The V-shaped value evolution of R&D projects

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The V-Shaped Value Evolution of R&D Projects*

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Abstract

On average the expected value at the moment of commercialization of an R&D project should remain constant during the different stages of new product development. Contrary to this intuition however, we find a systematic, non-constant pattern in the average expected value of an R&D project. First, the value declines after the initial screening, then rises after the first market analysis, but on average does not reach the initial level at the final stage of development when resources for market introduction are approved. Moreover uncertainty about the project value declines over time. The findings suggest a V-shaped value function of R&D projects. Our study seems to be the first attempt to make direct measurements of valuing R&D projects through time in a real managerial setting.

I. Introduction

Despite the cornucopia of concepts for R&D valuation developed by practitioners and management scientists about 43% of all newly developed technologies fail during R&D stages, and approximately half of the remaining 57% fails after the R&D stages[1] (Mansfield and Wagner, 1975). The percentages given are average numbers and vary across industry sectors.

Getting right numbers is a first prerequisite for a solid valuation, casu quo financial evaluation of R&D projects during the different stages of development. Obviously, R&D projects are non-tradable assets and their economic value can be based on estimated future cash flows only. Hence, with 'right' numbers we refer to numbers that are right on average. In fact, on average the expected R&D project value at the moment of market introduction (PV) should remain constant during the different stages of development without a systematic pattern. The purpose of this paper is to report the results of tracking the PV of twenty-two recently conducted R&D projects at Philips Electronics throughout the different stages of development.

Contrary to the intuitive of a constant PV, the results from this study, although subject to obvious limitations and shortcomings, show that there is a consistent non-constant pattern in the PV when tracking the PV during the R&D stages. The PV is highest on average at the initial screen of the R&D project, falls down, reaches a minimum and rises until the moment the project is transferred to a Business Unit for commercialization. However, on average, the PV will not reach the value it had at the initial screen.

Mansfield and Brandenburg (1966) first examine the expected profitability attached to real R&D projects directly after an initial screening and demonstrate

[1] No commercialization due to poor prospects or unsuccessful commercialization.

preliminary evidence of differences in estimates by the laboratory and divisions of a firm. Considering the reliability of estimates made before commercialization, Mansfield (1996) finds that firms tend to underestimate (overestimate) the return on new technologies with a relatively low (high) expected return. Though these studies provide insight in the allocation of R&D resources, they are limited to single stage analyses. Bukszar and Connolly (1988) suggest a longitudinal approach to analyze a portfolio of projects whereby each R&D project under consideration is evaluated at several stages of development. To the best of our knowledge, our study is the first attempt to make such direct measurement in a real managerial environment. It should provide us with a somewhat better understanding of the evolution of R&D project value throughout the different stages of development up to the moment of market introduction of the newly developed product or technology.

The paper is organized as follows. Section II describes the sample used for the analysis. In section III, results are presented. Section IV provides some explanations for the findings, and section V concludes the paper.

II. The Sample of R&D Projects

Our study originates from developing a scoring method to support management at Philips Electronics in making decisions concerning R&D projects and New Product or New Business Development. As a complementary result of our research activities, we have gathered a unique sample of project assessments by the assigned project teams for 22 projects during the whole R&D trajectory. We collected the data at four points during the R&D stages. The first point of observation concerns the moment just after the initial screen. The second observation is at the first market analysis, the third point

of observation concerns the start of product testing and the final observation was made at the moment the product was transferred to a Business Unit for commercialization. The points are chosen in order to balance the lengths of the intervals. They are consistent with the established sequential approaches to New Product Development, as for example described in Cooper and Kleinschmidt (1986) and Urban and Hauser (1993). For some projects, the research stages were longer, for others the development stages had a longer duration. The scope of the projects selected covered research topics ranging from advanced materials to multimedia devices.[2]

All selected projects concerned R&D proposals presented to top-management and monitored by an assessment committee at Board of Management level. Therefore, the projects cannot be regarded as randomly selected, but were chosen because of their strategic impact on the company's competitive position. The strategic impact was determined by one or more out of the following five reasons: (a) the total sum of investments in R&D passed a certain financial threshold, (b) commercial exploitation of the envisaged technology required a global standardization procedure, (c) successful R&D required the purchase of all or part of a business, including the purchase of shares, asset-based transactions, (cross-) licensing of patents, and establishment of joint-ventures or mergers that exceeded a certain exposure threshold, (d) the envisaged technology could not be assigned to a single product division (PD) but was of multi-PD interest, (e) commercialization of the technology would imply entering a market new to the company.

Liberatore and Titus (1983) found that conventional discounted cash flow techniques are heavily used to assess the value of R&D projects. In this study we concentrate on the expected value of R&D projects until the moment when the project

[2] For obvious proprietary reasons the full project data cannot be disclosed.

is transferred to a Business Unit for commercialization. PVs are discounted cash flows at the moment of market introduction. All PVs are normalized (initial stage=100) and averaged at four main stages. This methodology implies two important limitations. First, the study does not discriminate between small and large projects. Second, we only consider surviving projects and thus disregard failures. Since the sample only includes projects that went through all four screening points, the sample might be affected by a survivorship bias. However, we did not require a market introduction of all new products. The project values at the initial screen and all other milestones are estimated conditional on a successful ending of the R&D stages and are not multiplied with the probability of success. Moreover, including failures during the R&D stages has obviously a negative impact on the project value at each point. Hence, this would only strengthen our results that project values -on average- deteriorate after the initial screen and will not reach the initial level.

Through a uniform Excel-spreadsheet (see figure 1), filled out at the various points during the R&D stages, we get the project value of each individual project[3]. The project team consisted of members from different backgrounds. The diversity of the project team prevents cognitive dissonance (Festinger, 1957). Cognitive dissonance concerns the fact that after a complex decision the reasons in favor of the choice made are given more weight by a decision-maker than before that decision. Similarly, the reasons that were against the choice made are given less weight by a decision-maker after the decision compared to the situation before the decision. Cognitive dissonance would be relevant when a sole project champion would be

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[3] Apart from quantitative data, the spreadsheet includes qualitative questions about the team, competitors, entry barriers, etc., but a discussion of these elements is beyond the scope of this article. We merely state that they are part of the scoring method developed.

responsible for judging the project since he might show irrational persistence. A sole project champion could persist in his belief in the potential of an R&D project under his responsibility, and may disregard important aversive objections.

---------- Please insert figure 1 here ----------

After normalizing we calculate the percentage change in the project value between the initial screen and the first market analysis and add this percentage change to 100. This way, we get the normalized value at the second milestone. The normalized project value at the third and fourth milestone are obtained by calculating the percentage changes in the project values between the initial screen and the beginning of product testing and commercialization respectively and adding these percentages to 100. Therefore, the project values at the various milestones are relative to the project value at the initial screen.

III. Results

The average project value and the average project value minus and plus 2 times the standard deviation of the average value at each milestone are depicted in figure 2. Table 1 reports the average project values and the standard deviations of the average project value. Since the project values are relative to the value at the initial screen, the standard deviation of the project value at the initial screen is zero.

---------- Please insert figure 2 and table I here ----------

As indicated in table I, the project value falls by approximately 25% after the initial screen. Assuming a normal distribution of the observed project values, we find that the project value at the second milestone is significantly less than the project value at the initial screen. The hypothesis that the average project value is equal to 100 is rejected at the $\alpha = 5\%$ significance level.

After the decrease in project value, the average value increases, but still we reject the hypotheses that the average value at the third and fourth milestones equals 100.[4] To be more precise, only 4 out of 22 projects showed an increase in value.

Considering the increase in the mean between the second and the third milestone, we normalize the second milestone. We find that the mean at the third milestone equals 123.18, and its standard deviation is 6.90. By verifying the hypothesis of a significant change in the mean between the second and the third milestone, we find that the hypothesis that the mean does not increase between the second and third milestone should be rejected at the 95% level of confidence.

The same test is also performed between the third and the fourth milestone. Normalizing the third milestone, we find that the mean at the fourth milestone is 100.36, its standard deviation is 1.55. We find that the hypothesis of an increasing mean between the third and the fourth milestone cannot be rejected. Another interesting aspect is the reduction in uncertainty about the project value during the R&D stages. When the project values at each milestone are independent, table 1 shows that the uncertainty moderately decreases over time. A more realistic assumption would be that the project value at stage x is dependent on the project value at stage x-1. So, PV(x)=f(PV(x-1))+RV(x) where f(.) is some function and RV(x) is a

[4] The t-statistics are respectively -3.00 and -2.95. So, although the project value rises after the first market analysis, it does not reach the initial level.

state-contingent linear and independent disturbance (random variable). As a result of normalizing the first milestone -the initial screen- we get RV(1)=0. The more the project value depends on the previous project value, the more persistent the past disturbances, and the larger the decline in uncertainty about new disturbances. This becomes paramount when correlation between the disturbances is high.

IV. Explanations of the V-shaped Pattern

From psychology we single out three factors as explanations for the finding of the V-shape. The first of these factors concerns the calibration of probability judgments. In particular with respect to high-confidence judgments, subjects show overconfidence (Fischhoff, Slovic and Lichtenstein 1977). Overconfidence may exist during the approval stage of the project when resources are committed to R&D initiatives. This resource allocation entails a sunk cost (capital budgeting) decision by the management. For approval, a project champion has to demonstrate the potential of his project in order to pass a certain financial or weighted mutli-criteria threshold. The project champion will be optimistic about the technical development and the market potential of the R&D project. Schoemaker's (1993) empirical results on overconfidence show that managers are inclined to make estimates in too narrow ranges, i.e. they are unjustifiable certain of their estimates.

One might argue that the project champions in our sample overvalued their projects at the first milestone on purpose in order to "sell" the project to the management, while knowing in advance that their estimates were beyond reality. However, all project teams were familiar with the fact that the management would keep track of their estimates throughout the different stages of R&D. It is reasonable to expect that this would motivate the project teams to be consistent in their estimates.

Obviously, management would ask for detailed explanations if the estimated value of a project would be substantially lower at the second milestone[5]. Therefore, we do not consider the optimism or overconfidence at the first milestone to be motivated by the "selling" argument. In accordance, Tetlock and Kim (1987) demonstrate that external accountability reduces unrealistic optimism.

A second factor that psychologists have emphasized as a determinant for an inconsistent pattern of value estimation is illusion of control (Langer, 1975), which is likely to play an important role when the research and development stages unfold. Illusion of control concerns the finding that subjects think they have (some) control over the outcome of events even when they have no control at all. The project champion and other team members may over-estimate their span of control. When more (non-controllable) obstacles -technology or market-related events[6]- that have a negative impact on the expected value of future cash flows confront the project team than expected, the PV will show a decrease. Feather (1969) has initially pointed out that one's satisfaction with a particular outcome is influenced by the expectations of that outcome. Subsequently, Pyszczynski (1982) and Diener et al. (1991) discuss that the impact of negative outcomes on the level of dissatisfaction is larger when these outcomes were unexpected than when they were expected.

Defensive pessimism is the third factor that we borrow from social psychology to explain the V-shape. We observe that the estimate at the second milestone is even

[5] Absent major negative technological or market events.

[6] For example, in a detailed analysis of the project value of one of the projects under consideration, Pennings and Lint (1997), and Lint and Pennings (1998) found 17 exogenous, historical technology and market events during a five-year period that appeared to have a substantial impact on the R&D project value.

below the "objective"[7] project value at the stage of product testing. The reason for the transition from optimism (overconfidence) to pessimism (underconfidence) is that the project team gets anxious that their estimate of the value of the project will appear beyond reality as measured by the first market analysis. When the moment of first market analysis comes closer, the project team will substantially lower the estimate of the project value in order to avoid deception, resulting in negative affect (Feather, 1969).

Sheppard, Ouellette and Fernandez (1996) find in an experiment among students concerning the estimation of scores on a classroom exam that the temporal proximity of feedback determines the evolution of the estimates. They asked estimates at four points in time: 1 month before the exam date, right after the exam (5 days before feedback), 50 minutes before feedback, and 3 seconds before feedback. Their results show the following systematic pattern: overconfidence before the exam (Time 1), much lower yet more accurate estimates at times 2 and 3, and underconfidence (a significantly lower estimate than the students actually received on the exam) at Time 4. It should be noted that the participants did not get any new or additional information concerning the exam between Time 3 and Time 4. The temporal proximity of feedback information motivated participants to lower their estimates to a level significantly below the actual level in order to avoid disappointment.

After the second milestone, the estimate of the project value is adjusted in accordance with the results from the first market analysis, resulting in an increase in PV between the second and third milestone. We consider the third milestone as the

[7] Given that the company has judged the project several times at the stage of product testing, the value at this stage can be regarded as the most objective estimate of the project value.

most accurate estimate of project value, given that the company has processed most of the information concerning the potential of the project at this stage.

It is surprising to observe a further increase in the estimated project value between the third and fourth milestone. The evolution from an accurate estimate to an optimistic perspective can be explained as follows. As the project has survived during the different stages of development so far, the moment of transition to a Business Unit and subsequent commercialization of the R&D results comes closer. The decision by the Business Unit to adopt the project and to introduce the newly developed technology or product to the market is a capital budgeting (sunk cost) decision. A project team typically shows enthusiasm when the R&D stages have been completed successfully and the project is adopted for commercialization. The project team may be inclined to overvalue the project and this will result in overconfidence. However, the level of overconfidence is lower at the final R&D stage than at the initial stage.

V. Conclusion and Implications

Often, R&D management intends to build a balanced portfolio of R&D projects. The results in this article show that management has to take care in comparing R&D projects at different stages. Overconfidence seems to give an upward bias in the project assessment at the first and fourth stages in which there are capital budgeting decisions. In between these stages illusion of control and negative affect explain the decrease of the project value.

More specifically, the findings from our study represented in table I can be used to debias the value of R&D projects at the different stages of development. Given that the value at the moment of product testing can be regarded as the most objective estimate of the project value, our findings indicate that the project value –

contingent on technological and market success- should be adjusted in downward direction by 11% at the initial screen and in upward direction by 18% at the first market analysis.

We think we made progress by screening 22 real project values from the initial assessment to their transferal to a Business Unit in a real decision making setting. The study suggests directions for further research on the expectations of R&D project values over time, first of all for the study of the project value after transfer to a Business Unit and commercialization. It would not surprise us when illusion of control and negative affect would again negatively influence the project value. In this case, the perceived overconfidence could explain the large number of business failures that arise in the real world, although these products have been subject to extensive market studies.

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Table I. The mean and its standard deviation throughout the R&D stages.

	Initial Screen	First Market Analysis	Product Testing	Transferal
Mean	100	75.18	88.68	89.00
Standard Dev.	0	3.94	3.77	3.73

Figure 1

TITLE:

DATE:

Proposed by — Affiliation
Business owner — Affiliation
PDs involved — Source R&D
External partners — Source Strategy

Vision (scope, strategic fit)

Ambition: Sales potential (Mfl)
(5 yrs after market intro)
Project Value at Market Launch

Attractiveness:

	0	1	2
Market profitability:			
Market growth:			
Industry concentration:			
Value chain complexity:			

rating *(calculated by PAT)*

Competencies/challenge

	0	1	2
Technology:			
Production/sourcing/operations:			
Distribution/customer base:			
Entrepreneurial team:			

rating *(calculated by PAT)*

Issues

Investments: Capital Exp. (Mfl); Marketing Exp. (Mfl)

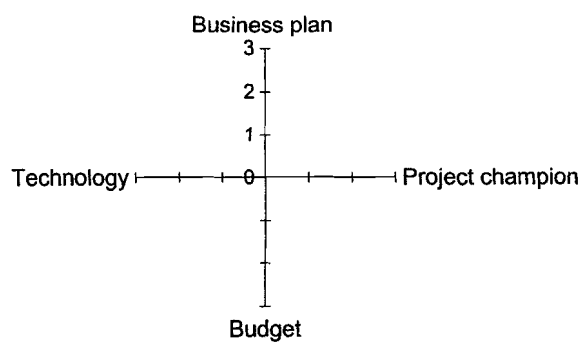
Financial Parameters Cost of Capital; Operational Cash Flow

Net Present Value

R&D Exp. (Mfl) (Cost of the option)

Timing: Philips time to market

Business Development Graph: Stage



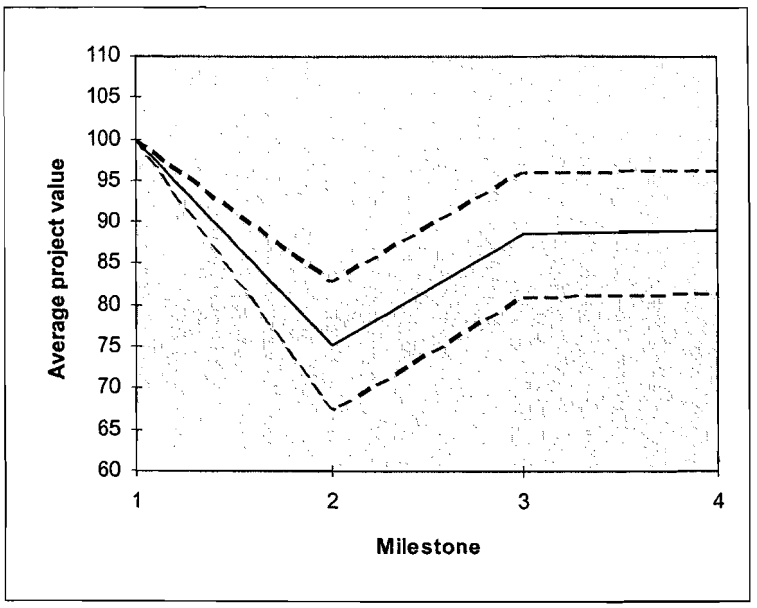


Figure 2: The solid line represents the average project value during the R&D stages.

The dotted lines represent the 95%-confidence interval.