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BUSINESS APPRAISAL OF TECHNOLOGY POTENTIALS: VALUING TECHNOLOGY

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ABSTRACT

The issue of assessing technology for business application remains a foremost concern for managers in industry. In practice, many managers know that there is something unsatisfactory about the standard use of Discounted Cash Flow (DCF) techniques, particularly when there is high uncertainty and a need for strategic flexibility. This is of central concern in the choice of development projects and when considering the acquisition of technology external to the firm. Recent advances in options and hybrid-model thinking have opened up new paths, but the application of these ideas in practice has been very limited.

This paper reviews the literature and practice in the field of technology valuation in the context of a "timeline" from early-stage technology to more mature technologies. This perspective is used to analyse the findings of recent interviews held with a range of companies to review the tools and techniques currently available to managers for the assessment of technology for business purposes, and identify gaps and limitations of these approaches. New approaches are proposed which integrate and complement existing tools and techniques to fill these significant gaps along the timeline. In the ongoing research project these developing tools will be applied in selected case examples to provide guidance to potentials users.

Keywords: technology, valuation, assessment, uncertainty, tools, techniques, options

INTRODUCTION

The many new manifestations of technology and the increasing intensity of technological development ensures that the issue of assessing technology for business application remains a foremost concern for managers in industry. In this environment companies may wish to diversify or focus their portfolio of technology as well as accelerate commercial exploitation. In addition there is increased trading of technology between firms and a wider range of acceptable business models and sources of finance (Arora *et al.* 2001). Consequently assessment and valuation techniques are assuming a greater importance in the development and acquisition of technology.

The financial value of technological projects or investments is difficult to ascertain because they are highly uncertain. Technology projects typically require sequential investments and projected rewards may not be realised until the final investment is made. In addition, as technology is inherently uncertain, recognising value in threats and opportunities arising from future events, and incorporating flexibility into managerial action in response to them, is essential. In practice, many managers know that there is something unsatisfactory about the standard use of Discounted Cash Flow (DCF) techniques, particularly when there is high uncertainty and flexibility (Faulkner 1996). Approaches such as those based on real options theory (e.g. Van Putten and MacMillan 2004) offer a way in which this flexibility value can be captured, while approaches that include qualitative aspects (e.g. Utunen 2003) take into account the complementary skills required to realise potential value. These are both necessary inputs to the decision making process for investing in promising technologies. However it is recognised that very few companies use non-financial tools and techniques to support technological decision making (Cooper *et al.* 1997). This may be due to a lack of awareness of what is available but perhaps also due to a lack of understanding of what tools may be most appropriate and how to use them.

To address this difficulty, there may be advantages in taking a time-based view of valuation decisions and tools, as views of risk and uncertainty change with technological maturity and the suitability of tools depends on the type of data available when they are used. Hence this paper reviews the literature and draws upon preliminary industrial interviews to develop the view of a simple "timeline" from early-stage technology to more mature technologies. The aim is to start a process of raising awareness of the underlying assumptions for the appropriate use of existing tools and to establish characteristics of new tools to fill current gaps.

REVIEW OF LITERATURE AND PRACTICE

Valuation of validated technologies

Capital expenditure decisions and business forecasting, including preparation of contracts, involve technology valuation. Typically such evaluations are carried out where there are known capital costs and where income streams can be estimated with some confidence. A ratio such as IRR or payback period in years is often fixed within an organisation and used to prepare a proposal based on discounted cash flow (DCF) using net present values (NPV). The proposal needs to meet the funding criteria to be awarded sufficient resources.

This process sounds straight forward but in reality the practical knowledge and intuition of financial managers based on experience are essential in successful financial decision-making. However, it is not easy to model and utilise this tacit knowledge. Expert systems can be used to capture this knowledge in a formalised manner. Once the expert knowledge is captured, it can be retained using different techniques. These systems facilitate knowledge sharing by multiple decision makers, help provide consistent results and reduce cycle time in the decision-making process. Rule-based reasoning (RBR), case-based reasoning (CBR) and artificial neural networks (ANN) are just three techniques widely used in the development of expert systems. Nedovic *et al.* (2002) surveys various expert systems in the domain of finance.

In the valuation of information technology and advanced manufacturing technology investments, the intangible benefits of the potential technology should be taken into account as the traditional economic analysis alone may not be sufficient to make a fair appraisal. Ordobadi *et al.* (2001) have developed a System Wide Benefits Value Analysis (SWBVA) using fuzzy expert system to assist decision makers facing such a problem.

Summary

For technologies that have been validated by previous application, the valuation process helps to justify proposed project spend. Tools include financial methods such as ratios, discounted cash flow and net present value. A weakness appears to be the lack of a structured way of taking past experience into account. Approaches that may help to fill this gap include case based reasoning and analysis of system wide benefits.

Valuation of early-stage technologies

There are recognised drawbacks in using the tools discussed above for the valuation of early-stage technologies (Hunt *et al.* 2004). There is value in waiting for more information and this value is not incorporated in the DCF calculation (Dixit and Pindyck, 1995). In addition the valuation process can be manipulated resulting in the decision process lacking credibility (Amram and Kulatilaka, 1999) and it is argued (Baldwin and Clark 1994) that firms have missed growth opportunities because they used traditional valuation tools. Valuing technology is seen as more of an art than a science and although methods have been developed from tools used to value tangible assets there is a need to include more qualitative approaches.

However in recent years the search for new methodologies has resulted in considerable attention on the options-based approach. Bernstein (1992) wrote that options can be used to control risk at a cost, losses can be limited while upsides can be magnified and "this is the most attractive feature of options". When financial options theory is adapted to real assets such as technology, it is known as real options and whether this may enable a more realistic process to be designed for valuing risky technological projects has been a subject of significant debate.

The term “real options” is used describe a range of ideas. Three of these are as follows:

- options thinking – being aware of the value of informed managerial flexibility
- decision tree analysis – quantifying the value of choices given a range of different possible outcomes
- real option valuation – adapting mathematical models from the financial markets

A fundamental idea behind so-called options thinking is that uncertainty can be good. This is so if a manager has the flexibility to amplify the benefits if things turn out well and minimise the negative effects if they do not. Mitchell and Hamilton (1988) make this point in the context of R&D, dividing projects into three types: knowledge gathering, investments and strategic options. MacMillan and McGrath (2000; 2002) further distinguish between options with high market uncertainty and ones with high technical uncertainty. They then suggest an appropriate balance of options and guaranteed investments for an R&D portfolio. Morris et al (1991) rehearse the basic argument why options thinking provides a more realistic assessment than (the naïve use of) discounted cash flows.

Decision tree analysis attempts to quantify options thinking. It classifies possible future outcomes e.g. a research project failing, producing a reasonable result or producing an exceptionally good result. It then ascribes probabilities to these outcomes, by some means e.g.

past data on similar projects or expert opinions. This can be done for a series of events e.g. the research project then the market launch, and from these a tree of outcomes can be constructed. Next decision points need to be inserted and the optimal decisions chosen to maximise the expected value. A criticism commonly levelled at decision tree analyses is the reliability (and meaning) of the probabilities. Loch and Bode-Greuel (2001) report on a real example of using a decision tree for evaluation pharmaceutical research projects.

Real options valuation is the term usually used for mathematical evaluation techniques inspired by the modelling of options on the financial markets. Particularly well known is the model produced by Black, Scholes (1973) and Merton (1973). This model assumes that the price of an asset on the stock market can be modelled as a type of random walk. It then derives a price for an option on this asset e.g. the right to buy a share in three months time at a guaranteed price. It does this by constructing an instantaneously risk-free portfolio i.e. one whose value is not affected by variations in the price of the asset, and then arguing that this portfolio must have the same price as other risk-free assets. There are examples of investigative application of real options to R&D in industry. Lint and Pennings (2001) describe a model at Philips, though it is unclear how useful it is. Jensen and Warren (2001) investigate applying real options to service offerings at BT. In general (and obviously) the financial modelling approach described in this section will be useful if the model is a good fit to the situation being modelled. Boer (2000) distinguishes market risk and technical risk and gives examples of where the main risk is market risk and real options models seem appropriate.

In conclusion, the term real options is used to describe various ideas, but the common essence of all of them is that uncertainty is not necessarily a bad thing. Incorporating uncertainty into calculations is not always readily accepted by managers (Boer 1999). But if it is done well it should lead to better understanding of the value of an investment.

Summary

In considering early-stage technologies, the valuation process acknowledges uncertainty, helps to “shape” strategy and technologies should be chosen to give strategic flexibility. Tools include decision trees, real option evaluation and perhaps most importantly, the mind set of ‘options thinking’. A gap appear to be visualisation and communication techniques that will stimulate options thinking without focusing on unknown probabilities.

Valuation of technologies falling between validated and early-stage classifications

Hybrid models are useful here and are often part of a portfolio approach. These may include elements of financial ratios and cash flows, options thinking and scorecard methods - all are useful. An example of a hybrid model is the concept 'Total project value' with a formula including elements of NPV, options and residual value (van Putten and MacMillan 2004).

Portfolio management is a decision process where a business's list of active new products and R&D projects is constantly updated, reviewed and revised (Mitchell, 2005). In this process, new products are evaluated, selected and prioritised; existing products may be accelerated, killed or de-prioritised (Cooper *et al.*, 2001).

Selecting a portfolio is in theory merely a question of optimising profitability within constraints of resources and timing. Well-proven mathematical techniques are available for doing this (Graves 2000) but, as several authors have observed (Cooper *et al.* 2001; Tritle, Scriven and Fusfield 2000) they are seldom used in practice. There are two key reasons for this: the first is that the financial information required for the analysis is often incomplete or unreliable, especially in the early stages. The second is that the selection process tends to be hidden by the mathematics. Managers cannot readily review or justify the results; nor amend them to take account of factors not explicitly included in the calculations. In practice there is therefore a preference for more transparent techniques.

Any portfolio management process must start with an evaluation of the potential worth of each of the projects under consideration. Financial analysis suffers from the fundamental problem that the data required may be unavailable, or of dubious quality, especially in the critical early stages. For this reason many companies prefer to replace, or at least supplement, it with a scoring method. In this projects are assessed and scored according to a range of criteria regarded as predictors of success. For example scores may be given for unique product features, size of market, the ability to leverage the company's core competences etc, as well as the planned cost and profit. The criteria may be very broad, reflecting what is known in general about success criteria for new products (Cooper *et al*. 2001, Davis *et al.* 2001), or they may be industry- or company-specific. The sum of the scores against all the criteria represents the overall merit, or potential value, of the project. A simple selection of projects can be done by ranking them according to value for money or for effective use of critical resources.

The portfolio must also be balanced in other ways. For example, a spread of projects over time is desirable: no company will want all its projects to come to fruition at the same time, with nothing planned before or after. The portfolio must also reflect the company's general strategic intent, ensuring that sufficient resources are allocated to strategically important businesses, markets or technologies. This may be achieved by simply allocating a certain proportion of innovation spend (known as 'strategic buckets') to particular businesses or types of project. Alternatively the company may draw up a strategic roadmap stretching several years ahead and use that to ensure that the longer-term orientation of the business is adequately served by the selected projects.

The balance of risk and reward across the portfolio must also be considered. The risk-reward profile of a portfolio may be displayed on a two-dimensional diagram with risk and reward (however quantified) as the two axes. Such displays are often called "bubble diagrams". Managers can use them as an aid to ensure that the portfolio is not inappropriately biased in one direction or the other. Many authors advocate the use of checklists to ensure that all relevant aspects of value and risk are captured (Tritle *et al*. 2000).

Summary

In considering immature technologies, the valuation process helps to balance risk. Tools include portfolio methods (financial, scoring and checklists) and hybrid options methods. A long standing gap in current literature is a customisation process for companies to adapt generic tools to suit their particular situation.

PRELIMINARY INTERVIEW FINDINGS

Interviews are being carried out in a range of companies with the aim of establishing what tools are being used, what the current issues are with these tools, and future requirements in the area of valuing technology for business benefit. So far companies include aerospace, consumer electronics and a technology supplier for the oil industry. An overview of the aims, methods, issues and future requirements is outlined below, followed by a summary of key points relating to the timeline.

Aims of valuation activities

The valuation "opportunity" or "problem" which underpins the use of valuation methods in different companies is of prime importance. Making business decisions about technology investment were expressed in different ways and may be classified as "justifying" or "shaping":

- Surviving a R&T budget challenge (problem – justifying portfolio and spend in terms of risk).
- Selecting strategic technology projects (opportunity – shaping portfolio in response to the environment).
- Reducing contract risk (problem – justifying work required to mitigate short term technical risk).
- Conveying the potential value to secure investment by a third party (opportunity – shaping own portfolio by selling vision)

Methods used

Gut feel is relied on to a large extent, both at strategic and operational levels. At strategic levels the aims is to set the long term direction of the technology investment. At operational levels individuals trust technical experts in their assessment of technical risk on both early research and contract work. Portfolios and NPV are used in some organisations but only one is exploring the use of Net Present Probabilistic Value and Real Options. However, there was evidence of "options thinking" in that projects were only funded to the next review point. Small exploratory projects are used to test out new technology areas before further investment is made. Go/no go gates after limited development are set for more mature technologies.

Issues

Issues with current valuation processes were numerous and challenging. The benefits of subjective (rather than a more objective process) decision making around technology were seen as speed and flexibility with drawbacks including lack of traceability. It was admitted in a multi-national company that valuation has cultural dimensions, for example different perceptions of risk. There were difficulties with assessing value in parallel technology developments and accounting for a mixture of quantifiable and unquantifiable benefits. There was also the over-arching question of whether the overall investment was "enough", suggesting the need for external benchmarking and validation. At the technology level, it was felt that integration of technologies required attention to extract full value without losing benefits by trade-offs in application.

Future requirements

One company expressed a need to make the valuation process less painful – less arduous and drawn out. The process must be manageable, obtaining sufficient resolution without getting lost in too much detail. However there is a need for transparency and the lack of precision achieved must also be communicated. Making the process traceable but retaining flexibility was seen as key. Another company stated "We need a robust and simple method for valuing technologies which takes account of the risks involved in R&D".

Mature technology valuation

Interviews discussing near term application of technology focused on several key areas. The need to quantify and mitigate the technical risk in commercial contracts, the need to obtain full potential of technologies during technology integration and the resultant performance trade-offs of individual technologies. Structured financial tools based on projected cash flows were used for bid responses but assessment of technical risk was taken on trust.

Immature technology valuation

Interviewees discussion of mid term application of technologies concerned how to select technologies coming out of research for further development and how to sell on development ideas to established business units. Here ways of communicating and developing an understanding with the customer were seen as key.

Early stage technology valuation

The findings with respect to the valuation of early-stage technologies was that there was a requirement for means to visualise and discuss what the next generation of research would be, that there could be a black hole when previously early stage research moved into development phase.

GAPS IDENTIFIED & NEW APPROACHES

There is a need to provide manufacturing (and other) companies with the means to assess systematically the benefit of new technologies to their business, at all levels of technology maturity. However, at different stages of technological maturity there appear to be different weaknesses (or gaps) in the tools widely available when compared to the requirements and aspirations of the industrial community spoken to so far.

Relatively mature technology stage

Even for relatively mature technologies, experience was seen as key in developing a robust assessment of a commercial opportunity. The desirability of being able to draw upon accumulated experience in a structured way was raised, both in literature and practice. Where it is possible (although not necessarily easy) to document experience, artificial intelligence (AI) methods are suggested as one way to fill this gap. An example method is given below.

Tan *et al.* (2004) propose an intelligent system for evaluating and selecting manufacturing technology projects in an industry where the injection of new technologies into manufacturing processes is frequent and critical to success. By integrating case based reasoning (CBR) and Fuzzy ARTMAP neural network modules, the system compares potential investment projects with those of the past according to its attributes. There is variability in economic measures such as the project NPV and relying on point estimates of these measures in decision-making may prove to be erroneous. Chaveesuk and Smith (2003) discuss this issue and conduct sensitivity analysis using both statistical models and neural network meta-models to compare their relative performance.

New technology stage

For immature technologies which have yet to be adopted, there is a need for transparency and a multi-perspective approach is seen as more robust than financial methods alone. Methods include taking data is available from historical examples and combining this with financial and qualitative data. Methodological guidance to allow customisation of such composite approaches are key to uptake. Two examples are given below.

The innovation and adoption of new materials was the subject of recent research (Maine 2000). The work developed an investment methodology to help identify promising material innovations at an early stage. The methodology was created by adapting existing and emerging predictive tools to materials innovations and linking them to give a practical, comprehensive procedure. The viability of the methodology was demonstrated through a major case study of the introduction of metal foams into cars. The methodology is aimed at SMEs and has three interwoven segments: viability analysis (to reduce risk), market forecast and value capture. A material is viable in an application if the balance between its technical and economic attributes are favourable. Assessing viability involves: technical modeling of the application, cost modeling of the manufacturing, input from the market assessment and value analysis. The market assessment consists of techniques for identifying promising market applications and for forecasting future production volume. Likelihood of value capture is assessed through an analysis of industry structure, organisational structure, intellectual property issues, appropriability, and the planned market approach. Control of intellectual property is seen as a key to value capture in the materials industry (Maine 2000).

An illustration of how an aerospace company developed its own portfolio technique is described in Farrukh *et al.* (2000). This activity started with a set of workshops considering how to develop a more structured method of making a judgement on the relative value of the R&D programmes necessary to meet aircraft project targets. The aim was to allow the company to make robust decisions on where it should focus its own funding on R&D, both long and short term to the benefit of the business. The work resulted in a project portfolio methodology being developed by the company. The technology selection criteria were divided into two main sets: benefit and cost. The 'benefit set' were further defined in terms of four company values: performance, partnership, technology and people. The 'cost set' were defined by risk and price. A fifth company value, the customer, was included to give a portfolio tool with two axes. Customer Focus aims to capture the value of the R&D in meeting the customer requirements. Technology Benefit/Cost aims to capture the value of R&D to the company as a piece of technology. The value of the technology to the company was addressed by combining the Benefit and Cost criteria via a weighting and scoring method.

Early stage technology

For early stage technology valuation the need is for discussion. Given the inherent uncertainty of future conditions, a balance needs to be struck between analysis and imagination. This is a particular gap in the timeline in terms of tools currently available. Two possible approaches are described to fill this gap in communication and visualisation.

The first is a hybrid model in venture capital and technology firms (Wong 2003; Hunt *et al.* 2003). This research was concerned with valuation techniques as applied to the technology sector and focuses on the venture capital and technological industries. The decision making process was seen as not only dependent on valuation but also other inputs such as marketing, identification of technologies, portfolio management and the project management team itself. The objective of the thesis is to illustrate the practical application of a hybrid form of real options using easily visualised decision trees rather than complex mathematical models in valuing technology projects. This was done using a spreadsheet model to calculate the compound option value of the project and perform sensitivity analysis for a case example based on a start-up technology firm. The model is seen as successful as a visual tool for valuing flexibility in decision making for sequential investments in technology projects and for supporting proactive management. However, the problem of reliable input data remains.

The second concept of interest that has emerged in early exploratory work is that of ‘Value roadmapping’. Value roadmapping (VRM) is a structured approach to explore and improve the value of technology projects at a very early stage (Hunt *et al*. 2004). It does this by providing a framework for mapping the value ‘proposition’ for individual R&T projects or programmes against time, in terms of the following layers:

- External market trends & drivers (social, economic, environmental, technological and political) and internal business factors that influence the development of products and technology in the area of interest, including strategic milestones and goals.

- Value streams (sources of future revenue and savings: products, services, business / facilities, technology / IP, cost / risk reduction, strategic position). All of these value streams relate directly to the generation of cash revenue, except for ‘strategic position’, which includes all non-financial factors that provide a foundation for future revenue generation.

- Enablers and barriers (technical and non-technical challenges and risks, together with complementary assets and actions needed to exploit the potential value of the technology or capability)

- Technology capabilities that result from R&T investment.

The value proposition that is explored and mapped in the VRM will typically depend on the strategic context or scenario that governs the discussion and defines the broad direction within which innovation is desired. It is important that the strategic context is clearly articulated, including assumptions and constraints. The time horizon for the VRM will typically extend considerably further into the future then the R&T project plan, providing a forward looking ‘radar’. Hence the VRM aims to provide a framework for supporting R&T evaluation and valuation – to explore, communicate, calculate, maximise and manage value.

DISCUSSION

In recent years much progress has been made, and many organisations now make extensive use of technology lifecycle and competitiveness analyses, R&D project portfolios and technology roadmapping to assist with the task of fully understanding the broader business impact of the technology at their disposal. However, the area of technology valuation is still a relatively unsupported area. Many key questions remain, in particular that of estimating the value of a particular technology to a particular organisation, now and in the future. This is of central concern in the choice of development projects, and when considering the acquisition of technology external to the firm. There are advantages and disadvantages to the various methods discussed above. The nature of valuation question posed by an organisation can range from “How shall we position ourselves for future success?” to “What new manufacturing technology shall we implement this year?”. It is also important to note that securing investment may be a matter of “selling” concepts to a wide range of audiences, include superiors, subordinates or colleagues or outside your immediate organisation. Further areas for exploration in more detail include risk, value chain positioning, technology integration and complementary assets. In addition the clock speed of an industry and other sectoral characteristics are important factors.

CONCLUSIONS

There is a need to review the presentation and explanation of tools and techniques currently available to managers for the assessment of technology for business purposes so that the strengths and weaknesses are appreciated. A preliminary examination of the gaps and limitations related to the use of these tools and techniques has identified the development of selected new approaches which integrate and complement existing tools and techniques. The new approaches should have specific characteristics, including transparency and breadth of analysis, and it is suggested that, for example, multi-perspective methods, customised portfolios and value roadmapping are concepts which show good signs of providing such benefits. Further research is required to apply the concepts in selected case examples to provide guidance to potentials users in the application of these new approaches.

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