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Using decision analysis to value R&D projects

Bert DE REYCK

Singapore Management University, bdreyck@smu.edu.sg

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by Bert De Reyck

EXECUTIVE SUMMARY

- Valuing R&D projects is a critical component of project portfolio management.
- Traditional methods for valuing financial assets cannot be easily used for valuing R&D projects, as they are very different in nature.
- Decision analysis is widely used for valuing projects in R&D-intensive industries such as pharmaceuticals and energy.
- Using decision trees, one can determine a project's expected net present value (eNPV) and downside risk, two essential ingredients for determining whether or not to proceed with the project.

INTRODUCTION

Project portfolio management, the equivalent of financial portfolio management but focused on R&D projects rather than financial assets, often relies on decision analysis methods to value projects rather than traditional financial valuation methods such as net present value (NPV). In finance, the idea of managing portfolios of assets goes back a long time, with the first formal methods being developed in the 1950s. Simply put, assembling a portfolio of stocks, bonds, and other financial instruments balances the risk a manager is taking with any one of the investments. Over time, this same idea has also taken hold for managing a portfolio of R&D projects, where it is referred to as *project portfolio management*.

Project portfolio management considers the company's set of projects in a holistic way, providing an overview of the potential value, as well as the inherent risks of both the projects a company is currently engaged in and those it plans to initiate in the future. By means of project portfolio management, risks can be reduced through diversification of the product portfolio and value enhanced by identifying synergies between projects. Companies in the pharmaceutical and energy industries, for instance, have long recognized the value of project portfolio management, and they are using sophisticated methods and software tools to support this process.

Project portfolio management comprises the following functions:[1]

- determine a viable project mix;
- balance the portfolio;
- monitor the projects in the portfolio;
- analyze and enhance project performance;
- evaluate new opportunities against the current portfolio, taking into account capacity and funding capabilities;
- provide information and recommendations to decision-makers.

THE DIFFERENCE BETWEEN FINANCIAL AND R&D PORTFOLIO MANAGEMENT

Financial portfolios and project portfolios are very different in nature. The main characteristics of investing in financial instruments include:

Divisible investments: Financial instruments allow investment in small portions of an asset, rather than being all or nothing.

Simple interdependencies: The interrelationships between different investment opportunities can typically be captured by: The correlation between the assets' returns; and their financial value, as established by the financial markets.

Passive participation: Investing in financial instruments is typically a passive form of participation: The decision is mainly whether or not to invest, and how much.

Availability of information: Much information is available about financial assets in the form of historical performance and fundamental analyses concerning the future outlook.

Tradability: Most financial instruments are tradable assets, resulting in agreed-on valuations and opportunities to sell assets that do not fit your portfolio.

Clear objectives: The main objective is to maximize the risk–return performance of your portfolio.

Contractual clarity: Clearly defined terms exist for investing in a financial instrument, outlining the rights of the parties involved relying on established market rules.

These characteristics are not shared by a portfolio of R&D projects, which can be characterized as follows:

Discrete investments: Investments in projects are nondivisible, increasing the impact of an investment decision on your portfolio.

Complex interdependencies: Complex interdependencies and interactions exist between projects. Project outcomes are subject to synergies—for example, through the sharing of proprietary knowledge—and investment decisions may affect the options available in related projects.

Active participation: Investing in projects requires active management. Besides making a go/no-go decision and setting a budget, numerous decisions will have to be made during the project lifetime that will impact the outcome.

Lack of information: Since projects are largely unique, not much information is available on related past projects or for the prediction of future performance.

Nontradability: Projects cannot be easily sold, resulting in a lack of valuation information and lock-in situations.

Fuzzy objectives: Projects are typically governed by a multitude of objectives, both financial and nonfinancial, and typically include qualitative objectives.

Contract ambiguity: Project investments may result in disagreement concerning who is entitled to which benefit, with multiple stakeholders holding different views.

As a result, conclusions derived from finance cannot simply be transferred to other areas, nor can their methods be used without adaptation. That is why a variety of approaches have been proposed for valuing R&D projects, which is *the* central issue in managing a portfolio of R&D projects. The most commonly used is *decision analysis*, in which decision trees are used to represent the project's potential outcomes and their likelihood.

DECISION ANALYSIS: A DEFINITION

A central component in decision analysis is the concept of a decision tree. An example of a decision tree is given in Figure 1. In the figure:

- The squares, circles, and triangles represent points in time, which proceeds from left to right.
- The squares, or decision nodes, indicate decisions to be made, and the circles, or chance nodes, indicate the time when the result of an uncertain event becomes known. The triangles, or end nodes, indicate the end of the time horizon.
- The branches indicate the stage that follows, depending on which decision is made or which scenario unfolds.
- A probability is given on top of each branch that emanates from a chance node. This indicates the likelihood of that particular outcome materializing, given that all the preceding steps have already happened. These uncertainties are outside your control. The probabilities of all the branches emanating from a chance node sum to one.
- Below each branch that emanates from a decision or chance node a monetary value can be added to indicate the cash in- or outflows associated with that particular decision or outcome.
- To the right of the end node two numbers are shown, the upper one representing the likelihood of ending up in that particular scenario, and the lower one the cumulative monetary value.

A key insight resulting from a decision-tree analysis is the so-called *expected value*. Starting at the right of the tree and working back to the left, we perform two types of calculations:

- At each chance node (circle), we compute an expected value as the sum of the probability-weighted expected values associated with the successor nodes.
- At each decision node (square), we determine the highest expected value of the successor nodes. The branch(es) resulting in the highest expected value are indicated by "TRUE," the others by "FALSE," indicating a preferred set of actions based on maximizing the expected value of the project.

Continuing this process, we arrive at the root node of the tree with the *expected value* of the decision tree. The term "expected value" is rather confusing, however, as this value should never be *expected*. In fact, it may even be impossible to obtain, and is merely a probability- weighted average of all the potential outcomes.

USING DECISION ANALYSIS TO VALUE R&D PROJECTS

Decision trees are a natural tool to value R&D projects, as these projects typically consist of several phases. Each project phase can be associated with a stage-gate, a point at which one decides whether or not to continue with the project, depending on the results of the earlier phases and new information obtained about the future. The results of each stage can be represented by a chance node in a decision tree, with the option to abandon the project as a decision node. Other chance nodes can be added to represent possible competitor actions, legislation uncertainties, and global economic conditions. Decision nodes can be added to represent different possible actions, including the injection of more funds and resources in case of favorable developments, accelerating the project to bring forward its market launch date, etc.

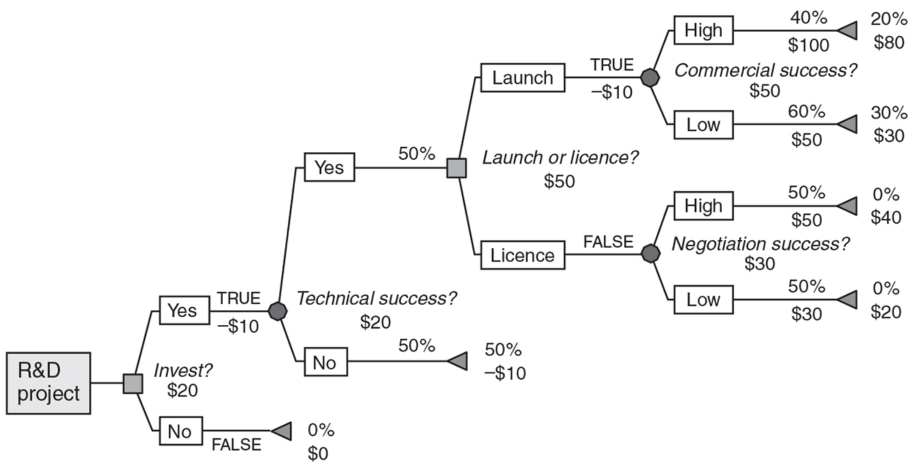

Figure 1. Example of decision-tree analysis for a R&D project

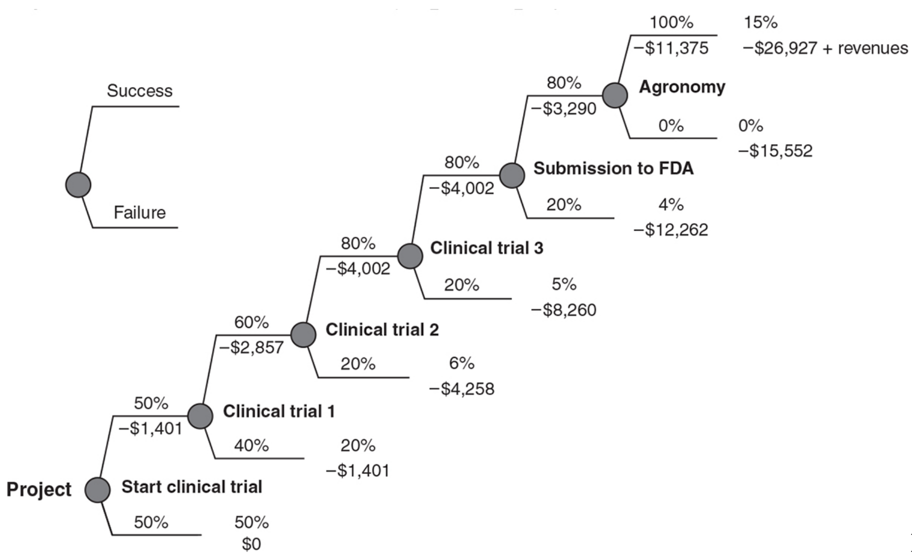

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Figure 2. Decision tree for the Phytopharm project

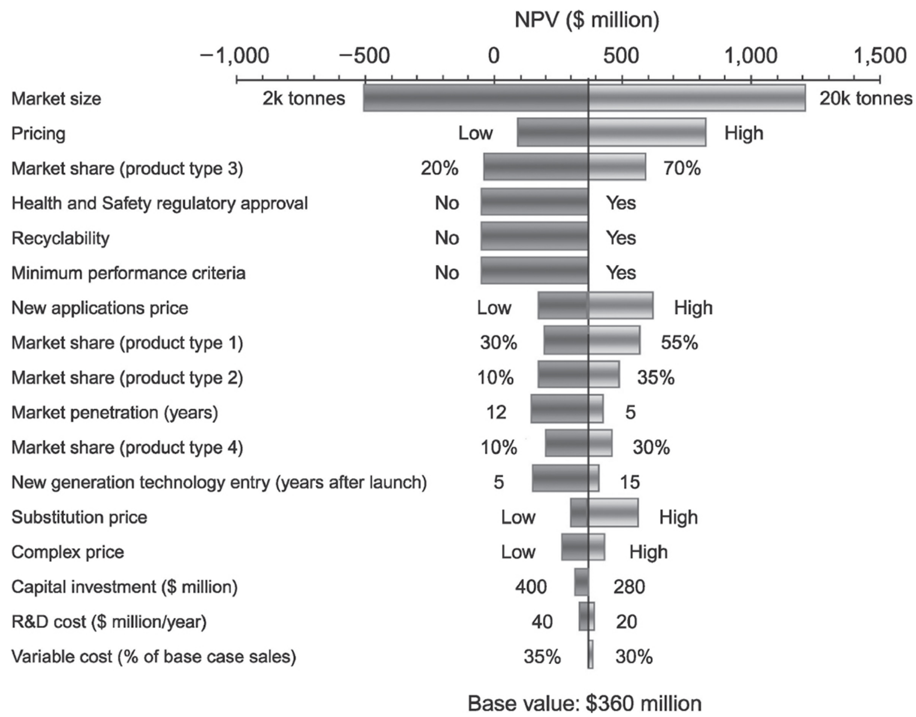

Figure 3. Example of a tornado diagram

As R&D projects typically take several years to complete, it is essential that the cash flows in the decision tree are discounted at an appropriate rate to take into account the firm's cost of capital. As each chance and decision node corresponds to a point in time, this can be accomplished by discounting each cash flow associated with a chance or decision node appropriately. When all cash flows are discounted, the expected value will then become an *expected net present value*, or eNPV.

Again, the eNPV should not be expected, but is merely a probability- weighted average of all the potential results, discounted at an appropriate cost of capital. Nevertheless, the eNPV is a crucial number, indicating the value of the project, because it considers all possible scenarios and how likely they are. In principle, if the eNPV of a project is positive, the project will add value and should be undertaken. Although for a one-time project the eNPV should not be expected, the strategy of pursuing projects with positive eNPV will, in the long run, result in the highest possible profit for your organization. If, however, the eNPV is negative, other and better uses for the required funds and resources can be found.

A second deliverable of a decision-tree analysis for R&D projects, apart from the eNPV, is the risk profile, which shows the potential outcomes and their likelihood. Of particular interest is the potential downside, the worst possible result with a nonzero likelihood. If this downside is large enough to cause potential financial distress to the company, then perhaps the project should not be pursued after all, despite a potential positive eNPV. If the worst-case scenario is very unlikely, another useful metric can be used, namely the value-at-risk (VaR). The VaR indicates the loss that could result from a project with a certain probability, for example 5%. So if the VaR of an R&D project is $10 million, this means that we estimate a 5% chance of losing $10 million or more if we pursue the project. Again, this could be a reason for rejecting a project that would otherwise be interesting (because of a positive eNPV), depending on the risk appetite and liquidity of the company.

CONCLUSION

Decision analysis and decision trees are widely used for valuing R&D projects, because they are ideally suited to deal with the phased nature of R&D investments. Traditional financial valuation methods are based on assumptions that are not realistic in a R&D environment. The key deliverables of a decision-tree analysis of a R&D project is the project's expected net present value (eNPV) and its value-at-risk (VaR), two crucial criteria when deciding whether or not to pursue a project and include it in the organization's portfolio. The general rule is that the eNPV should be positive, and the VaR not so high that it may cause financial distress in case of an unfavorable outcome.

CASE STUDY

Phytopharm plc

All of the world's leading life sciences companies use decision-analytic approaches to value their portfolio of R&D projects. In fact, many have a decision-analysis group, responsible for reviewing the R&D portfolio. They typically use a wide variety of criteria to assess R&D projects, including financial value measured by the projects' net present value, sales, and growth potential, with a special focus on potential blockbusters, pipeline balance over time and over different therapeutic areas, risk, unmet medical need, and strategic fit, expressed as a desire to build strength in certain therapy areas. An array of tools is used to support this analysis, including net present value, decision analysis, and Monte Carlo simulation.

Before a pharmaceutical drug can be approved for production and marketing, stringent scientific procedures must be followed in several stages to ensure patient safety. The drug development process is typically composed of basic research (approximately two years), preclinical testing (approximately three years), clinical trials (approximately six years, consisting of phases I, II, and III), followed by a review by regulatory authorities. A new pharmaceutical drug that is being investigated can fail to make it through any one of these stages due to potential harmful side effects or insufficient proof of effectiveness. On average, only one in five medicines that enters clinical trials is launched; and only 1 in 10,000 compounds in the research phase makes it to the market.

Due to the massive resources required to perform the late-stage clinical trials, smaller firms such as biotech companies or university spin-offs typically only perform the first steps of pharmaceutical research and development. If the product passes these first few stages, the product is outlicensed to partners with the financial, R&D, and marketing capabilities to further develop and launch it in the market. This was the case for Phytopharm plc, a pharmaceutical and functional food company based in Cambridgeshire, England.

Several years ago, Phytopharm acquired the exclusive license to develop and market a natural appetite suppressant derived from the *Hoodia gordonii* succulent, a cactus that grows in the Kalahari Desert. In 2004, Phytopharm's senior management was preparing to start negotiations for outlicensing this product, which had shown promise in early pre-clinical and clinical trials and successfully passed proof-of-principle. Although Phytopharm's senior management was confident that the product could be very successful, it needed a comprehensive and flexible methodology to rigorously predict and value the product's potential. A choice was made to use decision analysis as it provided transparency and flexibility, useful characteristics in a negotiation environment.

Figure 2 shows how the project was represented as a decision tree, with the different chance nodes corresponding to the different stages that had to be successfully navigated before the product could be marketed (all numbers are disguised and for illustrative purposes only). Decision nodes (not shown) could be added to represent decisions such as abandoning the development in case of unfavorable clinical trial results or commercial outlook, or choosing between different alternative technologies or markets.

In December 2004, Phytopharm licensed the product to Unilever for $40 million and an undisclosed royalty on the sales of all products containing the extract. Unfortunately, in November 2008, Unilever decided to abandon the product due to a recent clinical study that provided unsatisfactory results. This possibility was foreseen in the decision-tree analysis, and had been incorporated when calculating the project's value at the time of licensing[2].

MAKING IT HAPPEN

There are several challenges when using decision trees for valuing R&D projects. For example:

- Which discount rate should be used? Traditional finance theory suggests that a discount rate should be used that reflects the cost of capital of a typical project. The question, however, is what to do when a project is not very typical. And what if the risk changes profoundly over the life cycle of the project? These issues are currently the topic of heated debate, both in R&D organizations and business schools. Note, however, that since the possibility of failure is already explicitly included in a decision-tree analysis, this risk should not be used to further increase the discount rate used to evaluate the project. The only risk that should be considered is the nondiversifiable market risk of the project, i.e., the correlation of the project and market returns.
- When a project contains many stages, with numerous uncertainties and possible decisions, a decision tree can easily "explode" and become unwieldy. Therefore, it is recommended that before carrying out a decision-tree analysis, a sensitivity analysis is performed to determine the main causes of uncertainty, which can then be incorporated in the decision tree. A so-called tornado diagram, which visualizes the key risks in a horizontal bar chart that resembles a tornado, can be used to determine these key risks. An example is shown in Figure 3.
- The validity of any conclusions drawn from a decision analysis depends heavily on the quality of the information used in the analysis. The principle "garbage-in-garbage-out" applies in this context. A common issue that has been observed is the tendency for people to be overconfident, in the sense that we all typically underestimate the magnitude of risks that we are facing. This has led to many criticizing the value-at-risk concept for performing a financial risk assessment, as none of these models could predict the magnitude of the current financial crisis. Therefore, it is essential that sufficient attention is paid to the quality of the data used in the analysis.
- A chance node in a decision tree can distinguish several possible outcomes, but it cannot specify a continuous range of outcomes. This, of course, can be approximated by defining numerous separate outcomes, but doing this will result in the tree "exploding." A better approach is to combine decision-tree analysis with a Monte Carlo simulation, which is ideally suited for analyzing risks with a continuous range of potential outcomes.

MORE INFO

Books:

Savage, Sam L. *Decision Making with Insight*. 2nd ed. Cincinnati, OH: South-Western College Publishing, 2003.

Winston, Wayne L., and S. Christian Albright. *Practical Management Science*. 3rd ed. Cincinnati, OH: South-Western College Publishing, 2006.

Websites:

Decision Analysis Society, a subdivision of the Institute for Operations Research and Management Science (INFORMS): decision-analysis.society.informs.org

Palisade Corporation, a provider of decision-analysis software, used to create the examples in this article: www.palisade.com

Strategic Decisions Group, a strategy consulting firm specializing in decision analysis and founded by, among others, the father of decision analysis, Professor Ronald A. Howard of Stanford University: www.sdg.com

See Also:

- Real Options: Opportunity from Risk
- Reinvesting in the Company versus Rewarding Investors with Distributions
- Analysis Using Monte Carlo Simulation
- Understanding Decision-Tree Analysis
- Understanding Real Options
- Understanding the Weighted Average Cost of Capital (WACC)
- Amos Tversky

NOTE

1 Kendall, Gerald I., and Steven C. Rollins. *Advanced Project Portfolio Management and the PMO: Multiplying ROI at Warp Speed*. Boca Raton, FL: J. Ross Publishing, 2003.

“It ain’t what you don’t know that gets you into trouble. It’s what you know for sure that just ain’t so.” Mark Twain

“If a man will begin with certainties, he shall end in doubts, but if he will be content to begin with doubts, he shall end in certainties.” Francis Bacon

“Profits arise out of the inherent, absolute unpredictability of things.” Frank Knight

“Chance favors only the prepared mind.” Louis Pasteur