An investigation into the current practice of project portfolio selection in research and development division of the South African minerals and energy industry

by K.-H. Rutsch*, P.J. Viljoen*, and H. Steyn*

Synopsis

Project selection and the development of a portfolio of projects in line with corporate strategy is an important task of managers of research units. The projects selected have to meet the appropriate time frame for completion and delivery, a suitable risk profile and other distinct factors in order to pursue corporate objectives successfully. The authors believe that R&D project portfolio selection approaches required or applied in the process industry differ from the approaches used for selecting new product development projects, on which most literature is focused.

A case study approach was used to investigate the current practice of project portfolio selection in South African R&D divisions within the minerals and energy industry.

It was found that all companies interviewed during this study employ a semi-formal approach to select their R&D project portfolio. A formal process is followed for decision making, but no formal tools are applied to select the R&D portfolios, such as suggested by literature.

Background

The need for systematic project portfolio selection

Companies usually have the opportunity to choose from a number of different project proposals. Since financial and personnel resources are often limited, management has to decide which projects to pursue and which ones to terminate. Companies seek to maintain their position in their markets and even to gain a competitive advantage through R&D. According to Twiss[1], project selection and project termination are the two most critical and difficult decision areas in R&D management. The main difference between project selection and deciding whether to continue or terminate a project lies in the quality of information available. For R&D project selection, the information will consist mainly of relatively inaccurate estimations of something that needs to be researched. This is consistent with the notion that R&D is considered to be an investment to reduce uncertainty[1]. On the other hand, when a project is already underway and the decision to continue or to terminate the project needs to be made, some information on the technical feasibility and commercial acceptance is normally available.

In many companies research project portfolios are not focused. This could result in the execution of some projects that do not necessarily further company goals and strategy. Other projects, which might add more value are, therefore, either not pursued or not enough resources are made available for these projects. This could lead to a poorly balanced project portfolio that is not well aligned to business strategy.

For a company to operate successfully in a market, it needs to offer the right products at the right time for the appropriate price and with the expected quality. To be able to fulfil these criteria, technology-based companies need to have their R&D project portfolios aligned to these criteria as well as to their company strategy. Although projects also need to be executed efficiently, it seems obvious that everything really begins by choosing the right projects first time in order to save valuable time and resources.

The South African minerals and energy industry

The process industry could be viewed as a subset of the manufacturing industry and includes a variety of industrial sectors such as the mining and mineral industry, food and beverage industry, pulp and paper industry, as well as the oil industry. According to Lager[2], the process industry could be defined as:

'A...production industry using (raw) materials to manufacture non-assembled products in a production process where the (raw) materials are processed in a production plant where different unit operations ... take place ... and the different processes are connected in a continuous flow.'

* *Department of Engineering and Technology Management, University of Pretoria.*

© *The Southern African Institute of Mining and Metallurgy, 2006.* *SA ISSN 0038–223X/3.00 + 0.00. Paper received, Mar. 2006; revised paper received Aug. 2006.*

The minerals industry, largely supported by gold, diamond, coal and platinum production, is an important element of the economy of South Africa. The largest reserves of platinum group metals, manganese, chromium, vanadium, gold and aluminium in the world occur in South Africa[3].

For more than a century the minerals industry played an important role in the South African economy. This industry was a major driver for the development of an extensive and capable physical infrastructure within South Africa and has contributed to a great extent towards the establishment of secondary industries in the country. The South African minerals industry is recognized worldwide as a leading and reliable supplier of a large variety of minerals and mineral products of consistently high quality[3].

The export-orientated South African minerals industry is a deep-rooted and resourceful segment of the national economy and has a high level of technical expertise, as well as the capability of mobilizing capital for new development. This largest industry sector of the country, followed by manufacturing, employed 6.7 per cent of all workers in the non-agricultural formal sectors of the national economy during 2003 and contributed 7.1 per cent towards the gross domestic product (GDP) of South Africa. At that time, this was equivalent to ZAR 78.5 billion or US$ 10.4 billion. However, to be able to get a picture of the impact of the minerals industry on the South African economy, one needs to consider the full ramifications. The above-mentioned contribution towards the national GDP does not include companies that specialize in mineral processing, since these belong to the manufacturing industry. Furthermore, a vast number of South African companies are supplying the minerals industry with raw materials and equipment, transportation services and so forth. Thus, many millions of people in South Africa rely on the minerals industry as their source of income[3]. A number of major South African mining companies have adopted aggressive exploration strategies beyond the borders of the country, which resulted in the internationalization of large South African mining companies[3].

Research problem

Since R&D project portfolio selection is a complex task, it is necessary for companies to follow a systematic process. There are only a very small number of publications dealing with R&D project portfolio selection in the process industry. These include the work by Lager[2] and by Kavadias, Loch and Tapper[4]. Other literature that deals with process R&D strategy[5–8] sees this type of project as a supplement to optimal product development.

This research was intended to provide some insight into how South African companies of the minerals and energy industry deal with this topic.

Choosing the right projects helps companies to become and stay competitive, in order to outperform their competitors. Opportunities are lost if the wrong projects are chosen and resources are not concentrated on what the company needs to serve its markets in the best possible way, with the most appropriate product of the best possible quality. If strategically less important projects are not excluded early enough from the project pipeline, management and resource allocation of the R&D project portfolio become more complex than is necessary. Furthermore, it prevents important projects from being executed with the highest possible efficiency. It is believed that this would result in a loss of focus and therefore potential shortcomings in the marketplace[9]. Two managers interviewed noted that the selection of the 'right' R&D projects amounts to probably 50% of the work that needs to be conducted.

According to Stamboulis, Adamides and Malakis[8], process development is regarded as simply being a stage in product development in most of the literature on R&D portfolio management. Hence, this study examined the R&D project portfolio selection practised at companies in the process industry, whose R&D is mostly driven to create and improve processes.

The differences in the particular properties of process R&D compared to product development probably led to the use of different approaches in R&D project portfolio selection.

During the literature study it became evident that the tools suggested for use in R&D project portfolio selection do not take scarce resources into account other than money and time to completion or implementation. Personnel resources are a crucial factor to be considered in deciding on the R&D project portfolio, since they are a very common bottleneck. The capability of research staff is a crucial factor that determines what type of research could be conducted. For example, without extensive training in chemistry, a person highly qualified in electrical engineering might struggle to do research aimed at developing chemical substances with new properties. Due to this, human resources often determine the duration of R&D projects. Furthermore, the staff acquisition process, especially in the highly qualified research field, is very time consuming as well as costly[10].

The research objectives and research questions

The research was aimed at getting a representative overview of common practice of R&D project portfolio management conducted in the South African minerals and energy industry. It aims at providing a point of departure for South African companies in the process industry to develop and/or improve their decision making concerning R&D project portfolios. The following research questions were addressed in order to accomplish the above-mentioned objectives:

- *Question 1*—What methods are used for R&D portfolio selection in South African companies within the minerals and energy industry?
- *Question 2*—Why are the particular methods used?
- *Question 3*—Is a systematic approach used to take the availability of personnel resources into account in R&D portfolio selection?

Literature on project selection

In a real life R&D environment, resources are scarce. Selection methods should be easy to understand and to use. Moreover the use of methods for project selection should be transparent to business stakeholders. Examples of popular methods for R&D project portfolio selection could be divided into different categories, e.g. (1) traditional financial analysis, (2) decision trees as a simple method to deal with uncertainty in R&D, (3) portfolio analysis and (4) simplified models for options valuation.

The traditional approach to capital budgeting encompasses three steps, namely (1) estimating the relevant cash flows of a planned project or investment, (2) the application of an appropriate decision technique to these cash flows and (3) recognizing and adjusting the decision technique for risk[11]. The most common traditional decision techniques are the net present value (NPV) and the internal rate of return (IRR) technique[11,12].

As R&D generally involves high levels of uncertainty, literature suggests the use of stochastic models for project valuation as well as project portfolio selection. R&D managers face uncertainty not only in payoffs, but also from many other sources. Huchzermeier and Loch[13] present models to deal with five types of R&D uncertainty: in market payoffs, project budgets, product performance, market requirements, and project schedules. However, the authors do not perceive their model to be easy to use in practice. Decision trees[14,15] present a very simple and practical way to incorporate stochastic considerations into project valuation. As with the net present value methodology, the criterion for decision making is to select projects that have the highest values. which are required to be greater than zero. A very important advantage of decision trees, especially when compared with the NPV, is the realistic recognition of the risk profile of a project. Decision trees are easy to use, to understand and hence to implement. They also consider all possible options during the project. In a decision tree, the option to change or abandon a project could be implemented, which makes it possible to achieve a project valuation, depending on the specific case, that is close to the value derived by the real options method[15].

Portfolio maps, also called portfolio matrices, are two-dimensional matrices, depicting the project portfolio of a company or a department within a company. The position of a project within the matrix suggests the pursuit of a certain, standardized, strategy.

One dimension of the portfolio matrix considers internal criteria, i.e. variables that could be influenced directly by the company through action. The other dimension of the matrix is an external variable, on which the company has no influence[16]. Cooper, Edgett and Kleinschmidt[9] suggest a similar type of portfolio map, simply called a 'bubble diagram'. In this approach, it is not necessary that the axes on the matrix express internal and external dimensions within one diagram. An example of a bubble diagram is provided later on in this paper.

A modern view of valuation considers real options, rather than financial options, which are opportunities that are embedded in projects. An option involves the right to buy something; but it does not include the obligation to exercise it[17]. This enables managers to alter their cash flows and risk in a way that often results in a project acceptability that is different from that measured by the use of NPV. Real options are likely to exist in large capital budgeting projects[11]. By explicitly recognizing the value of embedded options, managers can make improved, more strategic decisions that consider the economic impact of certain contingent actions on project cash flow and risk in advance. The explicit recognition of real options embedded in capital budgeting projects will cause the 'strategic NPV' of a project to differ from its 'traditional NPV'. The 'strategic NPV' is defined as the sum of the 'traditional NPV' plus the value of real options[11].

Options theory was developed by Black and Scholes and published in 1973. They were awarded the Nobel Prize for their work. Luehrman[18] states that advice on using real options for project valuation in practice is rare and mainly intended for highly qualified specialists in this field. As a result, it would be very expensive and complicated for companies to apply real options valuation on real life projects. He presents a 'framework to bridge the gap between the practicalities of real world capital projects and the higher mathematics associated with formal option pricing theory.' His framework leads to quantitative results, can be used on different projects, and uses as a main source of information, the data that is already collected within spreadsheets that are used for discounted cash flow calculations. Nevertheless, this framework provides ease of use but at the expense of precision. Luehrman[18] suggests that if very precise valuations are essential, it is necessary to consult experts in the field of real options. However, the framework is precise enough for the valuation of many projects and considerably better than a traditional risk-adjusted analysis based on discounted cash flows[18].

Research methodology

For this study, a theory-based empirical research approach has been followed. A qualitative research design using the multiple case study strategy as suggested by Yin[19] was used. Yin states, that:

'…case studies are the preferred strategy when 'how' or 'why' questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context.'

Leedy and Ormrod[20] mention that a case study is:

'… a type of qualitative research in which in-depth data are gathered relative to a single individual, program, or event, for the purpose of learning more about an unknown or poorly understood situation'.

Leedy and Ormrod[20] also express that a case study is the appropriate method for investigation if the unit of analysis of the research has unique or exceptional qualities. The case study is likely to promote understanding or to inform practice for similar situations. This research project, investigating common practice of R&D project portfolio selection in the process industry, presents such an 'exceptional case'. Thus, the case study is the appropriate research strategy.

The study presented here constitutes a piece of exploratory and descriptive research. Eight R&D divisions within the minerals and energy industry exist in South Africa. Interviews with R&D managers of three South African companies of the minerals and energy industry as well as one company of the pulp and paper processing industry were conducted to gather the necessary data. It is assumed that R&D project portfolio management principles applied in these two industries do not differ. Internal company documentation served as a source for additional information to gain a complete picture of how the portfolio selection was executed at the companies.

To guide the interviews, a questionnaire was designed as part of the case study protocol. The questions were derived systematically by analysing the different aspects of R&D project portfolio selection relating to the research questions and propositions. The data obtained was analysed through classification techniques and through content analysis.

To ensure equivalence among the different discussions

undertaken, the researcher conducted the interviews personally. The interviews commenced with a broad discussion of the business. Interviewees agreed to the use of a voice recorder during the interviews and brief notes were taken as well. A list of open-ended questions was used to guide the interviews to ensure that all aspects of the research questions were covered during the discussions. Where applicable, data collected during interviews were supported by information published on company websites and in company documents. These documents include, for example, process diagrams and documents depicting or listing the R&D project portfolio of the company. The compiled summary of the interview results was sent to the interviewees with the request to confirm correctness of the document written by the researcher. Information collected was stored for review by external parties.

To increase the validity and reliability of data collected in case study research, Yin[19] recommends application of three quality-control principles, namely (1) the use of multiple sources of evidence, (2) the creation of a case study database, and (3) maintaining a chain of evidence. These three principles were applied throughout the research.

Yin[19] suggests consultation on a number of different categories as sources of evidence for data collection in case studies. However, as access to internal data and communication within South African R&D companies was limited, this study did not make extensive use of internal records and strictly confidential material. Rather, data collection was based mostly on discussions with senior managers of organizations, internal documents compiled for meetings, and publicly available material.

Data collection and analysis

The R&D project portfolio selection approaches used at four different companies, were examined. A clear pattern was found among the companies interviewed; all companies employ a semi-formal approach to select their R&D project portfolio. A formal process is followed for decision making, but no formal tools are applied to facilitate the portfolio selection. Information, such as probabilities of technical and commercial success, balance of different variables, as well as information on financial merits, is gathered on the different project proposals. This serves as an information baseline when portfolio decisions are made based on management judgement and input from various project stakeholders. NPV or IRR might serve to quantify financial information and are the only formal tools used during the portfolio selection phase. However, NPV and IRR were not used to rank projects; they merely served as a filter.

A wide range of criteria was considered in decision making at the companies interviewed. These included:

- Balance between business units served
- Risk profile of portfolio
- R&D/technical risk
- Market acceptance/stakeholder endorsement and resulting likelihood of commercialization
- Value add/NPV/IRR
- Available budget
- R&D cost
- Time frame for R&D
- Payback period
- Synergy effects between projects
- Personnel resources/capabilities
- Social, political and environmental issues
- Job creation/wealth creation
- Strategic alignment
- Strategic leverage
- Intellectual property issues.

As formal tools, bubble diagrams are used at two out of the four companies interviewed and will be introduced at another company in the near future. Thus, this tool can be seen as being considered useful. A typical example for a bubble diagram is shown in Figure 1.

Furthermore, one company out of the four investigated, makes use of the Wheelwright matrix. An example of such a matrix is shown in Figure 2. However, these tools are not used to facilitate the portfolio selection as suggested by literature. Rather, they are employed to double-check whether a portfolio, already decided upon, is aligned with company strategy and that it considers the particular balance that is being sought by top management. The company that plans to implement bubble diagrams, plans to use them as a tool for portfolio selection, as suggested in the literature. The other two companies already using the tool employ bubble diagrams only to double-check the proposed R&D portfolio. All formal tools and frequency of use are summarized in Table I.

Results and conclusions

Most interviewees expressed that R&D project portfolio management forms a very important part of the work of a research organization. The research questions could be answered as follows:

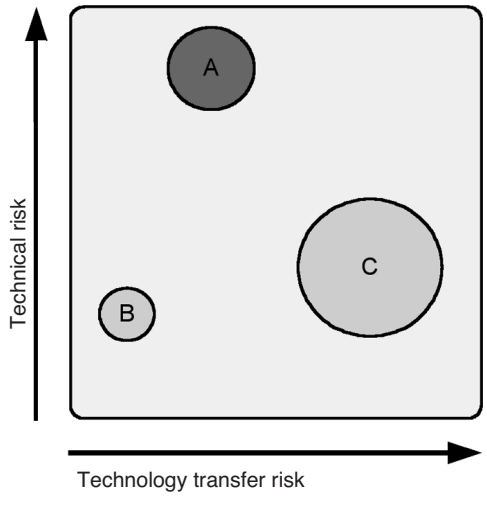

Figure 1—Example of bubble diagram

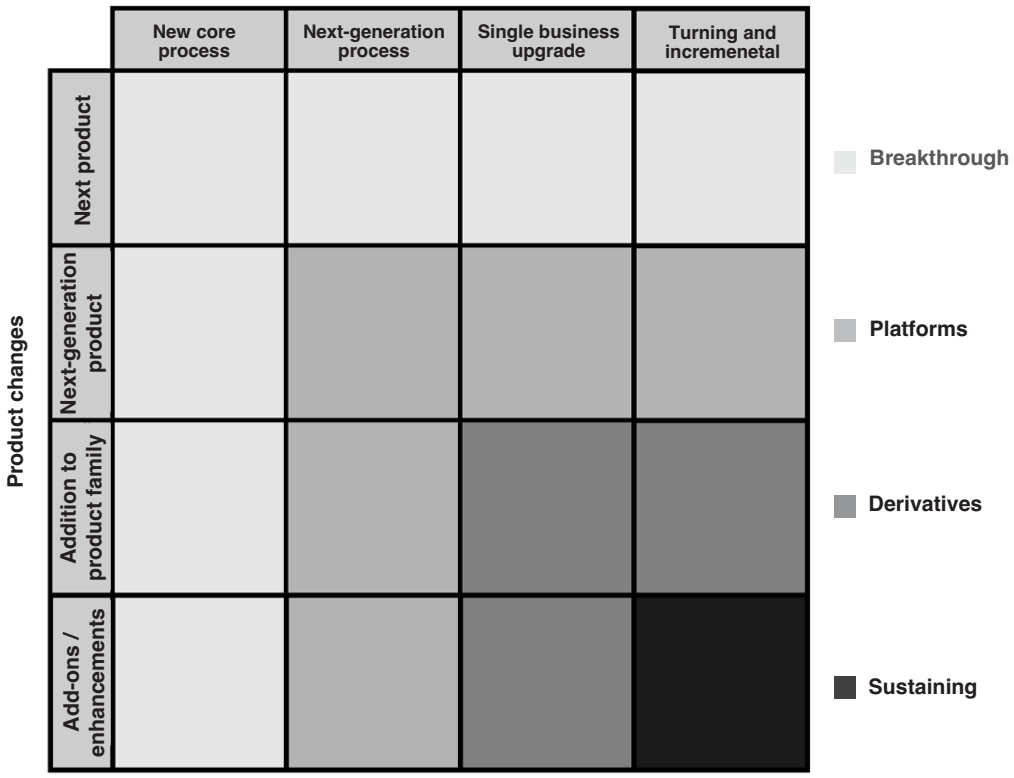

Figure 2.—Example ofWheelwright matrix

Table I

Summary of methods used

Method used	Company				
	No. 1 (Mineral and energy)	No.2 (Mineral and energy)	No. 3 (Mineral and energy)	No. 4 (Pulp and paper)	∑
IRR	No	Yes	Yes	No	2
NPV	No	Yes	No	No	1
Bubble diagram	No	Yes	Yes	No	2
Wheelwright matrix	No	No	Yes	No	1

- *Question 1*— What methods are used for R&D portfolio selection in South African companies within the minerals and energy industry?

  No formal methods were used to decide upon the R&D project portfolio. Rather, only the processes to make the decisions were formal. Once project ideas have been generated, further information is sought. Based on this information, senior staff and management jointly make the portfolio decisions, based on judgement and experience. At two of the four companies, bubble diagrams are drawn up to review the proposed decisions in order to make adaptations, should the overall portfolio not be balanced or not aligned to corporate strategy. Company No. 4 (see Table I) plans to implement the bubble diagram method in the near future and will use it as a direct method for designing the R&D project portfolio. One out of the two companies that employ bubble diagrams already uses the Wheelwright matrix as a further tool to ensure strategic alignment and balance of the R&D portfolio. One company out of the four does not use any formal tool at all.
- *Question 2*—Why are the particular methods used?

  All companies explained that they do not use any formal method for decision making about the R&D project portfolio due to the complexity of their business and the high uncertainty involved. According to the people interviewed, formal methods cannot deal appropriately with the vagueness that exists during the very early research phases. Thus expert experience and managerial judgement are used to pick 'the right' projects. Managers also mentioned that an approach that uses intuition to select the R&D project portfolio, supported by information about different criteria, is well suited to the company since this approach is not too formal. This leads to the assumption in the companies interviewed that formal methods are not effective.

- *Question 3*—Is a systematic approach used to take the availability of personnel resources into account in R&D portfolio selection?

  It was found that in all companies investigated, human resources were taken into account when R&D projects were chosen to be pursued. However, this is not done in a systematic or formal fashion. Rather, before the final R&D project portfolio decision is made, it is double-checked whether the portfolio could be executed with the staff available, or whether corrective measures would need to be taken.

  The study uncovered that the companies examined did not develop completely new tools or models to decide on the R&D project portfolio or to review it. For review purposes, the bubble diagrams found application without any specific adaptation to circumstances within the process industry. One company used the Wheelwright matrix to confirm balance of the R&D portfolio.

In line with the findings of the current study about research question 2, companies in the process industry might employ a simple and practical model to formalize project portfolio selection. Strategic alignment and balance of a proposed project portfolio were found to be the most important factors that needed to be taken into consideration at the companies interviewed. As it is difficult to gather exact information on project feasibility and the financial value, a model that suggests the choice of proposed R&D projects based on strategic alignment and balance is required. Portfolio maps, customized for specific company needs, seem to be appropriate. Portfolio maps require qualitative information. The axes of such matrices, as well as diameters and colours assigned to projects, could represent the dimensions crucial to make portfolio decisions to further company strategy. To formalize the process of R&D project portfolio selection, portfolio maps should be used to pick projects rather than to check the balance of an already suggested portfolio decision. The rating of different R&D projects on a qualitative scale is to be established in meetings involving different project stakeholders. In order to bring a suggested project portfolio in line with personnel resources, staff allocation might be given priority to projects being the most important as identified within the portfolio map.

Proposed further research

In further research, it could be of interest to conduct case studies of similar South African companies within a different industry, as well as foreign companies within the minerals and energy industry. This would make it possible to establish whether the fact that the companies did not use any formal approaches to make R&D project portfolio decisions, as suggested in the literature, results from the type of industry in which they operate, or whether it results from a specific geographical or cultural environment.

References

1. Twiss, B. *Managing Technological Innovation*, 3rd edition, London, Longman Group Ltd., 1987.
2. Lager, T. A structural analysis of process development in Process Industry - A new classification system for strategic project selection and portfolio balancing, *R&D Management*, Oxford, United Kingdom, Blackwell Publishers Ltd., 2002. no. 32,
3. Department: Minerals and Energy, Republic of South Africa, *South Africa's Mineral Industry 2001/2002*, Mineralia Centre, 234 Visagie Street, Pretoria, South Africa, 2002.
4. Kavadias, S., Loch, C.H., and Tapper, U.A.S. Using Marginal Returns to Allocate the R&D Budget at GemStone, Paper submitted to *Manufacturing and Service Operations Management,* New York, USA, 2004.
5. Utterback, J.M. *Mastering the Dynamics of Innovation—How Companies Can Seize Opportunities in the Face of Technological Change,* Boston, Massachusetts, USA, Harvard Business School Press, 1994.
6. Pisano, G.P. *The Development Factory—Unlocking the Potential of Process Innovation*, Boston, Massachusetts, USA, Harvard Business School Press, 1997.
7. Adler, P.S. *et al.* From Project to Process Management: An Empirically-Based Framework for Analysing Product Development Time, *Management Science,* March 1995. vol. 41, no. 3.
8. Stamboulis, Y. Adamides, E., and Malakis, T. A System-Dynamics Study of a Resource-Based Approach to Process Development Strategy, *Proceedings of the 2002 IEEE International Engineering Management Conference, Managing Technology for the New Economy*. Cambridge, United Kingdom. St John's College, 18–20 August 2002, vol. 1.
9. Cooper, R.G., Edgett, S.J., and Kleinschmidt, E.J. *Portfolio management for new products*, 2nd edition, Cambridge, United Kingdom, Perseus Publishing, 2001.
10. Grobler, P.A. *et al. Human Resources Management in South Africa*, Thomson Publishers, 2001.
11. Gitman, L.J. *Principles of Managerial Finance*, 10th edition, Boston, USA, Addison Wesley Publishers, 2003.
12. Schierenbeck, H. *Grundzüge der Betriebswirtschaftslehre*, 14th edition, Munich, Germany, Oldenbourg Verlag, 1999.
13. Huchzermeier, A. and Loch, C.H. Project Management Under Risk: Using the Real Options Approach to Evaluate Flexibility in R&D, *Management Science*. January 2001. vol. 47, no. 1.
14. Clemen, R. and Reilly, T. *Making Hard Decisions with Decision Tools*, Duxbury. 2001.
15. Faulkner, W.F. Applying 'Options Thinking' To R&D Valuation, *Research Technology Management*, May–June 1996, Parts 1 and 2.
16. Gochermann, J. *Kundenorientierte Produktentwicklung, Marketingwissen fuer Ingenieure und Entwickler*, Weinheim, Germany, Wiley-VCH Verlag, 2004.
17. Hommel, U., Scholich, M., and Vollrath, R. *Realoptionen in der Unternehmenspraxis—Wert schaffen durch Flexibilität*, Germany, Springer Verlag, 2001.
18. Luehrman, T.A. Investment Opportunities as Real Options: Getting Started on the Numbers, *Harvard Business Review*, July–August 1998.
19. Yin, R.K. *Case Study Research: Design and Methods*, 2nd edition, Sage Publications, Thousand Oaks, 1994.
20. Leedy, P.D. and Ormrod, J.E. *Practical Research—Planning and Design*, 7th Edition, New Jersey, USA, Merrill, 2001. ◆