“The Primary Assessment Tool at Philips Electronics: Capturing Real Options and Organizational Risk in Technology Portfolio Management”

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Abstract
I develop an extended scoring approach to build a balanced portfolio of new technology projects under uncertainty at early stages of development. My contribution is twofold. First, I show how the tool incorporates the option approach to decision making to create contingent claims on future market introduction of new technologies. Second, I focus on the endogenous organizational risk that essential competencies may not be (fully) in place when a firm introduces a new technology in the market, i.e. exercises an R&D option. When competencies are partly in place, successful market introduction is at risk and this risk lowers the option value of an R&D project compared to financial option valuation. I demonstrate how the tool captures this organizational risk in a qualitative setting. The insights gained originate from investigating the evaluation and selection of new technologies at Philips Electronics. The Primary Assessment Tool developed serves as a first step in amalgamating R&D and NPD option values with their organizational risk.
1. Introduction

In cooperation with Philips’ Corporate Strategy Department a software package has been developed, tested and evaluated to support management with the resource allocation process of new technology initiatives as well as to monitor projects throughout the different stages of development in a consistent manner. The aim was to develop a user-friendly and transparent tool that captures decisional flexibility and monitors relevant project and portfolio information on no more than three single data sheets. In particular, management at Philips Electronics wanted to explore the opportunity of incorporating recent option valuation insights in the scoring method.

Consumer electronics companies are facing an enormous pressure for innovation. In the case of Philips, only part of its current market capitalization can be attributed to existing products. This implies that capital markets have high growth expectations, which are largely fueled by what investors believe (or demand) might result from the R&D pipeline. Not meeting those expectations would erode shareholder value. At the same time, cost of innovation rise. New technological opportunities, such as Digital Versatile Disc or the fusion of the television with the personal computer increase the number of potential R&D and NPD projects significantly. Academic theory has provided a rich basis arguing that option valuation is, by its very nature, well applicable to R&D projects (see Dixit and Pindyck, 1994; Trigeorgis, 1996, and Amran and Kulatilaka, 1998, for surveys). However, option valuation in consumer electronics markets appears complicated (Pennings and Lint, 1999). Therefore, it was decided to focus development of the tool on the basic concept that R&D allocation is the creation of contingent claims on future market introduction of new technologies.

Contrary to financial options that are based on written contracts, however, it is in general not certain at the early stages of development that an R&D option can be exercised at the exercise time. A simple way to model this uncertainty is by means of a binary variable that takes a value of 1 if essential competencies are fully in place and 0 if competencies are absent. Hence, exogenous market circumstances and the endogenous capability of the firm to make sure that competencies are in place when introducing the new technology to the market determine the probability of technical and commercial success of a project. In case this probability is less than 1, the option value of the R&D project will be lower compared to financial option valuation. Still, the option value is always positive and higher than the expected value that is calculated with traditional discounted cash flow techniques such as the Net Present Value (NPV) method. The observed major difference between financial options that are exposed to exogenous uncertainty
solely and real options that are exposed to both exogenous and endogenous uncertainty serves as the backbone of the scoring method developed.\footnote{In a recent paper, Huchzermeier and Loch (1998) address this issue as well and explore the impact of higher uncertainty on the value of flexibility at an operational level. They find that the option value of managerial flexibility may be reduced because of an increase of operational variability. While they...}

The paper is structured as follows. I start with a brief summary of literature concerning conventional scoring methods and subsequently describe elements that are considered essential in developing an extended scoring tool. Next, I single out two dominating building blocks that are of paramount importance and that must be handled by management proactively: decisional flexibility or option value, and the risk that competencies are not in place when the firm strikes an R&D option. I show how the software developed supports management in handling both elements. In the final section I draw conclusions and give directions for further research.

\section*{2 R&D and NPD Project Scoring under Uncertainty}
Throughout this article I will not make a clear distinction between research, development and new product development. The primary scope of research is knowledge creation whereas development is aimed at implementation. In practice, the common denominator for all these activities is to develop new technologies to create commercially successful new products or production processes. Since research and development activities interact and have many characteristics in common, the existing literature on R&D selection models rarely differentiates explicitly between research activities and development activities. The outcome of both the research and the development stage is uncertain. Development projects tend to be more accessible to quantitative analysis because input data will be easier to estimate since market and technological uncertainty is resolved to a major extent during the latter stages of product development when more information becomes available. On the other side of the continuum, basic research projects are not directed to specified products or processes. Their broad orientation, accompanied by lack of information, induces a high level of uncertainty.

The process of new product development (NPD) incorporates R&D activities and covers all necessary development stages before market introduction, including research, development, design, prototyping, engineering, manufacturing and market testing or market research. Like with R&D, the boundaries between the different stages are not defined precisely and are interactive, but a common denominator is that throughout the different stages market and technology uncertainty prevails. Uncertainty affects technology, cost and market factors in a project. Although sophisticated models exist to handle uncertainty, empirical evidence suggests that conceptually simple models such as checklists and scoring approaches are widely used, whereas...
more sophisticated methods for decision analysis have had little impact in practice (Liberatore and Titus, 1983; Watts and Higgins, 1987). Therefore, I will discuss the benefits and practical use of scoring methods next.

According to Fahrni and Spätig (1990), scoring models belong to the category of selection models where there is a low degree of quantification, a low degree of interdependency among projects, and where multiple objectives exist. R&D and NPD scoring models have a long history. Mottley and Newton (1959) give an initial contribution on R&D project evaluation describing a scoring method. Subsequently, a variety of scoring models has been proposed (for a recent survey see Liberatore and Stylianou, 1995). Proponents argue that scoring models are perhaps the best screening tool available at the early stages of NPD, and that such models have utility for the following reasons (Cooper, 1985). First, they make highly judgmental decisions somewhat more objective and they systematize the review process. Second, they force management to subject projects to a consistent set of review criteria, meanwhile focusing attention on the most relevant issues. Also, they require management to state goals and objectives clearly. Moreover, scoring methods are easy to understand and use, and, finally, they are generally applicable and can be used company-wide for R&D and NPD project selection and initial evaluation.

Given the transparency and broad applicability of scoring methods, it was decided at Philips Electronics to develop an extended scoring method to support technology management. The approach developed, named “Primary Assessment Tool” (PAT) for New Business Creation specifies a minimum set of data that is required to make an initial assessment of the relative attractiveness of proposals and to determine their option value. Besides financial elements, the tool also incorporates a preliminary set of marketing and organizational elements to capture organizational risk. A high level of consistency of proposals is accomplished by accurately defined questions and scoring methods. The tool was customized for potential use by Corporate Research and Corporate Strategy as well as Product Divisions and has meanwhile been adopted as a “concise and powerful tool”\textsuperscript{2}. In the next section I describe how theoretical and practical findings have been amalgamated to develop PAT.

3 Project Complexity and Scoring Models

In spite of the ease of use and the popularity of scoring models they may lead to a false rationale or oversimplification due to serious shortcomings. For this reason the development of PAT was grounded in literature review and in-depth analysis with several key managers involved in the

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\textsuperscript{2} As stated in a letter to the Executive Board by a former Senior Director of Corporate Strategy.
R&D and NPD process. Table 1 summarizes main issues found in literature and subsequent interviews.

Six related conclusions were found that were considered as essential for an appropriate development of the project selection method. These conclusions will be described in more detail below. Moreover, I will explain how each finding has been incorporated in the tool developed.

A. R&D and Initial NPD Projects Are Tentative
In general, investment decisions in R&D and NPD are decisions with a contingent or optional character. If conditions develop favorably a commitment is made to some follow-on trajectory, but if developments are unfavorable, the follow-on trajectory is blown off in time. Especially in highly uncertain markets and long investment trajectories the importance of decisional flexibility and organizational competencies increases: the longer the final investment can be postponed, the more time there is to consider all technological and market elements with respect to the investment. Hence, the more beneficial the starting position. Also, high uncertainty increases the probability of profitable developments (upward potential), while at the same time the probability of an unprofitable scenario (downward risk) is limited to the first, relatively small, investment. Therefore, the value of managerial flexibility in technology decisions increases with higher uncertainty (Roberts and Weitzman, 1981).

The managerial flexibility consists of two components: the operational flexibility, which reflects the possibility of postponement, and the strategic value, which reflects the possibility to enter into a profitable follow-on trajectory (growth option). This line of thought is the basis for applying option thinking to contingent investments within the context of the corporation. Because of shorter product life cycles, rapid technological developments and expanding global competition, the uncertainty in the company’s environment increases and therefore the importance of decisional flexibility or keeping one’s options open⁴. In contrast, traditional

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⁢ Interviews concerning R&D option valuation were held from 1994 to 1996 with managers within R&D, marketing, finance, and strategy. I interviewed managers at different hierarchical levels, including R&D project/ product management level, group leader/product family level and (senior) director levels. Although the number of interviews (in total 65, regarding 20 research and 14 new business initiatives) with functional departments is unequal and the interviews are not proportionally distributed among the hierarchical levels, I did not weigh the answers but simply ranked the main issues raised to develop the scoring method.

⁴ Option management is focused on keeping options open, not just to adapt to environmental developments but also to initiate these developments. Especially R&D can have major influence on the company’s environment through technological breakthroughs and newly developed products. Option management fits well into the resource-based approach (Bowman and Hurry, 1994).
managerial approaches focus on a static decision process within which future go/no go decisions are made with all currently available information and these decisions will not be revised when new information alters the value of the investment opportunity.

From a numerical perspective, option analysis in R&D and NPD builds upon the flexibility that the decision on investment in worldwide marketing and in new production processes is being deferred to the moment of market introduction. Meanwhile research, necessary for creating the option, is conducted. Hence research provides an option on future market introduction (Mitchell, 1990; Mitchell and Hamilton, 1990; Lint and Pennings, 1998). The research costs until market introduction determine the price of the option. The final decision on market introduction is based on the project value at that moment. If this value is negative, the investment will not be made and the loss of research costs is taken. The option will not be exercised. If the project value is positive at that moment, market introduction takes place. Option analysis provides the crucial insight that market introduction is contingent and that the relating investment decision is being taken on a future date with more information and at reduced market and technological risk. The option value is always positive because market introduction does not take place when the project value at the moment of market introduction is negative. However, when at the initial stages of development key competencies are only partly in place, successful market introduction is at risk and this risk lowers the option value of an R&D project compared to financial option valuation. This organizational risk needs to be determined when assessing the option value of an R&D project.

In section 4 below I detail the way in which option analysis and an assessment of the accompanying organizational risk have been incorporated in PAT.

B. Criteria Interference
A major problem of simple scoring methods concerns criteria interference. Scoring models generally do not address the issue of criteria interference thereby biasing the evaluation and selection procedure. The Cooper (1985) model explicitly pays attention to the problem that criteria may not be mutually exclusive. The author develops a scoring model based on a factor analysis of project characteristics data of 195 projects from 102 companies. Half of the projects were commercial successes in terms of meeting or exceeding the acceptable financial return for the type of investment. The other half had been launched, but was subsequently rated as commercial failures. From statistical analysis it appeared that 8 factors were linked to product outcome in a significant way. These eight key dimensions are market criteria (market attractiveness, market competitiveness, and mass-market appeal), product advantage (product superiority and cost advantage for the user), and synergy criteria (compatibility with overall company resources, newness to the company (negative), and compatibility with technological
resources, such as R&D). The model has been validated and was found to yield an overall predictive ability of 84%.

The empirical findings from the Cooper (1985) study have been incorporated to a major extent in PAT. Our first idea was to make a similar study based upon project data at Philips Electronics to find out what factors drive product or technology success in consumer electronics markets. However it appeared that R&D and NPD projects were not monitored in a consistent manner and longitudinal research would be arduous. In discussions with managers involved we found that the key dimensions outlined could be changed into eight dimensions (see section 4) that match the positioning approach (Porter, 1985) and capture insights from the resource-based approach (Collis and Montgomery, 1995). One of the key dimensions management emphasized was human resources. From experience management knew that when the project or “entrepreneurial” team was not in place the probability of successful completion of the project was low. For this reason entrepreneurial team became one of the eight key dimensions of PAT.

C. The Time-Varying Character of Assessment Criteria

Criteria for selection and evaluation evolve over time as NPD projects move through the different stages of development, but this element is difficult to build into practical models. The approach described by Bell and McNamara (1991), though qualitative explicitly addresses the issue of the time-varying character of criteria. They discuss the Bell-Mason Diagnostic, a checklist model, developed to characterize and plot manually the status of a high-information technology venture at each stage of its growth. Four elements are incorporated in this diagnostic.

The first element captures four basic sequential stages of project development. The second element captures twelve dimensions that are measured to assess a business initiative. These dimensions are organized in four groups concerning technology, marketing, staffing, and financial elements. The third element incorporates the rules to evaluate each dimension. The rules are based on questions that constitute a checklist. These questions represent the ideal benchmark and the project is on track on a dimension if the answers to the related questions are positive. This way, the approach may also be used as a stage-gate approach since proceeding to a next stage can be made dependent on achieving positive answers to the different questions. The fourth element plots the scores of each dimension as a spider web along the four to twelve spokes of a polar graph during the different development stages. A major benefit of the approach is that the number of spokes and the rules are time varying since the questions evolve and become more detailed with each stage of development.

Management at Philips found the Bell-Mason Diagnostic helpful in monitoring the development of a project from a business oriented perspective. In particular the dimensions Business Plan Development and Staffing made sense. After discussions it was decided to
incorporate the Diagnostic as a separate graph in the first data sheet that PAT generates. The polar graph is automatically generated by PAT based upon interactive input from the project team.

D. Capturing Expert and Senior Knowledge
Throughout the different stages of R&D and NPD, the knowledge and expertise of project managers and senior management should be incorporated in methods and systems for project selection and evaluation. One way to capture this knowledge is by means of an expert system for NPD as developed by Liberatore and Stylianou (1995). At the core of their framework are the methods used for acquiring, modeling and processing the expert knowledge and data. Methods and techniques used include scoring methods, logic tables, the analytic hierarchy process, discriminant analysis, and rule-based systems. The approach merges the benefits of normative modeling with the flexibility and developmental advantages of expert systems. This way, modeling may evolve through the different stages of development and the use of a sophisticated expert system may substantially enhance more qualitative checklists. The authors focus on the strategic decision to commit to full-scale development of a new product. At this stage of new product development, quantitative information is likely to be available and more formal models can be applied more easily.

Another way to incorporate senior knowledge in the process of selection and evaluation is to have the projects assessed by a senior technology assessment team. In order to capture senior knowledge and absent most of the quantitative information at the initial stages, management at Philips decided to assess projects on quantitative and qualitative elements represented by PAT at specific meetings by means of a Technology and Business Assessment Committee.

E. Balanced Portfolio
Thomas (1985) develops a multi-stage evaluation method to NPD and concludes from practice at a consumer electronics firm that the screening process model used inevitably leads to a consensus problem. It appeared that managers still argued that the ability to pioneer long term technology development was more important than meeting short-term financial criteria. There was agreement that projects with different risk/return profiles should be balanced, offering the potential for long term development of strategic skills as well as the attainment of satisfactory short to medium term financial results.

Consequently, Walls, Morahan and Dyer (1995) find that decision makers perceive project risk not just as a function of the probability distribution of potential cash flows but also as the magnitude of capital exposed to the chance of loss. Where the expected values of two projects are equal, the expected value concept fails to give adequate weight to a company’s exposure to
the chance of a very substantial loss. Therefore, practice suggests a methodology that allows managers to make an appropriate trade-off between the potential and uncertain upside gains versus downside losses for individual projects and bundles of projects. They present a model that is based on certainty equivalent measurement to incorporate the company’s risk attitude into the project analyses. The certainty equivalent is the cash value attributed to a decision alternative that involves uncertain outcomes. The certainty equivalent of a risky investment is a function of the risk characteristics of the investment and the risk preferences of the decision-maker. The authors show important changes in the overall ranking of projects with the certainty equivalent analysis as compared to expected value analysis.

Absent most of the quantitative information at the initial stages a final direction to be considered for portfolio management is to plot key qualitative characteristics of projects against each other as put forward by management consultants Roussel, Saad, and Erickson (1991). In their approach key characteristics include fit with corporate strategy, inventive merit and strategic importance, sustainability of competitive advantage, financial return, and investment required.

From the findings of these studies we took that in the process of evaluation and selection projects should be balanced according to their time horizon and risk/return profile. In subsequent analysis we found the option valuation method more convenient for early stage assessment of R&D and NPD projects than the certainty equivalent approach. With option analysis the focus is also on upside potential and the limitation of downside loss but it is not necessary to specify the risk preferences of the individual decision maker as in the case of certainty equivalent measurement. Finally, our project team decided to rate both qualitative and quantitative characteristics and to plot the position of a specific project in relation to other projects on a separate data sheet. The sheet shows portfolio graphs regarding sales potential to investments, competence base to market attractiveness and aggregated market, technological and organizational risk to expected return.

F. Condensed Information, Transparency and User-Friendliness

The issue that information should be represented in an appropriate condensed format typically stems from management interviews. In particular, management at Philips Electronics demanded that data and graphics should be plotted on no more than three single sheets per project in order to ease assessment, to make consistent decisions and to monitor dozens of projects per annual quarter. Hence, the challenge was to strike an adequate balance between the Scylla of oversimplification that would create ineracious output and the Charybdis of complexity that would create a managerial black box. Moreover, transparency is essential in order users to comprehend the approach and its implications for assessment. Therefore the tool was designed to be self-explanatory, user-friendly and interactive.
4 Option Value and Organizational Risk

The scoring method developed, PAT, enables a preliminary assessment of the new business initiative by describing its vision, scope, strategic fit, unique selling points, entry barriers, challenges, competencies and a suited marketing mix. Moreover, the sales potentials of the new product together with the capital and marketing expenditures that are required for market introduction are estimated. The information gathered is represented on the first conveniently arranged data sheet (see figure 1).

4.1 R&D Option Value

The financial information from PAT (sales potential, probability of success, capital and marketing expenditures, cost of capital, level of operational cash flow (as % of annual sales) and time-to-market information are used to calculate the option value of a project. As a next step this value is compared with the costs of creating the option, i.e. estimated R&D expenditures. So the economic evaluation of R&D options takes place using five basic variables: underlying value, probability of obtaining the underlying value, exercise price, option price, and exercise time.

The underlying value \( (V) \) is the present value on the exercise date of future expected net cash flows from operation, generated by market introduction during the economic life of the investment. The level of operational cash flow resulting from sales is expressed as a percentage \( (b) \) that will vary across the Product Divisions of a company as a result of different market circumstances. The sales potential \( (S) \) is asked for the fifth year after market introduction assuming that sales resulting from the new technology or product reach their peak level in that year. After the fifth year after market introduction no revenues from the new technology or product are considered since product and technology life cycles in high technology markets tend to be very short and product prices drop fast after market introduction (see also Moriarty and Kosnik, 1989). By means of a dialogue box, PAT asks the user whether the development of sales in time for the first five years after market introduction is known. If so, these numbers are requested and used for calculations. If not, it satisfies if the user gives an estimate of the sales in the fifth year after market introduction. PAT makes subsequent calculations on the assumption that sales grow linearly to this peak level.

The cash flows are uncertain whereas the uncertainty can be expressed by a binary variable that takes a value of 1 if the project is successful and 0 if the project fails. The probability of success \( (p) \) depends on market and technology risks which are determined by
exogenous market circumstances and the endogenous capability of the firm to make sure that competencies are in place when introducing a new technology to the market, i.e. when exercising a technology option. PAT calculates this probability as the product of the scores on attractiveness (a) and on competency (c). Present values are calculated by discounting the cash flows against the firm’s cost of capital (i). This rate of return consists of the weighted average cost of attracting capital (equity and debt) by a company. So, a bit more formal, the underlying value at the exercise time is automatically calculated by PAT as follows:

\[ V = b \cdot S \cdot \{0.2/ (1+i) + 0.4/ (1+i)^2 + 0.6/ (1+i)^3 + 0.8/ (1+i)^4 + 1/ (1+i)^5 \} \]

The expected value of the underlying is determined by the product of the scores on attractiveness and on competency, so \( p \cdot V = a \cdot c \cdot V \).

The exercise price (X) consists of the present value on the exercise date of investments that are necessary for market introduction. These are investments in new production processes (I_p) and marketing expenditures, which cohere with the market introduction (I_m). So, in a formula, \( X = I_p + I_m \). The cost of the option (C) consists of the present value of R&D costs, which are necessary to create the option (the decision on market introduction).

The last variable is the exercise time (T). Three forces determine the exercise period. First, a minimal exercise time is required due to the throughput time of research. The necessary duration of experiments and various tests on material suitability and the durability of prototypes determine this. The second force is market pressure from competition. When a product is introduced to the market too late, important first mover advantages may be missed (Lieberman and Montgomery, 1988). The final effective force consists of a strong patent position or market dominance (for example Microsoft Windows) which has positive effect on maximum delay, because one can wait longer until making the final decision on market introduction\(^5\). So, \( T = \text{Max}(T_d - T_p, T_c - T_p) \) where \( T_d \) denotes the ultimate moment until which market introduction can be postponed, \( T_p \) is the present year, and \( T_c \) is the year in which the company completes the R&D stages and is able to go market.

In PAT it is assumed that \( T_d = T_c \) i.e. due to competitive pressure there is no time to delay market introduction after R&D completion. By fixing T I typically assume European options as opposed to American options that can be exercised at any moment. R&D options can be considered as European when two conditions hold. First, market introduction before successful completion of the R&D stages may have severe implications on market performance, as recently illustrated by Lever’s market introduction of OMO Power\(^6\). Crawford (1992), and Griffin and...

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\(^5\) Cohen, Eliashberg and Ho (1996) analyze in a deterministic setting the optimal time to market in relation to the product performance target of a new product.

\(^6\) In 1994, Lever launched its new Persil and Omo Power detergents based on manganese, a catalyst that could dramatically increase cleansing power. However, the detergent was subjected to claims that
Page (1993) argue that reducing time to market is only advisable when this does not limit the probability of success of the final product to be introduced to the market. Second, when waiting to introduce a new product leads to a loss of first mover or pioneering advantages. In markets where strong first-mover advantages exist, management typically exercises R&D options just at the moment of market introduction when the NPV is positive at that moment. Since waiting is useless due to evaporating first mover advantages, these R&D options are European. Therefore it will be attractive for firms with superior R&D competencies facing strong price erosion such as Philips Electronics to exercise a technology option right after the R&D stages. If successful, these firms are able to set a generally accepted technology or dominant product standard and license the results of its R&D efforts subsequently.

Now the Net Present Value of an R&D project can be calculated as:

\[(a \cdot c \cdot V - X)/(1+i)^T\]  where  \(a \cdot c \cdot V - X \geq 0\).

Taking the option perspective as outlined above, however, the final decision about market introduction of the newly developed technology or product is contingent on the outcome of the previous stages, and only takes place when \(V - X > 0\) at the moment of market introduction. So, commitment to the market introduction investment is postponed. The net option value \(Z\) can be written as

\[Z = L - C\] where \(Z \geq 0\),

\[L = \{a \cdot c \cdot \text{Max} \{(V - X, 0)\} + (1 - a \cdot c \cdot 0)/(1+i)^T\},\] and \(C\) is the cost of the option\(^7\).

Thus, the essential adjustment made by the option approach to the net present value method is that both project value and irreversible follow-on investment are treated as uncertain \(a \cdot c \cdot (V - X)\).

### 4.2 Organizational Risk

Option valuation assumes an R&D option can be exercised at the exercise moment, i.e. technology and organizational elements must be in place. This is a major difference with financial options that are based on written contracts where the holder of the option is certain about materializing a favorable outcome at the exercise date but is not able to influence the value of the underlying. Uncertainty surrounding financial instruments, such as stocks and exchange rates, is fully determined by exogenous uncertainty in the macroeconomic environment. Examples include uncertainty surrounding inflation, economic growth, interest rates and political stability in relevant countries. The holder of a financial option can not influence this uncertainty.

the new powder damaged clothes. Sales of the new product dropped to a disappointing level and Lever responded by adapting the product formula and by heavy price discounts.

\(^7\) Note that \((1 - a \cdot c \cdot 0)\) drops out since the project fails in this case and market introduction is thus abandoned. Furthermore, Max \(\{V - X, 0\} = V - X\) since it is assumed that market introduction is fruitful
Since R&D options are not traded, the holder of an R&D option is uncertain about materializing a favorable outcome at the exercise moment. However, in general the uncertainty of R&D and NPD options can be influenced since it is not fully determined by uncertainty in the macroeconomic environment. The uncertainty can be decomposed into uncertainty stemming from the macro-environment and the microenvironment. As with financial options, the holder of the option cannot control exogenous uncertainty, but can reduce endogenous uncertainty by proactive management. Examples of proactive management include the filing of patents and licensing in order to set a global technology standard, building an appropriate entrepreneurial team, defining a smart supply chain management system, and leveraging an existing customer base.

From the previously described literature review and interviews at Philips Electronics, our project team determined how exogenous and endogenous uncertainty could be assessed in an effective and efficient way. As a first step, in figure 1 eight key dimensions are used to balance the attractiveness of a targeted market with the competencies of the firm. By means of market analysis an assessment is made of the attractiveness of the targeted business, independent of the company’s ambitions and competencies. Market attractiveness is an exogenous factor that generally cannot be influenced by proactive management. To determine the market attractiveness of a particular project, scores are asked for the following key market dimensions: market profitability, market growth, industry concentration, and value chain complexity.

Porter’s model (1985) is used to estimate market profitability by determining for each of the following five forces, if they are either weak or strong: bargaining power of suppliers, bargaining power of customers, threat of new entrants, threat of potential substitutes, and rivalry. Finally, the total score of the market profitability is determined according to the number of unfavorable forces. Market growth is classified according to the expected annual growth percentage of the targeted market. The industry concentration determines the competitive structure of the targeted market and is related to the current aggregated market share of the four main players in the industry. To assess value chain complexity, the main underlying question is which elements in the value chain have to be altered and are new to the business. By determining the number of elements that are affected or have to be put in place before the new product or service can be launched, value chain complexity can be set. Finally, the program calculates the scores of market profitability, market growth, industry concentration and value chain complexity to determine the overall rating of attractiveness.

As a second step and similar to determining market attractiveness, the relative position of the core competencies of the company in relation to the targeted market is assessed. Scores are

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asked for the following four items: technology/patent position, production/sourcing/operations, distribution/customer base, and entrepreneurial team. For these items the scoring is more subjective and expresses the opinion of the project team whether the item is absent, partly in place or fully in place. By determining the scores an overall rating on the company’s competencies in accordance with the targeted business is established. The missing competencies can be viewed as challenges and targets to secure a successful market introduction after R&D completion. This way, an explicit link is made with internal factors that can be influenced by proactive management to reduce endogenous uncertainty.

4.3 An Improved Approach to R&D and NPD Portfolio Management

The overall organizational risk of a project is calculated based upon both ratings (attractiveness and competencies) and is used in the risk / return plot (see figure 2). This risk mirrors the probability of success of a project (1-p) and is plotted against the option value of the project. The option value is expressed as the internal rate of return (IRR). The IRR is the discount rate that makes \( \frac{(V-X)}{(1+i)^T} = 0 \). This IRR is plotted on a logarithmic scale varying from 1 to 1000. The risk factor is divided in three categories: low risk (0-50%), medium risk (50-75%), and high risk (75-100%). In order to develop an integrative portfolio perspective on different R&D and NPD projects, the position of a specific project in relation to other projects is also illustrated by figures relating sales potential to investments and competence base to market attractiveness.

--- Please insert figure 2 about here---

Moreover, the development of cash flows in time of an individual project is shown. In a histogram the annual cash flows are plotted until five years after market introduction. To visualize the distinction between reversible R&D investments and irreversible follow-on investments in market introduction, capital and marketing expenditures are considered at once at the exercise time whereas conditional R&D investments are equally spread over the years before. In the first five years after market introduction the annual operational cash flows from which the investments must be recovered are illustrated. The investment bars are negative and colored blue. The cash flow bars are red and yellow. The red bars represent the minimal cash flows -based on a linear sales development- required to cover investments (NPV=0) and the yellow bars illustrate the surplus cash flows as derived from the sales potential. The spread between the red and yellow bars

\[ a - c \cdot \frac{(V-X)}{(1+i)^T} \]

\(^8\) To calculate this option value or, equivalently, this IRR it is assumed that the option can be exercised or that \( p = 1 \) (see also the previous footnote). In order to avoid confusion between the
bars indicates the attractiveness of the project from a conventional, static discounted cash flow perspective that is consistent with current managerial thinking. If the spread is absent or very small, traditional mechanisms of selection suggest dropping the project. However, from a dynamic perspective the risk/return portfolio should also be considered. It may well be that the option value of the project in relation to its organizational risk counterbalances the static view of the total project as a fixed sequence of irreversible investments with a negative NPV.

The selection of a specific portfolio from the project database is flexible. It can be easily adapted in time and to a variety of selection criteria, e.g. to particular markets (e.g. Lighting or Multimedia), to the same class of risk as perceived by management or to projects with the same time-to-market. Consequently, the third data sheet (see figure 3) captures four plots that are relevant once several data sets are gathered over time.

The plots show the development of the project over time compared to the average scores of the selected portfolio (the benchmark) with respect to the following criteria: (1) attractiveness, (2) competencies, (3) investments, sales potential and net present value, and (4) Company Time to Market.

By means of the different portfolio figures, management can easily compare projects on key dimensions from an integrated organizational, technological, marketing and financial perspective. As a consequence, management is better able to value decisional flexibility (keeping options open) and to select and manage the R&D and NPD portfolio in accordance with capital market growth expectations. In contrast, conventional processes for the selection and evaluation of R&D and NPD projects are generally not capable of valuing decisional flexibility at the different stages to continue or abandon a project. Managers using traditional phase-review processes will favor short-term oriented projects with a relatively low risk over highly uncertain projects with a long-term strategic impact resulting in an R&D portfolio that truncates future growth options. This may result in under-investment in R&D, under-exploitation of technologies and badly timed decisions on investment, disinvestment and outsourcing.

The options portfolio approach captured and visualized by PAT adjusts this shortcoming. At each stage of the development process, management has the opportunity, but not the obligation to step into the next stage. By balancing R&D and NPD option value with organizational risk in a consistent manner and by keeping options open, including the decision to expected option value (p-(V-X)) and the potential option value (V-X), management preferred to use this IRR as a parameter.
refrain from market launch when market and technology conditions turn out to be unfavorable, downward risk is limited while upward potential and shareholder value are maximized.

5 Conclusions and Directions for Further Research

In a joint effort with the Corporate Strategy Department of Philips Electronics I made progress in the process of valuation, selection and monitoring of R&D and NPD projects. We successfully developed an extended scoring method, the Primary Assessment Tool (PAT) that supports management in handling R&D option values and their accompanying organizational risks. At initial stages of development the findings suggest that this fairly simple approach to option valuation and risk management suffices. It captures the flexibility and strategic value of optional decision making in highly uncertain markets and technological circumstances, and highlights that proactive management must secure that competencies are in place when introducing new technologies to the market. As directions for further research I list some practical ways to further develop the tool and its basis of application as well as some interesting directions for empirical research in R&D option valuation.

First of all, the probability of technical and market success used in PAT to calculate the underlying value of the R&D option is based upon market intelligence and (subjective) management estimates. Since these management's judgements yield different observations for the probability that market conditions are favorable and competencies are in place, this probability parameter is a random variable itself. Therefore incorporating more advanced statistical techniques may enhance the straightforward approach outlined. PAT assumes discrete points of the distribution of the underlying value and determines the probability of success of the project as the product of the scores on attractiveness and on competencies. Still, the underlying value may take a wide range (continuum) of possible outcomes and the entire distribution must be considered for a valid option valuation.

One direction that we investigated was to borrow from financial theory and to use the initial Black and Scholes (1973) option pricing formula for real option valuation (see also Luehrman, 1998). However, practical experience suggested that such Black and Scholes type of analysis would lead to unrealistic assumptions about the R&D and NPD process and as a result, a more advanced discontinuous model was derived (Pennings and Lint, 1997). Also, we studied the complex option value of simultaneous product development under the condition that the final product standard was still to be set by the market (Lint and Pennings, 1999). An interesting direction for further research is to capture such complex extensions in PAT without losing transparency.

Moreover, by introducing PAT in other industries, such as Automotive or Pharmaceuticals, the approach can also be further developed and the application base can be
extended. Although the main elements of PAT may stay the same, the current assumption that revenues from sales beyond five years after market introduction can be ignored needs to be relaxed. Technology life cycles in these markets are not as short as in consumer electronics markets that are dominated by excessive price erosion. The same relaxation holds for other applications within R&D and NPD such as using the PAT to assess licensing contracts or the decision to outsource R&D activities that are not considered core competencies. Such arrangements have a long-term perspective and in general the stream of revenues evolves gradually.

Finally, by keeping track of various projects throughout the different stages of development, a rich empirical database can be created for detailed empirical analysis. By classifying a variety of past and current R&D and NPD projects into similar sets of organizational risk and financial returns, heuristics can be derived to assess and select future projects on an option valuation base (see also Newton and Pearson, 1994). Such a database could also be used for empirical validation of the hypothesis that project champions are biased and show overconfidence about a project’s potential revenues (Schoemaker, 1993). Since appropriate use of PAT requires input from different disciplines (R&D, marketing, strategy and finance), keeping track of input data in a consistent and systematic way is facilitated. This way, PAT enables longitudinal research on overconfidence among a variety of real-life projects.
References


Table 1. Main issues from literature and interviews concerning R&D/NPD assessment.

<table>
<thead>
<tr>
<th>A. Initial NPD stages are tentative</th>
<th>D. Capturing expert/senior knowledge</th>
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<tbody>
<tr>
<td>B. Criteria interference</td>
<td>E. Creation of a balanced portfolio</td>
</tr>
<tr>
<td>C. Time-varying character of criteria</td>
<td>F. Transparency/user-friendliness</td>
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</table>
Title

Proposed by: Business owner
PDs involved
External partners

Scope: (scope, strategic fit, USPs, sustainable competitive advantage, entry barriers)

Ambition: Sales potential (Mfl) 4000

Probability of Success: (Calculated by PAT) 47%

Attractiveness:
- Market profitability: 1 2 3
- Market growth: 1 2 3
- Industry concentration: 1 2 3
- Value chain complexity: 1 2 3

rating (Calculated by PAT) 75%

Investments:
- Capital Exp. (Mfl) 400
- Marketing Exp. (Mfl) 1000

Financial Parameters:
- Cost of Capital 15%
- Operational Cash Flow 20%

Option Value: (Calculated by PAT)
- (Cost of the Option) 75%

Timing:
- Philips time to market jan 2002
- Market take-off jul 2002

Business Development graph:
- Stage

Competences/challenge:
- Technology/patent position: 1 2 3
- Production/sourcing/operations: 1 2 3
- Distribution/customer base: 1 2 3
- Entrepreneurial team: 1 2 3

rating (Calculated by PAT) 92.50%

Issues:
- Budget
- Ownership

Figure 1: Data sheet PAT

Figure 2: Portfolio sheet PAT
Figure 3: Project development in time