), Pilot Programme on Prevention and Control of Diabetes, CVD and Stroke

(diabetes, cardiovascular disease, stroke), Revised National TB Control Programme (tuberculosis), and Universal Immunization Programme
- Medical Council of India
- Dental Council of India
- Pharmacy Council of India
- Indian Nursing Council
- All India Institute of Speech and Hearing (AIISH), Mysore
- All India Institute of Physical Medicine and Rehabilitation (AIIPMR), Mumbai
- Hospital Services Consultancy Corporation Limited (HSCC)
- Food Safety and Standards Authority of India

A.2.4.1 Department of Family Welfare

The Department of Family Welfare (FW) is responsible for aspects relating to family welfare, especially in reproductive health, maternal health, pediatrics, information, education, and communications; cooperation with NGOs and international aid groups; and rural health services. The Department of Family Welfare is responsible for 18 Population Research Centres (PRCs) at 6 universities and 6 other institutions across 17 states, National Institute of Health and Family Welfare (NIHFW), South Delhi; International Institute for Population Sciences (IIPS), Mumbai; Central Drug Research Institute (CDRI), Lucknow; and Indian Council of Medical Research (ICMR), New Delhi, founded in 1911, it is one of the oldest medical research bodies in the world.

Institutes under the control of the Department of Ayurveda, Yoga and Naturopathy, Unani, Siddha, and Homoeopathy (AYUSH) are North Eastern Institute of Folk Medicine, Pasighat; All India Institute of Ayurveda, New Delhi; Institute of Post Graduate Teaching & Research in Ayurveda, Jamnagar; National Institute of Ayurveda, Jaipur; North Eastern Institute on Ayurveda & Homeopathy, Shillong; Rashtriya Ayurveda Vidyapeeth, New Delhi; National Institute of Siddha, Chennai; National Institute of Homeopathy, Kolkata; National Institute of Unani Medicine, Bangalore; Morarji Desai National Institute of Yoga, New Delhi; and National Institute of Naturopathy, Pune.

A.2.5 Ministry of Communication and Information Technology

The Ministry of Communication and Information Technology is an Indian government ministry. It comprises three departments:

- Department of Telecommunications
- Department of Electronics and Information Technology
- Department of Posts

The above cadre controlling authority of the Civil Services (including Indian Telecommunication Service, Indian Postal Service, Telegraph Traffic Service, and Indian Posts and Telegraphs Accounts and Finance Service) are under the administration and supervision of the Ministry of Communications and Information Technology. This ministry also has attached offices, which are National Informatics Centre (NIC) and Standardisation and Testing and Quality Certification (STQC).

Several autonomous bodies are part of the Ministry of Communication and Information Technology such as Centre for Development of Advanced Computing (C-DAC), Centre for Development of Telematics (C-DOT), Centre for Liquid Crystal Research (LCR), Centre for Materials for Electronics Technology (C-MET), Education and Research Network (ERNET), Electronics and Computer Software Export Promotion Council (ESC), MIT Accreditation of Computer Courses (DOEACC), Society for Applied Microwave Electronic Engineering and Research (SAMEER), and Software Technology Parks of India (STPI).

Likewise, public sector units and joint ventures also operate successfully in this ministry. Some of them are Bharat Sanchar Nigam Limited (BSNL), Indian Telephone Industries Limited (ITI), Mahanagar Telephone Nigam Limited (MTNL), Media Lab Asia, National Informatics Centre Services Incorporated (NICSI), National Institute for Smart Government (NISG), Semiconductor Complex Limited (SCL), Telecommunications Consultants India Limited (TCIL), Controller of Certifying Authorities (CCA), Cyber Appellate Tribunal (CAT), Semiconductor Integrated Circuits Layout-Design Registry, Indian Computer Emergency Response Team (ICERT), In Registry (IR), Standardization, Testing and Quality Certification (STQC) Directorate, National Informatics Centre (NIC), Media Lab Asia, National Informatics Centre Services Inc. (NICSI) (PSE under control of NIC), National Internet Exchange of India (NIXI), Education and Research in Computer Networking (ERNET), Development of Advanced Computing (C-DAC), Centre for Materials for Electronics Technology (C-MET), DOEACC Society, Society for Applied Microwave Electronics Engineering and Research (SAMEER), Software Technology Parks of India (STPI), and Electronics and Computer Software Export Promotion Council (ESC).

A.2.6 Ministry of Science & Technology (S&T)

Department of Science and Technology (DST) plays an important role in promoting S&T in India. It was established in May 1971 with the objective of promoting new areas in the field of S&T and to play the role of a nodal department for organizing, coordinating, and promoting S&T activities in the country. The department has major responsibilities for specific projects and programs as listed below:

- Formulation of policies relating to S&T
- Matters relating to the Scientific Advisory Committee of the Cabinet (SACC)

- Promotion of new areas of S&T with special emphasis on emerging areas
- Research and development through its research institutions or laboratories for development of indigenous technologies concerning bio-fuel production, processing, standardization and applications, in coordination with the concerned ministry or department
- Research and development activities to promote utilization of by products to develop value-added chemicals
- Futurology
- Coordination and integration of areas of S&T having cross-sectoral linkages in which a number of institutions and departments have interest and capabilities
- Undertaking or financially sponsoring of scientific and technological surveys, research design and development, where necessary
- Support and Grants-in-aid to Scientific Research Institutions, Scientific Associations and Bodies
- Few national departments involved in supporting S&T
- Science and Engineering Research Council
- Technology Development Board and related Acts such as the Research and Development Cess Act, 1986 (32 of 1986) and the Technology Development Board Act, 1995 (44 of 1995)
- National Council for Science and Technology Communication
- National Science and Technology Entrepreneurship Development Board
- International Science and Technology Cooperation including appointment of scientific attaches abroad (these functions shall be exercised in close cooperation with the Ministry of External Affairs)
- Autonomous Science and Technology Institutions relating to the subject under the Department of Science and Technology including Institute of Astro-physics, and Institute of Geo-magnetism
- Professional Science Academies promoted and funded by Department of Science and Technology
- The Survey of India, and National Atlas and Thematic Mapping Organisation
- National Spatial Data Infrastructure and promotion of G.I.S
- The National Innovation Foundation, Ahmadabad
- Matters commonly affecting scientific and technological departments/organizations/institutions, for example, financial, personnel, purchase, and import policies and practices
- Management of Information Systems for Science and Technology and coordination
- Matters regarding Inter-Agency/Interdepartmental coordination for evolving S&T missions
- Matters concerning domestic technology particularly the promotion of ventures involving the commercialization of such technology other than those under the Department of Scientific and Industrial Research
- All other measures needed for the promotion of S&T and their application to the development and security of the nation
- Matters relating to institutional S&T capacity building including setting up of new institutions and institutional infrastructure

- Promotion of S&T at the state, district, and village levels for grassroots development through State Science and Technology Councils and other mechanisms
- Application of S&T for weaker sections, women, and other disadvantaged sections of society

The ministry includes various aided institutions and other organizations of DAE, such as Tata Institute of Fundamental Research, Saha Institute of Nuclear Physics, Tata Memorial Centre, Harish-Chandra Research Institute, Institute of Physics, National Institute of Science Education and Research, Institute of Mathematical Sciences, Institute of Plasma Research, Board of Research in Nuclear Sciences (BRNS), National Board for Higher Mathematics (NBHM), Atomic Energy Education Society, and Homi Bhabha National Institute.

In addition to the aided Institutions, autonomous S&T institutions of DST are also part of the ministry,. specifically, Agharkar Research Institute, Pune; Aryabhatta Research Institute of Observational Sciences, Nainital; Birbal Sahni Institute of Palaeobotany, Lucknow; Bose Institute, Kolkata; Centre for Liquid Crystal Research, Bangalore; Indian Association for the Cultivation of Science, Kolkata; Indian Institute of Astrophysics, Bangalore; Indian Institute of Geomagnetism, Mumbai; International Advanced Research Centre for Powder Metallurgy and New Materials, Hyderabad; The Institute of Advanced Study in Science & Technology, Guwahati; Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore; National Accreditation Board for Testing & Calibration Laboratories, New Delhi; Raman Research Institute, Bangalore; S.N. Bose National Centre for Basic Sciences, Kolkata; SreechitraTirunal Institute for Medical Sciences & Technology, Thiruvananthapuram; Technology Information, Forecasting & Assessment Council (TIFAC), New Delhi; VigyanPrasar, New Delhi; and Wadia Institute of Himalayan Geology, Dehradun.

There are few equally important institutes of DSIR such as

- Autonomous Bodies: CSIR (Council of Scientific and Industrial Research) and CDC (Consultancy Development Cell)
- Public Enterprises: CEL (Central Electronics Limited) and NRDC (National Research Development Corporation)
- United Nations Agency: APCTT-UNESCAP (Asian and Pacific Centre for Transfer of Technology)

Department of Biotechnology is also an important part of the ministry, which includes Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad; Institute of Bio-resources and Sustainable Development (IBSD), Imphal; Institute of Life Sciences, Bhubaneswar; National Institute of Immunology, New Delhi; National Institute for Plant Genome Research (NIPGR), JNU, New Delhi; National Brain Research Centre (NBRC), Gurgaon; National Centre for Cell Sciences, Pune; Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram; National Agri-Food Biotechnology Institution (NABI), Mohali; International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi; Institute of Stem Cell Science and Regenerative Medicine (ISCSRM), Bangalore; Translational Health

Science and Technology Institute (THSTI), Faridabad; National Institute of Biomedical Genomics (NIBMG), Kalyani; UNESCO Regional Centre for Biotechnology Training and Education (URCB), Faridabad; and Bharat Immunological & Biological Corporation, Uttar Pradesh.

A.2.7 Ministry of Defence

India's neighbors are all undergoing a transition giving rise to varied political experiences and experiments. The Government of India is responsible for ensuring the defence of the Indian Territory. The Supreme Command of the Armed Forces vests in the President, while the responsibility for national defence rests with the Cabinet. This is discharged through the Ministry of Defence, which provides the policy framework and wherewithal to the Armed Forces to discharge their responsibilities in the context of the defence of the country.

The principal task of the Defence Ministry is to frame policy directions on defence and security-related matters and communicate them for implementation to the service headquarters, Inter-Service organizations, production establishments, and R&D organizations. It is also required to ensure effective implementation of the government's policy directions and the execution of approved programs within the allocated resources. Ministry of Defence comprises four departments, viz., Department of Defence (DOD), Department of Defence Production (DDP), and Department of Ex-Servicemen Welfare & Finance Division.

Directorates of the Ministry of Defence are Directorate General of Quality Assurance (DGQA), Directorate General Resettlement (DGR), and Directorate of Standardisation. The Ministry has Controller General of Defence Accounts (CGDA), Defence Research and Development Organisation (DRDO), Indian Armed Forces and Ordinance Factories Board (OFB) as its subordinate offices. And also, it has an Autonomous Body (Institute for Defence Studies and Analyses (IDSA)), a Board (Air Force Naval Housing Board (AFNHB)), and a Secretariat (Integrated Defence Staff (IDS)). Further, public sector units and joint ventures include Bharat Dynamics Limited (BDL), Bharat Earth Movers Limited (BEML), Bharat Electronics Limited (BEL), Garden Reach Ship Builders and Engineers Limited (GRSE), Goa Shipyard Limited, Hindustan Aeronautics Limited (HAL), Mazagon Dock Limited, and Mishra Dhatu Nigam Limited (MIDHANI).

A.2.8 Ministry of Agriculture

The Ministry of Agriculture, a branch of the Government of India, is the apex body for the formulation and administration of the rules, regulations, and laws relating to agriculture in India. The three broad areas of scope for the ministry are agriculture, food processing, and cooperation.

India is largely an agrarian economy, with 52.1 % of the population estimated to be directly or indirectly employed in agriculture and allied sectors in 2009–2010. Agriculture in India is of significance because of this as well as a history of food shortages and a growing population.

A.2.8.1 Origins

Department of Revenue and Agriculture and Commerce was set up in June 1871 to deal with all the agricultural matters in India. Until this ministry was established, matters related to agriculture were within the portfolio of the Home Department.

In 1881, Department of Revenue & Agriculture was set up to deal with combined portfolios of education, health, agriculture, and revenue. However, in 1947, Department of Agriculture was redesignated as Ministry of Agriculture.

A.2.8.2 Departments

- Department of Agricultural Research and Education (DARE)—External website that opens in a new window
- Department of Agriculture and Cooperation—External website that opens in a new window
- Department of Animal Husbandry and Dairying

A.2.8.3 Indian Council of Agricultural Research

There are four Deemed Universities, viz., Indian Agricultural Research Institute, New Delhi; National Dairy Research Institute, Karnal; Indian Veterinary Research Institute, Izatnagar; and Central Institute on Fisheries Education, Mumbai.

Forty-five institutions, viz., Central Rice Research Institute, Cuttack; Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora; Indian Institute of Pulses Research, Kanpur; Central Tobacco Research Institute, Rajahmundry; Indian Institute of Sugarcane Research, Lucknow; Sugarcane Breeding Institute, Coimbatore; Central Institute of Cotton Research, Nagpur; Central Research Institute for Jute and Allied Fibres, Barrackpore; Indian Grassland and Fodder Research Institute, Jhansi; Indian Institute of Horticultural Research, Bangalore; Central Institute of Sub Tropical Horticulture, Lucknow; Central Institute of Temperate Horticulture, Srinagar; Central Institute of Arid Horticulture, Bikaner; Indian Institute of Vegetable Research, Varanasi; Central Potato Research Institute, Shimla; Central Tuber Crops Research Institute, Thiruvananthapuram; Central Plantation Crops Research Institute, Kasargod; Central Agricultural Research Institute, Port Blair; Indian Institute of Spices Research, Calicut; Central Soil and Water Conservation Research & Training Institute, Dehradun; Indian Institute of Soil Sciences, Bhopal; Central Soil Salinity Research Institute, Karnal; ICAR Research Complex for Eastern Region including Centre of Makhana, Patna;

Central Research Institute of Dryland Agriculture, Hyderabad; Central Arid Zone Research Institute, Jodhpur; ICAR Research Complex, Goa; ICAR Research Complex for NEH Region, Barapani; National Institute of Abiotic Stress Management, Malegaon; Central Institute of Agricultural Engineering, Bhopal; Central Institute on Post-harvest Engineering and Technology, Ludhiana; Indian Institute of Natural Resins and Gums, Ranchi; Central Institute of Research on Cotton Technology, Mumbai; National Institute of Research on Jute & Allied Fibre Technology, Kolkata; Indian Agricultural Statistical Research Institute, New Delhi; Central Sheep and Wool Research Institute, Avikanagar; Central Institute for Research on Goats, Makhdoom; Central Institute for Research on Buffaloes, Hissar; National Institute of Animal Nutrition and Physiology, Bangalore; Central Avian Research Institute, Izatnagar; Central Marine Fisheries Research Institute, Kochi; Central Institute Brackish Water Aquaculture, Chennai; Central Inland Fisheries Research Institute, Barrackpore; Central Institute of Fisheries Technology, Kochi; Central Institute of Freshwater Aquaculture, Bhubaneswar; and National Academy of Agricultural Research and Management, Hyderabad.

Seventeen national Research Centres, viz., National Research Centre on Plant Biotechnology, New Delhi; National Centre for Integrated Pest Management, New Delhi; National Research Centre for Litchi, Muzaffarpur; National Research Centre for Citrus, Nagpur; National Research Centre for Grapes, Pune; National Research Centre for Banana, Trichi; National Research Centre Seed Spices, Ajmer; National Research Centre for Pomegranate, Sholapur; National Research Centre on Orchids, Pakyong; National Research Centre Agroforestry, Jhansi; National Research Centre on Camel, Bikaner; National Research Centre on Equines, Hissar; National Research Centre on Meat, Hyderabad; National Research Centre on Pig, Guwahati; National Research Centre on Yak, West Kemang; National Research Centre on Mithun, Medziphema; and National Centre for Agriculture Economics and Policy Research, New Delhi.

Six National Bureaus, viz., National Bureau of Plant Genetics Resources, New Delhi; National Bureau of Agriculturally Important Microorganisms, Maunath Bhanjan; National Bureau of Agriculturally Important Insects, Bangalore; National Bureau of Soil Survey and Land Use Planning, Nagpur; National Bureau of Animal Genetic Resources, Karnal; and National Bureau of Fish Genetic Resources, Lucknow.

Twenty-five Directorates/Project Directorates, viz., Directorate of Maize Research, New Delhi; Directorate of Rice Research, Hyderabad; Directorate of Wheat Research, Karnal; Directorate of Oilseed Research, Hyderabad; Directorate of Seed Research, Maunath Bhanjan; Directorate of Sorghum Research, Hyderabad; Directorate of Groundnut Research, Junagarh; Directorate of Soybean Research, Indore; Directorate of Rapeseed & Mustard Research, Bharatpur; Directorate of Mushroom Research, Solan; Directorate on Onion and Garlic Research, Pune; Directorate of Cashew Research, Puttur; Directorate of Oil Palm Research, Pedavegi, West Godavari; Directorate of Medicinal and Aromatic Plants Research, Anand; Directorate of Floriculture Research, Pusa; Project Directorate for Farming Systems Research, Modipuram; Directorate of Water Management Research, Bhubaneswar; Directorate of Weed Science Research, Jabalpur; Project Directorate on Cattle, Meerut; Project Directorate on Foot & Mouth Disease, Mukteshwar; Project Directorate on Poultry, Hyderabad; Project Directorate on Animal Disease Monitoring and Surveillance, Bangalore; Directorate of Knowledge Management in

Agriculture (DKMA), New Delhi; Directorate of Cold Water Fisheries Research, Bhimtal; and Directorate of Research on Women in Agriculture, Bhubaneswar.

Colleges under Department of Agriculture Research and Education (DARE) are College of Agriculture, Iroisemba, Imphal, Manipur; College of Veterinary Sciences and Animal Husbandry, Selesih, Aizawl, Mizoram; College of Fisheries, Lembucherra, Agartala, Tripura; College of Horticulture and Forestry, Pasighat, Arunachal Pradesh; College of Home Science, Tura, Meghalaya; College of Agricultural Engineering & Post-Harvest Technology, Sikkim; and College of Post-Graduate Studies, Barapani, Meghalaya (Figs. A.9, A.10, and A.11).

Institutes under Ministry of Food Processing Industries are National Institute of Food Technology Entrepreneurship and Management, Indian Institute of Crop Processing Technology (IICPT), National Meat and Poultry Processing Board (NMPPB), and Indian Grape Processing Board (IGPB).

A.2.8.4 Ministry of Petroleum

Public Sector Undertakings include Balmer Lawrie and Co. Ltd., Bharat Petroleum Corporation Ltd., BieccoLawrie Co. Ltd., Bongaigaon Refinery and Petro-Chemicals Ltd., Chennai Petroleum Corporation Limited, Cochin Refineries Ltd., Engineers India Ltd., Gas Authority of India Ltd., Hindustan Petroleum Corporation Ltd., IBP Co. Ltd., Indian Oil Corporation Ltd., Numaligarh Refinery Ltd., Oil India Ltd., Oil

Expenditure on R&D by Different Departments

Ministries /Departments	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
DARE				2826.46	3143.44	3592.5
DAE	872.74	1003	1215	3083.13	4025.37	4189.93
MoES	340	438	690	321.39	616.46	739
DST	1250	1367	1526	1805.2	2003.61	2329.33
DSIR	846	975	1070	2387.2	2685.44	2975
DOS	2800	3220	3420	3255.48	2685.44	5062.22
DBT	445	521	675	-	-	-

www.indiastat.com

Fig. A.9 Expenditure on R&D by different departments (*Source*: Twelfth Five Year Plan, Ministry of Science & Technology 2011)

S&T Related Ministry/Departments in India

S No	Department / Ministry / Organization	No of Institutions	Annexure No
1	Council of Scientific and Industrial Research (CSIR)	39	2.0
2	Defence Research and Development Organization (DRDO)	48	2.1
3	Indian Council of Medical Research (ICMR)	30	2.2
4	Indian Space Research Organization (ISRO)	18	2.3
5	Department of Atomic Energy (DAE)	12	2.4
6	Department of Science and Technology (DST)	18	2.5
7	Department of Scientific and Industrial Research (DSIR)	5	2.6
8	Department of Biotechnology (DBT)	16	2.7
9	Ministry of Environment and Forests (MoEF)	13	2.8
10	Ministry of Food Processing Industries (MoFPI)	4	2.9
11	Department of AYUSH	11	2.10
12	Ministry of Communications and Information Technology (MoCIT)	17	2.11
13	Ministry of Petroleum (MoP)	23	2.12
14	Ministry of New and Renewable Energy (MNRE)	5	2.13
15	Ministry of Power (MoP)	14	2.14
16	Department of Coal (DOC)	6	2.15
17	Ministry of Water Resources (MoWR)	16	2.16
18	Ministry of Earth Sciences (MoES)	8	2.17
19	Indian Council of Agriculture Research (ICAR)	97	2.18
20	Department of Agriculture Research & Education (DARE)	7	2.19
22	Ministry of Human Resource Development (MHRD)		

Fig. A.10 S&T related Ministry/Departments in India (*Source*: Twelfth Five Year Plan, Ministry of Science & Technology 2011)

& Natural Gas Corporation Ltd., Mangalore Refinery and Petrochemicals Ltd., Centre For High Technology, Directorate General of Hydrocarbons, Oil Industry Development Board, Oil Industry Safety Directorate, O.N.G.C. Videsh Ltd., Petroleum Conservation Research Association, Petroleum Planning And Analysis Cell; and Petroleum Federation of India (Petro Fed).

Ministry of New and Renewable Energy includes Indian Renewable Development Agency, Alternate Hydro Energy Centre, National Institute of Renewable Energy, Centre for Wind Energy Technology, and Solar Energy Centre.

Ministry of Power includes Central Electricity Authority, National Thermal Power Corporation (NTPC), National Hydroelectric Power Corporation (NHPC),

Resource Mapping of Institutions in S&T	No's
Central Universities	40
Universities	520
IGNOU	1
IITs	15
IISERs	5
IIMs	13
National Institute of Technology (NITs)	40
IIITs (Indian Institute of Information technology)	4
National Institute of Technical Teachers Training & Research	4
Regional Board of Apprenticeship / Practical Training	4
Other Organizations	**No's**
PSU (EdCIL)	1
Technical Education (AICTE)	1
NAAC	1
National University of Education Planning & Research (NUEPA)	1
National Book Trust	1
Indian Institute of Advanced Studies	1
Engineering Colleges	2466
Medical Colleges	2230
Educational Training Institutes (B.Ed)	3284
Polytechnics	1742
Others (ITIs , Vocational Colleges etc)	25990

***Source:** Higher Technical Education Report in India by Prof. Chopra and Prof. Sharma (2007) & Ministry of HRD and DST*

Fig. A.11 Resource mapping of institutions in S&T (*Source*: Twelfth 5-Year Plan, Ministry of Science & Technology 2011)

Rural Electrification Corporation (REC), North Eastern Electric Power Corporation (NEEPCO), Power Finance Corporation (PFC), Power Grid Corporation of India (POWER GRID), THDC India Limited, Sutlej JalVidyut Nigam Ltd. (SJVN), Central Power Research Institute (CPRI), National Power Training Institute (NPTI), Damodar Valley Corporation (DVC), Bureau of Energy Efficiency (BEE), and Bhakra Beas Management Board (BBMB).

Department of Coal includes Coal India Limited (CIL), Neyveli Lignite Corporation (NLC), Singareni Collieries Company Limited (SCCL), Coal Mines Provident Fund Organization (CMFPO), Coal Controller and Commissioner of Payments.

Ministry of Water Resources includes Upper Yamuna River Board, Central Water Commission, New Delhi; Central Ground Water Board, Faridabad; Central Water and Power Research Station, Pune; Central Soil and Materials Research Station, New Delhi; National Water Development Agency, National Institute of Hydrology, Roorkee; WAPCOS Limited, National Projects Construction Corporation Ltd, New Delhi; Narmada Control Authority, Indore; Sardar Sarovar Construction Advisory Committee (SSCAC), Farakka Barrage Project, Farakka; Bansagar Control Board, Betwa River Board; Brahmaputra Board; and Tungabhadra Board.

Ministry of Earth Sciences includes Indian National Centre for Ocean Information Services, Hyderabad; National Institute of Ocean Technology, Chennai; National Centre of Antarctic and Ocean Research, Goa; Indian Institute of Tropical Meteorology, Pune; Integrated Coastal and Marine Area Management, Chennai; Centre for Marine Living Resources and Ecology, Kochi; Earthquake Risk Evaluation Centre, New Delhi; and National Centre for Medium Range Weather Forecasting, Noida.

Apart from this, the country today has extensive R&D in private and public sector organizations. Some of India's most valuable public sector companies are Oil & Natural Gas Corporation, NTPC, NMDC, MMTC, State Bank of India, Bharat Heavy Electricals, Steel Authority of India, Indian Oil Corporation, Power Grid Corporation of India, GAIL (India) National Aluminum Co., Neyveli Lignite Corporation, Hindustan Copper, Punjab National Bank, Power Finance Corporation, Bank of India, Infrastructure Development Finance Co., Bharat Petroleum Corporation, Mangalore Refinery & Petrochemicals, Container Corporation of India, and more.

Corporate laboratories in India have made their presence felt through focused work on innovation and acquiring patents. They have also fostered a culture of collaboration, working with bright minds from the academia. This is the right step for a country, and India is already reaping the benefits of its Corporate Research Laboratories.

Some of the Corporate Research Laboratories including the multinational companies are that there are more than 400 laboratories at present apart from small and large R&D laboratories recognized by the department of scientific and research of the Government of India. Some of the laboratories are ABB Corporate Research Centre, India, Bell Labs Research, Biocon, Dr. Reddy's, GE Research India, GM India Science Laboratory, HP Labs, IBM Research, Microsoft Research, Motorola Labs India, Philips Innovation Campus, Ranbaxy Laboratories Limited, Yahoo Research, India, Nokia Research Center, and India and Texas Instruments R&D, India. These are just illustrative.

A.2.9 Manpower Employed in Research & Development

The following table provides full-time equivalent manpower employed in R&D establishments as on 01-04-05, and this data represents the industrial sector having 1,510 in-house R&D units including 1,108 Private Sector industries, 112 Public Sector industries, and 290 SIRO units. India represents strong technical manpower in different sectors of economy. India has been successful in creating competent manpower in various sectors. Good management systems and practices will enable innovation capabilities and build strong economy through their contributions (Table A.3).

Table A.3 Manpower employed in Research & Developments (*Source*: Statistical Tables 2007–2008)

Name of establishment	Personnel engaged in			
	R&D activities (1)	Auxiliary activities (2)	Administration activities (3)	Total (1+2+3)
Institutional sector				
Major scientific agencies	47,587	51,285	52,786	**151,658**
Central government ministries/ Departments	8,645	16,410	19,665	**44,720**
State governments	19,135	20,146	46,141	**85,422**
Total Institutional Sector (A)	**75,367**	**87,841**	**118,592**	**281,800**
1. Higher Education Sector	22,100			**22,100**
Industrial Sector				
Public Sector including Joint Sector	9,281	3,787	1,576	**14,644**
Private Sector	42,096	8,976	4,918	**55,990**
SIRO	5,983	5,204	5,428	**16,615**
Private + SIRO	48,079	14,180	10,346	**72,605**
Total Industrial Sector (B)	**57,360**	**17,967**	**11,922**	**87,249**
TOTAL (A + B)	**154,827**[a]	**105,808**	**130,514**	**391,149**

Source: Data collected and compiled by DST

Notes

Data for industrial sector refer to 1,510 in-house R&D units including 1,108 Private Sector industries, 112 Public Sector industries and 290 SIRO units

[a]Data include estimated 22,100 researchers employed in Higher Education Sector

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K.B. Akhilesh, *R&D Management*, DOI 10.1007/978-81-322-1946-0