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International Journal of Project Management xxx (2004) xxx–xxx
INTERNATIONAL JOURNAL OF PROJECT MANAGEMENT
www.elsevier.com/locate/ijproman

Towards the sixth generation of R&D management

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Received 1 July 2003; received in revised form 16 September 2003; accepted 27 October 2003

Abstract

Many companies perceive research and development (R&D) as somewhat fuzzy, involving high uncertainty, with unclear rate of return, and troublesome to manage. On the other hand, companies that succeed at commercializing new technology in a rapid and precise manner achieve possibilities of attaining a greater market share, premium prices and dominant designs, leading to a much sharper competitive edge.

The perspective on managing R&D processes has changed over the years, moving from a technology-centered model to a more interaction-focused view. This paper deals with management of research and development (R&D), with focus on synthesizing five generations of R&D processes and *combining* those with related management responses as well as with examples of managerial approaches – all within a described company context. The choice of combining these three categories represents a dynamic and nuanced picture improving the understanding of R&D management contingencies.

A sixth generation of R&D has also been elaborated, one generation re-focusing the research part connecting to loosely tied multi-technology research networks. The bases for this new set of approaches are a broader multi-technology base for high-tech products and a more distributed technology-sourcing structure. The 'Bluetooth' case study, originating within Ericsson, has been used to exemplify the roots and ideas of the sixth generation of R&D. The Bluetooth case represents a joint cross-industrial, open intellectual property-based, effort in developing and bringing a new technology to the market by utilizing the resources from more than one thousand companies.

Properly managing R&D processes has long been a matter of debate and considered a troublesome area with no simple answers; ranging from an Achilles' heel in some firms to the sole basis of competition for others, many of the differences have contributed to R&D management issues [Product Development Performance, Harvard Business School Press, 1991, p. 1; Developing Products in Half the Time, Van Nostrand Reinhold, New York, 1991, p. 170]. By properly managing R&D processes, companies can reach an increase in lead-time precision, increased quality of final products, and reduced development cost. Overall, companies' competitive advantage can be strengthened as placed efforts are managed in a leaner manner and more aligned with overall business strategy.

1. Five generations of R&D management

R&D has been studied for a long time within different contexts, economies, and environmental demands throughout the years. The transition from early days' booming markets and economic growth in the 1950s to today's highly competitive and global marketplace is reflected in the way R&D has been managed. Early success stories such as the industrial research laboratories Bell Labs, Xerox Parc and Lockheed Martin Skunkworks have been replaced by companies like the more market-focused 3M, the rapid introductions of new product ranges from Japanese manufacturers like Toyota and Sony, and R&D collaborations like Ericsson's network of companies around the "Bluetooth" technology and standard.

The perspective on R&D processes has been different throughout the years, since the structure and prerequisites of the economy have changed and so has the presumption of best practice. One attempt at describing the last 50 years of evolution within the R&D field is shown in Exhibit 1. Worth noticing is that these five models of R&D generations, though presented on a time scale, hold components or ideas still valid and sought for by many companies, and hence do not represent a map of where companies today are to be placed. Throughout these periods, different industries or companies have

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doi:10.1016/j.ijproman.2003.10.002

R&D Generations	Context	Process Characteristics
First generation	Black hole demand (1950 to mid- 1960s)	R&D as ivory tower, technology-push oriented, seen as an overhead cost, having little or no interaction with the rest of the company or overall strategy. Focus on scientific breakthroughs.
Second generation	Market shares battle (mid-1960s to early 1970s)	R&D as business, market-pull oriented, and strategy-driven from the business side, all under the umbrella of project management and the internal customer concept.
Third generation	Rationalization efforts (mid-1970s to mid-1980s)	R&D as portfolio, moving away from individual projects view, and with linkages to both business and corporate strategies. Risk-reward and similar methods guide the overall investments.
Fourth generation	Time-based struggle (early 1980s to mid-1990s)	R&D as integrative activity, learning from and with customers, moving away from a product focus to a total concept focus, where activities are conducted in parallel by cross-functional teams.
Fifth generation	Systems integration (mid-1990s onward)	R&D as network, focusing on collaboration within a wider system – involving competitors, suppliers, distributors, etc. The ability to control product development speed is imperative, separating R from D.

Exhibit 1: Description of five generations of R&D processes (developed and adapted from Roussel, 1991, p. 39; Rothwell, 1994; Miller and Morris, 1998, p. 19; and Chiesa, 2001, p. 12).

functioned as role models or drivers of best practice, a phenomenon that can also be recognized from research results.

During the first generation of R&D (1950 to mid-1960s), most of the new products that were produced were also sold, new industries emerged, and technology was generally seen as the remedy for all ailments [17,20]. This first generation of R&D worked under the assumption that the more R&D went in, the more products came out. In short, R&D was seen as an overhead cost [22, p. 26]. With regard to the R&D process, it was viewed as linear and as focused on pushing technology downstream towards the marketplace (e.g. [18]) – a marketplace characterized by a demand matching or sometimes exceeding the supply.

During the second generation of R&D (mid-1960s to early 1970s), the supply and demand were in a more stable relationship, competition was intensified, and more emphasis was placed on marketing efforts to increase the sales volume [20]. Within this environment, more focus was placed on the short-term demand side, neglecting long-term research in favor of ideas from the market. Process-wise, the market-pull effect was strengthened and the process was seen somewhat oppositely as compared to the first generation of R&D – i.e. ideas originated from the market, to be refined and developed by R&D (e.g. [26]). Project management was also introduced to direct and monitor the R&D efforts, and the business side as the internal customer of R&D was highlighted [16, p. 13].

Further, the third generation of R&D can be discerned during the period of the mid-1970s to mid-1980s, when the economy was shivering with high rates of inflation and demand saturation [20]. Cost control and cost reduction became the name of the game [16, p. 15], leading R&D to eliminate wasteful efforts by reviewing and improving the way new technology was developed and monitored within the company (e.g. [1,12,19]). This strong process-focus resulted in a more linked and interaction-focused view of R&D (instead of the two extremes as before), tying the technological capabilities more closely together with the market needs. The port-

folio view of R&D also resulted in numerous ways of balancing the risk-reward continuum of probability of technical and market success [6,21].

The next identified period ranged from the early 1980s to mid-1990s, when the economy recovered and business people rethought their diversification strategies in favor of returning to their core business, all under a time-based competition paradigm driven by Japan and companies like Toyota, Sony, and Honda [20]. Overall, the automotive industry was heavily benchmarked and functioned as a role model for many [2,5,27]. The focus shifted from developing products to putting the product in a total business concept, including also for example services, distribution, and multi-product platforms [16, p. 274]. With regard to the R&D process, the new product development process was highlighted, and the integration and parallelization of activities were brought forward as success factors when striving for speed [7,10,11,24].

Finally, the predicted fifth [1] generation of R&D broadens the boundaries for companies' R&D activities, all in the light of increased global competition, rapid technological change, and the need for sharing heavy technology investments [20]. Hence, R&D needs to interact with the business environment, e.g. competitors, distributors, customers, suppliers, etc., placing more emphasis on the ability to coordinate and integrate systems from different parties (e.g. [14]). Examples of this type of rapid system integration are companies from the computer hardware and software industry, e.g. Microsoft Corporation, Netscape Corporation, and Dell Corporation [15,25]. Further, the ability not only to be speedy in product development, but also to control the speed and thus be timely, is in even stronger focus. In line with this logic, reducing the uncertainty due to development by separating the more research-oriented tasks is one common approach, strengthening the need for efficient and effective integration of a coherent whole.

To summarize, the fivefold classification indicates that the perspective on R&D processes is changing, adapting to the surrounding context and prerequisites, and that R&D processes can be a source of vital competitive advantage when facing those changes. The challenge for companies to stay profitable is tougher than ever. Hence, being a fast and timely innovator by bringing new technology successfully to the market is seen as an increasingly important factor determining a company's competitiveness in markets where product life cycles are short and the rate of technological change is high [14].

[1] Equivalent to the description by Miller and Morris [16] of their fourth-generation R&D model with innovation as the company's responsibility and not constrained by the traditional company boundary.

1.1. Managerial approaches

The management of R&D has changed throughout the years, moving from an isolated view to a more connected and complex situation to handle. The previous section classified and described overall perspectives on R&D processes, using a time scale. This section describes in more detail, and in a more dynamic and coupled manner, the managerial approaches and company responses related to those R&D environments.

Managing R&D processes involves several challenges for firms – e.g. strategic, operational, and methodological. Traditionally, the amount that companies spend on R&D has been used by business analysts as an indicator of competitiveness, i.e. similar to the first-generation R&D discussed in the previous section [3]. However, Badawy [3] states that many companies have had great success in developing new technology, though not in managing it to result in commercially successful products. Iansiti [13] argues further that the R&D spending is less important than "*a company's process for rapidly and efficiently translating its R&D efforts into products that excel in satisfying the market's needs* [which] *is much more important*". Nevertheless, even though the challenges in managing R&D and R&D processes have changed throughout the years, some issues have stood their ground, and others have arisen. This view is more cumulative and evolution-oriented in contrast to the static description of the five generations of R&D presented in Exhibit 1. This dynamic view is presented in Exhibit 2, where not only the five generations are noted, but also the related company responses and examples of associated managerial approaches.

Exhibit 2 moves away from describing the characteristics of each generation, to discussing the company responses and related managerial approaches, all in a potentially cumulative manner. Today, industries and firms struggle with a mixture of the noted responses and approaches, all depending on, for example, history, context, and market.

The company reaction related to the first generation of R&D was to create corporate research labs, labs where technology could flourish and where main managerial challenges were to decide the geographical location of the labs and to stimulate scientific advances [18]. The characteristics of the second generation of R&D were typically handled by incorporating R&D into the business unit. Ideas were gathered from the market, and internal customers of each R&D task were appointed at the firm, all in order to secure closeness to the market. Further, the characteristics of the third generation of R&D were met with a stronger focus on the R&D projects, introducing portfolio and project management techniques and structured design methods to improve the efficiency. Long-term strategies were evaluated and analyses were made of the consequences of the choices; further, the

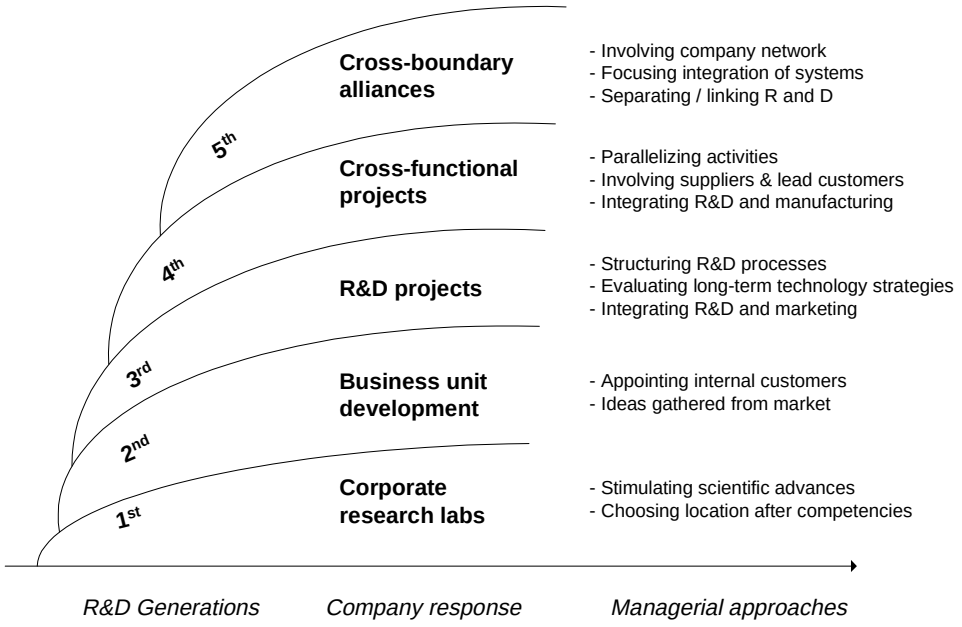

Exhibit 2: Visualization of five generations of R&D management from the early 1950s until today, related company responses, and examples of associated managerial approaches.

integration of the R&D function with the market was in focus. The fourth generation of R&D introduced the concept of lead customers, parallelized activities, and involved suppliers in the development efforts in an attempt to bring in other perspectives for increased cross-functionality. Finally, the fifth generation of R&D is met by firms taking on a cross-boundary alliance strategy, involving the company network in both research and development, and linking research to development to enhance the overall precision.

The integration dilemma is clearly evident as a contemporary management issue, involving integration of systems and processes to deliver a coherent and effective whole. A noted trend of separation between research and development (cf. [4, p. 173,8]) to reduce uncertainty and gain speed has placed even tougher demands on managing and integrating R&D processes, a challenge which is the main focus of this thesis. Eldred and Mcgrath [11] note, for example, that the key to more effective R&D is improving its underlying management process – a challenge that is even more intense when separating, or otherwise balancing, research and development efforts. There has, however, been limited research on the interaction between research and development, especially under the prerequisites of today.

The integration of technology development and product development may have been present throughout the first five generations of R&D, but its importance and actuality has been amplified during the latter generations, due to the increased time pressure, the need of higher precision, and the tougher system-integration tasks facing companies in today's context. Hence, having a well-functioning interaction between technology development and product development can increase lead-time precision, increase the quality of products launched at the marketplace, reduce development cost, and become a foundation for competitive advantage as placed efforts are more aligned with overall business strategy.

2. Methodological note

This paper is mostly elaborative in nature and is based on literature studies and own experiences within the field as well as on a case study used for illustrating purposes.

Complementing a literature review with a case study pointing at the Sixth generation R&D practices may give a richer picture. This is in line with Dyer and Wilkins [9] reasoning that using case studies aim at developing exemplars, i.e. stories against which other researchers (or, one might add, managers) can compare their experiences and gain theoretical insights. The case study provided represents an extract of a study at Ericsson Mobile Communication where a total of 31 persons involved in technology and product development were interviewed. Further, during the study, it was found that Intel Corporation had been playing a vital role in the execution, hence, key employees at Intel's headquarters in Santa Clara was also interviewed. These interviews were then combined with attendance at Bluetooth training seminars, organizational announcements, and company internal presentations in order to nuance the picture.

The literature study is based on key word and citation searches in major databases (such as Compendex) where keywords included were, for example, research and development, management, technology development, product development, collaboration, generation, radical innovation, incremental, approaches, etc. The time frames set for this study goes back to the early 1950s up til 2003, and the review has mostly covered European, Japan, and US work within the area. The work has further been focused around R&D within manufacturing companies, though the author belive the general trends and managerial approaches may be found usefule outside the manufacturing areas [2] as well.

3. Elaboration of managerial approaches

This section elaborates upon a sixth generation of R&D and visualizes the related R&D system with two case studies. The section starts with describing one illustrative case study (the Bluetooth [3] development) and ends by picturing a new set of R&D working practices.

3.1. Bluetooth special interest group

The successful and rapid evolution of the revolutionary 'Bluetooth' technology has not gone unnoticed. As of 2003, over 1600 companies have joined what is now, one of the fastest growing industrial organizations ever to promote a new technology. The core of this special interest group (Bluetooth SIG [4]) unite several of the leading firms in the computer, network, and communications industry, with Ericsson Mobile Communications serving as the initial catalyst. The developed Bluetooth specification has been accepted as the (de facto) standard for wireless personal area networks.

This specification [5] is developed, published and promoted by the trade association Bluetooth SIG. What is worth noticing is that the SIG is driving the development of the technology and is actively bringing it to the market. The Bluetooth SIG consists of more than one thousands of companies that has freely joined. The Bluetooth SIG is primarily a volunteer organization run by employees from the member companies. The Bluetooth SIG work with several areas, e.g. engineering, qualification and marketing.

Any company sympatizing with the Bluetooth SIG agreement is allowed to join. The agreement involves, among else, freeing the companies own potential patents that may hinder the development of the Bluetooth technology. The benefits of the Bluetooth SIG then includes a royalty-free license to build products based on the same technology as well as access to the Bluetooth specification. Additionally, joining the Bluetooth SIG provides the ability to influence the development of the specification and offers potential partners for co-development opportunities. The creation of the SIG also enabled some inter-industry transfer of good practices, facilitating research speed to market.

The choice of opening up the intellectual property (IP) was early on identified by Ericsson and Intel Corporation as a basis for reaching a global presence. As Simon Ellis at the strategic marketing department at Intel Corporation stated "...open IP is a way of reducing the politics from the collaboration equation". The open IP and the dispersed network idea caused a large debate internally at Ericsson for example, some stating that Ericsson is giving the control and also important patents away. Others argued for the value of opening up the IP in the SIG network, such as an increased value of other related patents, increased value of the mobile phones, increased value of the Bluetooth network to come, and also, a speedy and powerful joint effort in bringing the de factor standard in place.

It is now foreseen that the future growth of the Bluetooth technology will be driven mainly by developers who will find an ever-growing number of applications for Bluetooth beyond mobile phones and PCs, with automotive and industrial applications the most obvious areas. For the companies involved in developing standards and applications for the technology, success will mean finding the right market segments and business strategies to appeal to the broadest number of users and hardware makers seeking to add the technology to devices.

3.2. Towards sixth-generation R&D management

Throughout the five identified R&D generations, the complexity of R&D has continually expanded. Drivers of complexity have been, for example, the need to take *more aspects* into account (e.g. interoperability, industrial design, environmental, manufacturability, and after-market considerations), the demand to cooperate and interact with *more actors* outside the traditional R&D departments (e.g. with marketing and manufacturing functions, with suppliers, competitors, and distributors), and the necessity of efficient and effective commercialization of new technologies (e.g. timely, ef-

[2] Though there may be so, for example, that sectors under heavy dependance of governmental financial support may discover another pattern than discussed in this paper.

[3] 'Bluetooth' is originally, and most simply put, a name for a radio-based cable replacement developed by a large network of (mainly) telecom and computer companies such as Ericsson and Intel Corporation. Bluetooth first hit the market in meaningful volumes in 2001, when 10 million units were shipped, and by the end of 2002 that number had tripled to almost 35 million devices.

[4] The main Bluetooth SIG members include 3Com, Agere, Ericsson, IBM, Intel, Microsoft, Motorola, Nokia and Toshiba.

[5] The royalty-free initial Bluetooth standard 1.0 was released on the 26th of July 1999.

ficient deliveries of new products with predicted quality). The need for taking more aspects into account is driven by product and technology complexity; the demand to cooperate with more actors is driven by larger technological investments and rational specialization; and the necessity of efficient and effective commercialization of new technology is driven by rate-of-return demands and the cost of being late. Hence, facing this rising complexity challenge, management of R&D is predicted to take on a set of new working methods resulting in a new identifiable generation. The route forward involves issues of a more-of-the-same character; i.e. it is likely that there will be a continuous expansion of the complexity of R&D driving an increased number of aspects to integrate and actors to involve.

However, apart from this evolution, a more radical shift is predicted to characterize the sixth generation of R&D management. This shift towards sixth generation of R&D management is predicted to return to the roots, i.e. back to the purpose of the first generations corporate research labs, one pursuing more radical innovations. One could see this as a re-focus towards the research part of research and development. The corporate research labs as such are not predicted to resurface, instead the re-focus is taking on other approaches. The before mentioned Bluetooth scenario represents one example of a new approach. The bases for the shift or new set of approaches are a broader multi-technology base for high-tech products and a more distributed technology-sourcing structure. There will be a palette of technology-sourcing strategies available, e.g. corporate research labs, internal corporate venturing, technology company acquisitions, intellectual property acquisitions, corporate venture capital, joint ventures, independent research groups or networks, and internally driven R&D (cf. [23]). The strategic choices are related, for example, to the R&D intensity of the firm, the industry context, and the business strategies.

The multi-technology aspects refer to products consisting of a broader technology basis, e.g. from basic mechanical products to infotainment products building also on biotech, telematics, and software functioning in a broader system delivering also related services. In the Bluetooth case studies, the telecom, network, and computer industry (followed later by the automotive, kitchen appliances, etc.) needed to combine their forces and deliver a set of services of value for the customer no matter what device that were to be in use. Traditional networks of companies (automotive, telecom, etc.) are thereby not sufficient to deliver these new kinds of products, instead new alliances and cooperation need to be established cross borders and based on functions instead of technology – increasing the demands on companies' combinatory capabilities. Much of the breakthrough research will not be a result of one company's lab efforts, instead breakthroughs will be based on joint efforts from loosely tied networks of smaller players driven more of pure interest than profits. The Bluetooth SIG was not set up as a business unit within one company, instead it was created as to function as an arena for collaboration and sharing of ideas among more than thousands of companies. In a way, other early examples strengthening this view is evident from the independent programmers contributing to the Linux [6] operating system, powerful enough to challenge the prime example of a de facto standard – Microsoft's Windows system.

The need for companies to keep up with, tap into, and stay connected with the research efforts around the world is even more accentuated. This means that the research part of R&D in the long run weakens its solid ties to one company, merely being part of a larger ecosystem. The Bluetooth case study reveals one approach towards establishment of such a network based ecosystem, a system where under certain openness ideas, joint research efforts could thrive. Experts from leading firms and industries gathered and co-developed the specification and the marketing of the coming products and product areas. Further, there has also been several other attempts targeted at development alliances, now the turn has come to niche-based alliances also within the research efforts, involving actors as disperse as the Universities, independent freelancers, temporary interest groups, and competitors. The Bluetooth SIG proves one example of an application of this approach of cross-industry commitment and research collaboration. The knowledge about ongoing research efforts and their potential implications and results may also lead to daring to have greater flexibility in the development cycle, thereby increasing their precision.

This shift towards the sixth generation of R&D is conducted with the aim of increasing the likelihood of recognizing, joining, and developing breakthroughs affecting whole industry segments. It is also a stylized fact that when predicting the future, the business impact of technological changes is overestimated in the short run, while underestimated in the longer run as wildcards [7] occur more frequently with a larger impact than would be expected. Hence, there is a larger risk/reward ratio than evident in the earlier generations of R&D that now need to be taken into account. Within this new kind of R&D system, new opportunities or companies will be formed, functioning as intermediaries for the research efforts towards the potential users or developers. Those

[6] Linux operating software is a product generated from a distributed group of individuals, dispersed across space, time, and organizational boundaries that shares the source code freely.

[7] A wildcard represents an event with low probability of occurrence which, if it occurs, has a dramatic impact. Wildcards and their impact have been studied by, for example, the Institute for the Future in San Francisco.

distributed intermediaries might function as marketing channels for the research efforts, as segment information providers, and as seekers of new application areas. Managing this multi-technology, multi-project network will be a daunting task.

In sum, the sixth generation of R&D management is expected to re-focus the research part, and to enlarge and enhance the capabilities by connecting to loosely tied multi-technology research networks. The pursuit of breakthroughs will take on other organizational approaches and open up for new players in the arena. In short, "*chance favors only the prepared mind*". [8]

3.3. Remark on R&D generations

The notion of R&D generations is a difficult term, especially since most companies constitute a mixture of the generations and since the relevant time period for them most likely differs depending on industry segment, demographics, company age, research intensity, legislation demands, etc. Hence, the question could be asked: what constitutes a generation, and why is the term generation useful to depict? My experiences are that the concept behind generations is easy to grasp and communicate, points to different types of approaches with related pros and cons, and describes in some senses an evolution within the area – all with the aim of assisting companies to improve their R&D capabilities, and to develop a common language for researchers and companies to work with. It is important to realize that the notion of R&D generations is one way of communicating different management approaches under certain conditions and contexts.

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