Integration Project

INT1.2 Prioritisation/ Optimisation Tool

For Beacon Pathway Ltd – Sustainability in the Residential Built Environment Research Programme 2004-2010

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CONTENTS

EXECUTIVE SUMMARY

This report compares methods for Beacon Pathway Ltd to adopt for the prioritisation of its research programme. Two evaluation methods are assessed; the Analytical Hierarchy Process (AHP) and real options analysis (ROA). The evaluation methods are assessed based on:

- i) a review of the R&D investment literature
- ii) application of AHP and ROA to an hypothetical Beacon research programme
- iii) a problem analysis.

The choice between the Analytical Hierarchy Process and real options analysis is a trade off between complexity of representation of the Beacon programme and ease of use of methodology. If Beacon considers uncertainties and dependencies among workstreams important the additional complexity and cost of real options analysis may be worthwhile.

Before work proceeds on the next phase of the Integration project, feedback is required from project teams as to the acceptability of the:

- i) data requirements of the AHP and real options analysis, particularly the more demanding data needs of real options analysis (such as the need for decision trees), and the need to identify uncertainties affecting projects
- ii) simplifying assumptions of the AHP and real options analysis, particularly the simpler representation of dependencies in the AHP.

INTRODUCTION

The purpose of this report is to recommend an evaluation method that enables Beacon Pathway Ltd to prioritise its future research programme.

The report Introduction includes a description of the problem Beacon faces in structuring its research programme, a review of the literature on strategic investment in research and development, and presents an example Beacon research programme to which the evaluation methods are applied. This is followed by descriptions of the project evaluation methods considered; the Analytical Hierarchy Process (AHP) and Real Options Analysis (ROA). This section also demonstrates the AHP and ROA methods with their application to the example Beacon programme. The third section is a problem analysis of the suitability of the AHP and ROA for evaluating the Beacon research programme. The Conclusion presents the report recommendation, and describes the next stage of work in the Integration Project.

Beacon Research Programme

The Beacon programme *confirmation phase* (July to September 2004) will:

i) summarise existing work on the sustainability of the residential built environment. For example, the National Scorecard (NS1) project includes identification of existing government regulations used to improve the sustainability of the residential built environment

ii) provide benchmark information, such as a description of New Zealand's existing housing stock, in terms of its ownership and current sustainability

iii) identify research workstreams that will suggest intervention alternatives; actions that will have an impact on the sustainability of New Zealand's residential built environment. For example, the NOW7 project will identify alternative demonstration home strategies that increase the uptake of sustainable housing.

This information will be used, in conjunction with the proposed project evaluation method, to develop a combination of projects that will make up Beacon's overall *research programme* from 2004 to 2010. The goal of that research programme will be that "90% of New Zealand homes will incorporate sustainable features by 2012". An example Beacon programme might include projects to develop a sustainable building code, generate consumer demand for sustainable housing, develop a training programme for sustainable building practices, build demonstration homes in New Zealand's main centres, and develop guidelines to local government for planning sustainable neighbourhoods.

There are two types of *workstreams* (or objective areas) that make up the overall Beacon research programme; underpinning workstreams and intervention workstreams (Figure 1). *Underpinning workstreams* are those that cannot be tied to specific interventions. They influence Beacon's overall goal indirectly. An example would be a workstream that identifies the current and future, size and capability, of the residential construction work force. Carrying out this work will not directly contribute to Beacon's goal, but it will indirectly, by informing the likelihood of success of different intervention workstreams. *Intervention workstreams* are those that directly influence Beacon's overall goal, by identifying projects to develop interventions. They lead to the development of the intervention alternatives that are identified in the Beacon programme confirmation phase. An example might be a workstream to develop and recommend a government regulation that sets a minimum recycled material content in new and retrofit construction.

Workstreams may be further broken into *projects*, and further into *milestones and deliverables* (Figure 1). These are work with clear outcomes, which upon completion provide information as to the likelihood of success of subsequent projects and the workstream as a whole. Continuing the example of a government regulation, a project may be a review of the success of overseas examples of such regulations. This review may indicate that such regulations have not been successful in improving the sustainability of houses, therefore the workstream may be abandoned.

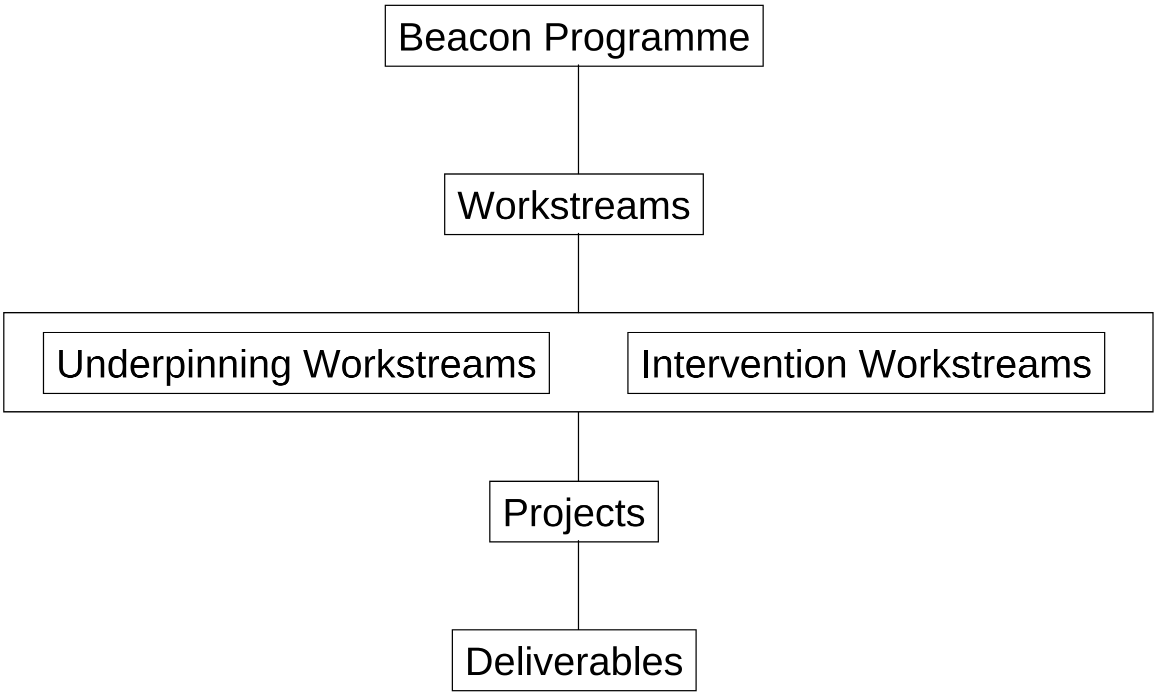


Figure 1: Division of the Beacon research programme into workstreams, projects and deliverables.

In order to evaluate the combination of *workstreams* that might make up the overall Beacon programme, a set of *evaluation criteria* are needed. These criteria describe the potential impact a workstream will have on Beacon's goal, and the cost of achieving that impact. For *intervention workstreams*, these criteria are[1]:

- i) magnitude of sustainability impact
  - a) number of houses impacted
  - b) sustainability change per house
- ii) timing of impact
- iii) likelihood of successfully achieving impact
- iv) cost of workstream, and timing of costs
- v) cost of implementing recommended interventions
- vi) importance to other workstreams.

For *underpinning workstreams*, the criteria are:

- i) timing of impact
- ii) cost of workstream, and timing of costs
- iii) importance to other workstreams.

[1] These criteria will be further developed throughout this report, and will be described in more detail in the data requirements for the Analytical Hierarchy Process and Real Options Analysis.

The *magnitude of the sustainability impact* of intervention workstreams is a critical criterion for assessing the affect of a workstream on Beacon's goal. Estimating the *number of houses impacted* will require a description of New Zealand's housing stock in terms of ownership and current sustainability. Estimates of impacts will be uncertain, and for this reason, a likelihood of success of the intervention workstream is needed. Estimating the *sustainability change per house* is also uncertain, and this uncertainty is again captured by the likelihood of success.

The importance of one workstream to another describes the *dependencies among workstreams*. Blau et al. (2004)[2] identify four types of dependencies:

i) resource dependencies – for example, reductions in workstream time due to experience from previous workstreams
ii) cost dependencies – arise from opportunities for resource sharing
iii) impact dependencies – arise from synergism or antagonism in the residential built environment
iv) technical dependencies – likelihood of success of an intervention may be improved based on outcomes from other intervention or underpinning workstreams.

An example of a technical dependency could be information from a workstream that describes how industry capacity responds to changes in demand for residential housing. This workstream would inform the likelihood of success of a workstream that increases consumer demand for sustainable housing. A workstream, upon which other projects are dependent, may be an important part of the Beacon programme. It is therefore critical that the evaluation method recommended is able to consider these important dependencies.

Strategic Investment in R&D

Strategic investment in research and development is about evaluating the alternative R&D projects that a company may undertake, to identify those that will provide the greatest return to the company. There is a wide range of R&D evaluation methods. Poh et al. (2001) presents a classification and review of these. They identify two broad categories of evaluation method; weighting and ranking methods, and benefit-contribution methods. Weighting and ranking methods compute relative weights and rank a set of proposed projects in order of preference. Examples include the comparative method (Easton 1973), scoring method (Balachandra and Brockhoff 1996), and the Analytical Hierarchy Process[3] (Liberatore 1987). Benefit contribution methods are used to determine how well projects satisfy the R&D objectives of an organisation. Examples include economic analysis (Graves and Ringuest 1991), cost/ benefit analysis (Link 1993), and decision tree analysis (Faulkner 1996).

The comparative method uses mathematical models to calculate the merit of alternative projects (Poh et al. 2001). The method has been criticised for relying too heavily on subjective judgements, evaluations performed by different people and at different times are not directly comparable, and changes in the set of alternative projects can change rankings (Poh et al. 2001).

The scoring method evaluates projects by scoring them based on how well they meet defined objectives. Usually a formula is used to incorporate factors that are important to assessing projects. The formula commonly includes weights reflecting the relative importance of factors. Projects are then ranked in the order of their scores (Poh et al. 2001). An example is the comparison of interventions in the residential built environment on the basis of average cost of

[2] Blau et al.'s (2004) financial return dependency is defined here as an impact dependency.
[3] The Analytical Hierarchy Process is described in detail in the next section.

intervention per sustainability point (Paul Minett, pers. comm.). The factors considered are cost and sustainability points gained. The formula used - the ratio of cost to sustainability point - weights the two factors equally. This scoring method is applied to the example Beacon research programme described below.

Economic analysis and cost/ benefit analysis are based on capital budgeting techniques (Poh et al. 2001). These approaches have been criticised for their focus on economic return measures, which can result in an unbalanced portfolio of projects, their failure to allow analysis of the trade off between risk and return (Blau et al. 2004), and their failure to capture managerial flexibility (Poh et al. 2001). The latter two criticisms are addressed by real options analysis (Dixit and Pindyck 1994).

Decision tree analysis allows the representation and analysis of a series of decisions made over time, a typical feature of R&D projects (Poh et al. 2001). Its basis on decision theory formalises the concepts of risk and return (Blau et al. 2004). The approach has been criticised because of the unmanageably large decision trees that occur as the size of the portfolio of projects being analysed increases (Copeland and Antikarov 2001).

Poh et al. (2001) presents a framework for comparison of R&D evaluation methods. The authors use the AHP to make the comparison, and assess six evaluation methods based on seven criteria. The methods considered are the scoring method, AHP, comparative method, decision tree analysis, economic analysis and cost-benefit analysis[4]. The seven criteria are:

i) handles multiple objectives
ii) incorporates risk and uncertainty
iii) simplicity of the R&D evaluation method
iv) availability of data required by the R&D evaluation method
v) ability of R&D evaluation method to adapt and incorporate experience and knowledge of different decision makers
vi) requirements for quantitative and/ or qualitative data
vii) cost (monetary and time) of adopting and implementing the R&D evaluation method.

The authors ranked the relative importance of these criteria, using an AHP pairwise comparison matrix, resulting in the criteria order given above. The ranking of R&D evaluation methods identified by Poh et al. (2001) was:

i) Scoring
ii) AHP
iii) Decision tree
iv) Economic analysis
v) Cost/ benefit analysis
vi) Comparative method.

The AHP is ranked highly[5] because of its ability to handle multiple objectives, the data required is readily available, and it is able to handle quantitative and qualitative data. Economic analysis and decision tree analysis were ranked highly because of their ability to handle risk and uncertainty, but do not handle multiple objectives well.

[4] For comparison, real options analysis extends economic analysis by using decision trees to capture managerial operating flexibility (Amram and Kulatilaka 1999).
[5] Scoring and the AHP had similar priority scores in the evaluation performed by Poh et al. (2001).

Example Beacon Programme

This example is intended to provide a basis for testing real options analysis, the AHP, and scoring as methods for prioritisation of the Beacon research programme. The example programme is made up of three workstreams in the area of Consumer research, and two in the area of National Scorecard. Each workstream is described in terms of:

i) research cost (and timing of costs)
ii) intervention cost (and timing of costs)
iii) the estimated impact on the residential built environment, in terms of
   a) percent of total housing stock
   b) percent increase in sustainability index
   c) year of impact
iv) likelihood that workstream will lead to an intervention that achieves estimated impact
v) dependencies on other workstream results, described in terms of how other workstream findings will affect the workstreams likelihood of success or estimated impact.

For decision tree representations of the two workstreams refer to Figure 3 and Figure 4 below.

Consumer Research Workstreams

CON1 - Do nothing

Cost of R&D	2005	$0.6 million	
	2006	$0.6 million	
Cost of intervention		$0.0 million	
Impact	Houses (% housing stock)	5%	"green" households
	Sustainability index (% of total)	40%	
	Year	2009	
	Likelihood of success[1]	80%	
Dependencies		None	

[1] likelihood that approach will achieve impact, versus zero impact

CON2 - TV advertisements

Cost of R&D	2005	$0.6 million	
	2006	$0.6 million	
Cost of intervention	2008	$4.0 million	
Impact	Houses (% housing stock)	10%	
	Sustainability index (% of total)	60%	
	Year	2009	
	Likelihood of success	40%	
Dependencies	IND1 industry capacity research	$1.2 million	
		40%	Likelihood if capacity exists
	IND1 industry capacity does not exist	10%	Likelihood if capacity does not exist

CON3 - Demonstration Homes

Cost of R&D	2005	$0.6 million	
	2006	$0.6 million	
Cost of intervention	2008	$8.0 million	
Impact	Houses (% housing stock)	40%	
	Sustainability index (% of total)	90%	
	Year	2009	
	Likelihood of success	80%	
Dependencies	IND1 industry capacity research	$1.2 million	
		80%	Likelihood if capacity exists
		10%	Likelihood if capacity does not exist

National Scorecard Workstreams

NS1 - No National Scorecard Output, resulting in few sustainability provisions in Building Code

Cost of R&D	2005	$0.5 million	
Cost of intervention	2007	$0.0 million	
Impact	Houses (% housing stock)	0-10%	
	Sustainability index (% of total)	50%	
	Year	2008	
	Likelihood[1]	80%	
Dependencies	Information on trends in new home building	$0.05 million	
		0%	of housing stock with *low* growth in new home building
		10%	of housing stock with *high* growth in new home building

NS2 - National Scorecard Output, resulting in more sustainability provisions in Building Code

Cost of R&D	2005	$0.5 million	
Cost of intervention	2007	$0.6 million	
Impact	Houses (% housing stock)	0-10%	
	Sustainability index (% of total)	80%	
	Year	2008	
	Likelihood[1]	60%	
Dependencies	Information on trends in new home building	$0.05 million	
		0%	of housing stock with *low* growth in new home building
		10%	of housing stock with *high* growth in new home building

The Scoring Method

The scoring method compares workstreams on the basis of the average cost of the research and proposed intervention per sustainability point (Paul Minett, pers. comm.). The factors considered are research cost and sustainability points gained. Estimates of the number of houses impacted, the average change in sustainability points per house, and the Beacon cost of research are from the example workstreams presented above and in Figure 3 and Figure 4. The cost of research, and sustainability impact are optimistic estimates.

Table 1: Evaluation of example Beacon research programme using the scoring method.

Workstream	Description	Number of Houses Impacted[1]	Avg Change in Pts/ House[2]	National Sustainability Points Gained (millions)[3]	Beacon Cost of Research ($ million)	Avg Cost per Sustainability Point ($)
CON1	Do nothing	90,000	40	3.6	2.40	0.67
CON2	TV adverts	180,000	60	10.8	6.40	0.59
CON3	Demo homes	720,000	90	64.8	10.40	0.16
NS1	No NS Output	180,000	50	9.0	0.55	0.06
NS2	NS Output	180,000	80	14.4	1.15	0.08

[1] Assumes there are 1.8 million homes in 2012, [2] Assumes a 1% gain is equivalent to a 1 point gain in the sustainability index. [3] National sustainability points gained is the product of number of houses impacted and the average change in sustainability per house.

Based on the scoring method, the best allocation of research funds is to CON3 – Demonstration Homes, and NS1 – No National Scorecard Output.

THE ANALYTICAL HIERARCHY PROCESS

Description

The analytical hierarchy process is a weighting and ranking method used to identify preferred options. It provides a total score for each project, which can then be listed in order of worth. It may not necessarily identify optimal combinations of projects, many of which are interdependent. However it is a simple to perform and provides a check on other prioritising methods. It has been applied to research and development projects (Poh et al 2001), and to building investment decisions (ASTM 1995). It is a tool that is used widely in business to help make decisions involving quantifiable and hard–to-quantify factors in a structured manner.

An example follows, relating to the Beacon objectives. In its simplest form the procedure is done manually, but software is available for complex projects. The main steps are:

i) Define the alternatives (Beacon projects)
ii) Define the evaluation criteria (number of houses impacted, sustainability change per house, likelihood of success, cost, and linkages to other projects)
iii) Decide the weight for each criteria. The weights add to 100%
iv) Score each alternative against each criteria
v) To get the total score for an alternative multiply the criteria score by the weight, and add for all criteria
vi) The total score for each alternative is a measure of its rank or worth.

The difference in scores is an indication of how much more/ or less important a project is compared to the others. For the Beacon programme the alternatives will include at least two levels of expenditure in a particular objective area.

Example Application

This example, shown in Table 2, is performed manually and the aim is rank the projects, including different levels of output within projects.

The scoring is a scale of 1 to 5 where the higher the score, the more favourable the project. The earlier example Beacon projects are used (CON1 to CON3 and NS1 and NS2). The cost score is assumed to range from 5 for zero cost, to 1 for $1.2 million expenditure, but this scale would to be reassessed when the cost estimates are available from the various objective areas. In the example, the number of houses impacted is low for all 5 projects, so the scoring is low for all, (see the discussion later, in which it is suggested the NS1 impact could in fact be quite high). The sustainability score is the percentage divided by 20% (so that the 0 to 100% range fits into a 1 to 5 scale), similarly for the likelihood of success. Linkages or dependencies in the AHP is a measure of how important the project’s output is to other projects, and hence is slightly different in concept to real options analysis.

Table 2: AHP scoring

Scoring
5= very high (except a high cost has a low score, and vice versa).
4 = high
3 = average
2 = low
1 = very low

		Criteria					
	Weights=	28	28	10	24	10	100%
		Cost	Number houses reached	Index of Sustainablity	Success likelihood	Linkages	**Total**
Project							
CON1	Score	5	1	2	4	1	
	Wt score	1.4	0.3	0.2	1.0	0.1	2.9
CON2	Score	3	2	3	2	2	
	Wt score	0.8	0.6	0.3	0.5	0.2	2.4
CON3	Score	1	3	5	4	4	
	Wt score	0.3	0.8	0.5	1.0	0.4	3.0
NS1	Score	5	1	2	4	1	
	Wt score	1.4	0.3	0.2	1.0	0.1	2.9
NS2	Score	3	2	4	3	3	
	Wt score	0.8	0.6	0.4	0.7	0.3	2.8

Note that the scores used in the example are estimates and are not necessarily a reflection of what the score will be once data is received from the various projects. For example, it is possible that the number of houses reached in a NS2 project could be quite high, if that project was successful in introducing stringent sustainability requirements into the building code.

The choice of weights for the criteria is important. It can be based on the decision makers "gut feeling" of what criteria are important. A more formal way to arrive at the weights is to carry out pair-wise comparisons between the criteria (Poh et al. 2001), as shown in Table 3.

Table 3 Pairwise comparisons in AHP to get the criteria weights

Criteria weights by pairwise comparisons

Compare pairs of criteria for the preference:

5= very strong preference
4 =strong preference
3= moderate preference
2 = weak preference
1= equal preference

	Symbol	Cost	Numb	Index	Success	Links	
Cost	C						
Number hses	N	C-1,N-1					
Index sust	I	C-2	N-2				
Success likeilh	S	C-2	N-1,S-1	I-1.S-1			
Linkages	L	C-1,L-1	N-2	I-1,L-1	S-3		
Count all the scores against each Symbol							
Raw score		6	6	2	5	2	
Adjusted weight		6	6	2	5	2	21
Percentage		29	29	10	24	10	100

The weight is adjusted so that no criteria is more than 9, or less than 1.

Each criterion is compared in turn with others, for example, comparing Number of Houses Impacted with Index of Sustainability the result is N-2 which means there is weak preference for the Number Impacted criteria, so it scores a 2. In some cases there is no preference, so each of the pair scores a 1. Each symbol is added up, so that there are 6 points against N or Number of Houses Impacted. The scores are then adjusted, so that no criterion has more than 10 points, nor less than 1 point. This is an arbitrary adjustment so that no one criterion has an overwhelming influence, or a nil influence. These adjusted criteria are then used to weight the scores that each programme achieves for each criterion.

REAL OPTIONS ANALYSIS

Description

Discounted cash flow (DCF) analysis has become increasingly criticised as being inappropriate for valuing research and development investments. The argument is that real options analysis, rather than DCF, is the appropriate way to evaluate R&D projects (Cooper 2001). Brealey et al. (2003) have suggested that DCF analysis is of little use for valuing R&D, because the value of R&D is mostly option value. There is a rapidly growing literature describing real options analysis and its application to valuing R&D investment (Dixit and Pindyck 1994, Amram and Kulatilaka 1999, Cooper 2001, Mun 2002, Copeland and Antikarov 2003). Real options analysis has been applied to valuation of investments and development in the oil (Smith and McCardle 1999), pharmaceutical (Loch and Bode-Greuel 2001), high tech (McGrath and MacMillan 2000), real estate (Grenadier 1996), and construction (Ng and Björnsson 2004) industries.

An option is defined as (Amram and Kulatilaka 1999):

> "the right, but not the obligation, to take an action in the future. Options are valuable when there is uncertainty. For example, an option contract traded on the financial exchanges gives the buyer the opportunity to buy a stock at a specified

price on a specified date and will be *exercised* (used) only if the price of the stock on that date exceeds the specified price. Many strategic investments create subsequent opportunities that *may* be taken, and so the investment opportunity can be viewed as a stream of cash flow plus a set of options."

Real options analysis is based on options pricing theory (Dixit and Pindyck 1995); a method for valuing financial options (Black and Scholes 1973, Merton 1973). Financial options are available on shares, foreign exchange, bonds, commodities, share market indices and futures contracts (Brealey et al. 2003). An example is a call option on a company's shares. The call option gives its owner the right to buy shares at a specified exercise price on a specified date. If, on the specified date, the company's shares are selling above the exercise price, then the owner of the call option will exercise the option and make the difference between the share price and the exercise price. If the share price is below the exercise price, the owner of the call option will let the option lapse, and they will be out-of-pocket the cost of the option (Brealey et al. 2003).

In the case of R&D, investment in research gives a company the right to decide, at some future date, whether or not to *exercise* that R&D investment. If the outcome of the research looks promising, the company will *exercise* the option created by making a commercialisation investment. If the research does not look promising, the company can allow the option to *expire* and the loss will be limited to the amount of the initial investment (Faulkner 1996, Leurhman 1997). The key is that real options analysis allows situations where uncertainty represents a potential for future gain to be identified (Faulkner 1996).

Different types of investment have different options associated with them (Amram and Kulatilaka 1999). The types of investments that are found in R&D include irreversible, platform, and learning investments. *Irreversible* investments include the option to delay investment until a significant amount of uncertainty is resolved (Amram and Kulatilaka 1999). For example, the building of a geothermal power station may be delayed until uncertainty about future energy prices is resolved. *Platform* investments create valuable follow-on contingent investment opportunities. For example, the value of research comes from the products developed that *may* lead to marketable products (Amram and Kulatilaka 1999). *Learning* investments are made to obtain information that is otherwise unavailable. For example, oil exploration is a learning investment in geological information (Amram and Kulatilaka 1999).

The implications of options thinking for strategic R&D investment include (Faulkner 1996):

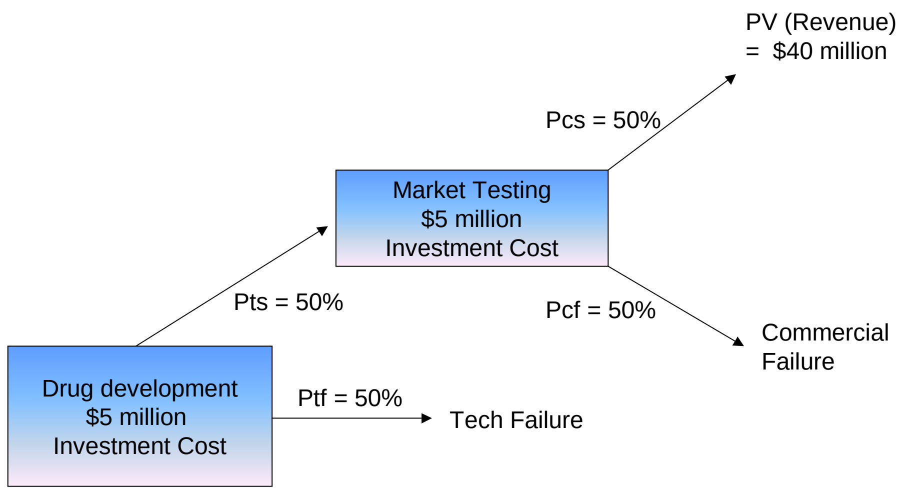
i) recognition of uncertainty by considering "optimistic" and pessimistic" scenarios, and identifying critical future uncertainties
ii) identification of decisions that can be made after uncertainties are resolved, recognising these as opportunities to adjust
iii) use of 'flexibility' as criteria for evaluating projects, recognising that flexible projects can allow decisions to move one way or another as uncertainty is resolved
iv) building a 'phased approach' into project investment decisions, so that future decisions are conditional on downstream decisions
v) maintaining a long-term focus
vi) a tool for valuing intangibles such as flexibility and learning.

Application of Real Option Analysis to Pharmaceutical R&D

Real options valuation has been applied in practice to the evaluation of pharmaceutical R&D options. Much of the literature on real options valuation uses the example of R&D in drug development to illustrate real options analysis (Amram and Kulatilaka 1999, Copeland and Tufano 2004, Dixit and Pindyck 1995). Drug development is a well-defined process established phases with identifiable decision points; preclinical and clinical testing, official approval, and marketing.

Amram and Kulatilaka (1999) describe the development of pharmaceuticals as a learning investment, in which R&D investments reduce the uncertainty about the cost of developing the product and the size of the market. Throughout the life cycle of developing the drug, there are a number of decision points at which we could decide to stop development or marketing efforts. If development is halted, the drug can be abandoned, licensed to another company or sold. The drug development and marketing process, therefore, can be modelled as a sequence of learning investment and abandonment options.

A simplistic representation of drug development is shown in Figure 2, and includes three different methods of valuing the project – the conventional net present value (NPV) with no assigned probabilities of success or failure of the project, expected net present value (E(NPV)) which includes probability of success or failure, and options pricing method (O(NPV)) which includes the option to abandon the R&D.



NPV = 40 - 5-5 = $30 million

E (NPV) = (0.5 x 0.5 x 40) – 10 = $0 million

O (NPV) = (40 [0.5] + 0 [0.5] - 5) 0.5 + 0 [0.5] - 5 = $2.5 million

NPV = net present value E(NPV) = expected net present value O(NPV) = options value	Pts = probability of technical success Ptf = probability of technical failure Pcs = probability of commercial success Pcf = probability of commercial failure

Figure 2: Valuation of a drug research and development project using different valuation methods, including options valuation[6]

[6] Adapted from an example given in Cooper 2001.

- In this example, the NPV method, without considering probabilities, grossly overestimated the value of the project.
- With probabilities the NPV method understated its value and according to this method the project should not be started
- The options valuation method suggests that the project has a positive value.

If we compare the Beacon research programme with that of pharmaceutical R&D, there are some similarities and a number of differences that will need to be addressed.

- In drug development, the decision points are easily identifiable; the process of drug development being straightforward, well defined, and easily described. The Beacon programme is a portfolio of workstreams, each of which has its own pathway and in some cases, not easily identifiable decision points.
- In drug development the options are comparatively clear. Some of the Beacon projects involve multiple options, which may make real options analysis complicated and perhaps unworkable.
- The drug development examples cited in the literature do not allow for dependencies between projects. The Beacon workstreams will need to allow for dependencies.
- Options valuation of drug development is made on the basis of financial values. The Beacon workstreams provide information about interventions and the project's ability to impact on sustainability criteria, not financial values.
- There are different sources of uncertainty for drug R&D and the Beacon workstreams. For drug R&D they are well known and fairly standard to all drug R&D (for example, size of the market, and the probability of passing regulatory tests). Each Beacon project will have its own sources of uncertainty and these must be identified.

Calculating Option Values

The main methods for performing real options analysis are the Black-Scholes formula, and dynamic programming (decision trees or the binomial method) (Amram and Kulatilaka 1999).

The Black-Scholes formula (Brealey et al. 2003) is used in the valuation of financial options, and has been recommended for the valuation of R&D investments (Amram and Kulatilaka 1999). The major advantage of the Black-Scholes formula is that calculation of the value of an option is quick and easy, though the formula itself is complex (Faulkner 1996). This complexity means that results from the Black-Scholes formula can be difficult to interpret. The formula also makes a number of simplifying assumptions, such as future uncertainty being described by a log normal distribution, which may not hold in the case of R&D investment (Faulkner 1996).

If today's decisions affect what you can do tomorrow, then tomorrow's decisions have to be analysed before you can act rationally today (Brealey et al. 2003). Decision trees represent the possible decisions and values during the life of the project and fold back the value of the optimal decisions from the future (Amram and Kulatilaka 1999). The real options analysis examples presented in this report have all been analysed using decision trees. The decision tree approach has two advantages over the Black-Scholes formula (Faulkner 1996). Firstly, analysis is more visible and understandable, making review of assumptions and their implications easier. Secondly, decision trees do not require the use of a log normal distribution to describe uncertainty. The disadvantage of decision trees is that they are time consuming and complex to construct (Faulkner 1996). A simpler alternative is the structured, semi-quantitative approach recommended by Sharp (1991). Phase 2 of the Integration Project will explore suitable real options analysis methods further, with the aim of recommending the most suitable method for Beacon Pathway Ltd.

Example Application

Figure 3 shows the decision tree representing the Consumer Research workstream. Shown is the dependency of the success of consumer interventions on a platform investment, Industry Capacity research, which increases the likelihood of success of the interventions. There are two questions regarding the Consumer research workstream:

i) is investment in Industry Capacity research worthwhile?
ii) which consumer interventions are preferred?

Figure 3 describes the Consumer Research workstream as follows. $0.6 million is spent in 2005 and 2006 on consumer research, leading to identification of possible consumer interventions; do nothing, a television advertising campaign, and demonstration homes. The likelihood of success of the later two interventions is influenced by whether or not Industry Capacity research is carried out. Investing $1.2 million in developing industry capacity increases the likelihood of success of advertising from 10% to 40%, and that of demonstration homes from 10% to 80%.

To assess whether the $1.2 million investment in industry capacity is worthwhile, the sustainability impact of interventions needs to be converted to an economic value. In the example an arbitrary value of 1% = $1 million was used. If television advertising is successful it is estimated to result in 10% of houses adopting sustainable features by 2012, with an average increase in sustainability of 60%. This translates to a 10% x 60% = 6% increase in sustainability, which is equivalent to $6.0 million in economic terms. To achieve this sustainability impact $4.0 million is spent on advertising. The expected value of a television advertising campaign (following industry capacity research) then is:

-$1.6 million = 0.40 x ($6.0 million - $4.0 million) + 0.60 x ($0.0 million - $4.0 million)
= 0.40 x $2.0 million + 0.60 x (-$4.0 million)
= -$1.6 million

Equivalently the expected value of doing nothing is $1.6 million, and of demonstration homes is $20.8 million. Without industry capacity research the expected value of the interventions is $1.6 million for doing nothing, -$3.4 million if television advertising is used, and -$4.4 million if demonstration homes are used. The negative value of demonstration homes reflects the lower likelihood of success if industry capacity is not developed.

The recommendation identified from the decision tree representing the Consumer Research workstream (Figure 3) is to first perform industry capacity research, then develop demonstration homes (CON3).

Figure 4 shows the decision tree representing the National Scorecard workstream. The decision tree includes valuation of a learning investment; an analysis of growth in new housing. This analysis resolves uncertainty about the size of the housing market that would be impacted by a new Building Code. There are two questions regarding the National Scorecard research workstream:

i) is investment in New Home Trends research worthwhile?
ii) should their be investment in getting sustainability provisions into the new Building Code?

The decision tree analysis in Figure 4 (top branch), shows the value of analysing the growth in new housing before investing in adding sustainability provisions to the new Building Code. If growth in new homes is low (0%), the new Building Code with sustainability provisions will have no impact, and the outcome is a loss of $0.6 million. If growth in new homes is high, (10%), the new Building Code will have a large impact, and the outcome is $7.4 million, which covers the $0.05 million investment in analysis of new housing growth.

If there is no analysis of the growth of new housing (Figure 4, lower branch), the impact of sustainability provisions in the new Building Code on residential built environment sustainability is uncertain. The assumption in Figure 4 is that there is a 50% probability that no houses will be affected by a new Building Code, and a 50% probability that 10% of houses will be impacted. The expected outcome of including sustainability provisions in the Building Code then is $1.8 million, while the outcome is $2.0 million without sustainability provisions in the Building Code.

The recommendation identified from the decision tree representing the National Scorecard workstream (Figure 4) is to first analyse the growth in new housing, then incorporate sustainability provisions in the Building Code (NS2) only if growth in new housing is predicted to be high.

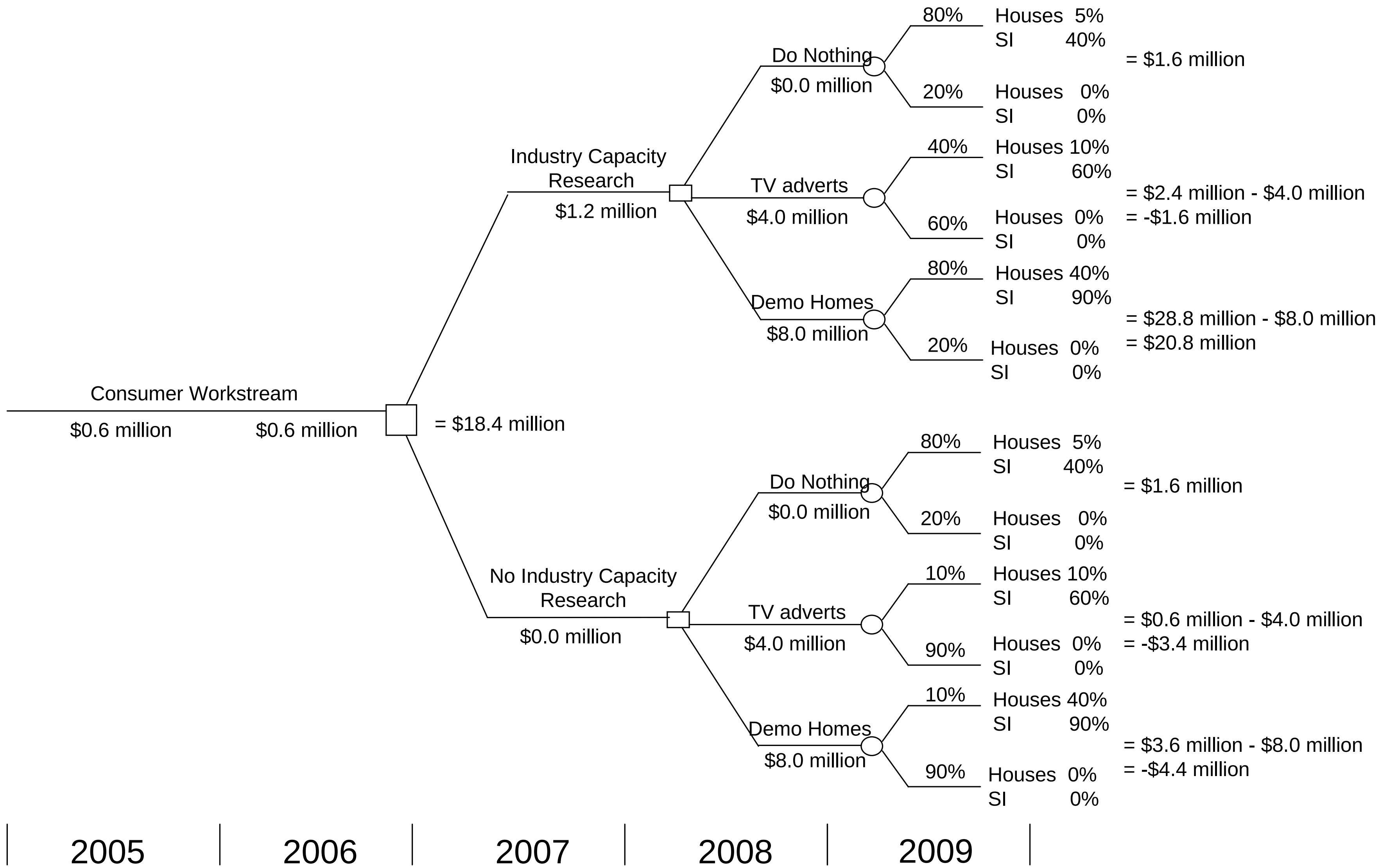


Figure 3: Decision tree representing the example Consumer Research workstreams.

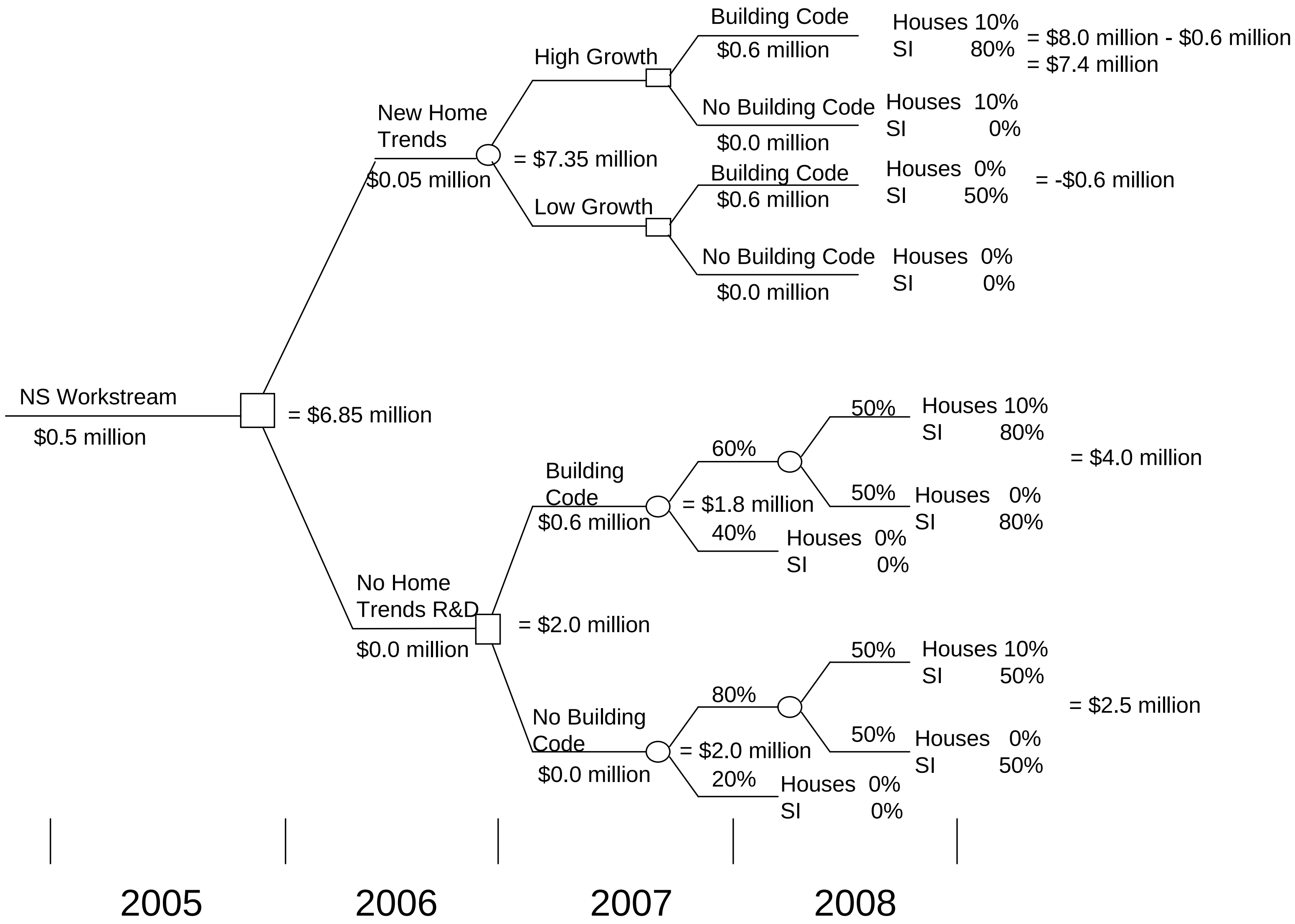


Figure 4: Decision tree representing the example National Scorecard research workstream.

PROBLEM ANALYSIS

The problem analysis was performed by evaluating the Analytical Hierarchy Process and real options analysis in terms of the following criteria:

- i) enables review of assumptions made
- ii) includes method of benchmarking and measuring progress over time
- iii) can include timing of project outcomes
- iv) handles project and market uncertainties
- v) data requirements and data availability
- vi) cost and ease of application of method
- vii) information provided
- viii) extent of historical use
- ix) generality
- x) applicability to all 10 objective areas in the Beacon research programme.

The Analytical Hierarchy Process

Review of Assumptions

The main assumptions with the AHP are the criteria weights, which can be simply entered in the spreadsheet by the decision maker, or arrived at by the more formal process of pairwise comparisons. It has been found in studies using the AHP (Saaty and Vargas 1994), that these weights do not vary greatly between decision makers when they have a good knowledge of the various alternative projects in an overall programme. However in the Beacon case it is possible that because of different backgrounds of the board members (who are assumed to be the decision-makers and will decide on the weightings), the weights given to different criteria could vary somewhat.

It is assumed that the project scores by criteria can be objectively measured; however it is likely that some judgement will also be required. Cost data will be provided for various alternatives, and is solid data. The sustainability index will also be an objective measure. However likelihood of success, and linkages between projects, will involve some judgement to derive a score for each project. It is suggested that the INT1 team could decide on the scores by project for these latter criteria.

Benchmarking and Measuring Progress

An advantage of AHP is that the weights given to each criterion by the decision-makers are explicit, and are open to debate by the board members.

As work progresses in each objective, more information will become available to refine the score for some of the criteria, such as number of houses impacted, and likelihood of success. This will enable rankings of projects to be reassessed, as required.

The AHP will enable projects to be ranked by total score, enabling identification of the most important projects. However, it will not necessarily provide optimal combinations of projects, since a project vital for other objectives may be ranked quite low.

Timing of Workstream Outcomes
AHP does not allow for project inter-dependencies to be easily considered when assigning resource. The scoring does include the linkages criteria, but the actual timing of when project stages need to be complete is not considered in the AHP method.

Project and Market Uncertainties
Project and market uncertainties can be readily accommodated in the AHP as a score on the likelihood of success.

Data Requirements
The AHP requires the following data for each workstream:

i) number of houses impacted
ii) sustainability change per house
iii) likelihood of success
iv) cost of project
v) linkages to other projects, i.e. reliance of others on the projects output.

As far as possible the AHP requires quantitative data, however assigning scores to these criteria can incorporate qualitative data.

Cost and Ease of Application
The AHP as outlined in the simplified version above is an easy and inexpensive process to carry out. This assumes that the required data, discussed above, is available. Some work may be involved in assessing success likelihood and linkages with other projects. A simple spreadsheet was set up to produce the example in Table 2, and can be readily provided.

Information Provided
The main information provided is a score for each project on a scale of 1 to 5, the higher the better. Projects can be ranked using this score and the difference between scores is a measure of how much better or worse a project is, compared to another. Decision-makers would not necessarily choose to fund, for example, only the top three. Lower ranked projects may still be important to the overall objective. So the AHP will not provide optimal solutions, however it provides a simple check on the value of individual projects.

Extent of Historical Use
The AHP has been applied in economic, political, social and technological environments since the early 1990s. For complex decisions, involving several layers of decision hierarchy, software has been developed to automate the process. This software also checks that the weighting given to criteria is consistent, i.e. in pairwise comparisons if A is preferred to B, and B is preferred to C, then the software checks that A is preferred to C.

Generality and Applicability
The AHP can be used in a wide range of problems where ranking of the alternatives is required. It can use a mix of qualitative and quantitative data, and is a method for making explicit the assumptions and judgements of the decision-makers to outside observers.

Real Options Analysis

Review of Assumptions

Using decision trees to perform real options analysis is a transparent means of representing the flow of work, decisions, and dependencies within a workstream. This transparency enables easy review and modification of assumptions, and reanalysis. The use of the Black-Scholes formula to perform real options analysis is a considerably less transparent method, making review of assumptions difficult.

Benchmarking and Measuring Progress

A strength of real options analysis using decision trees is that important decision points and criteria are identified. For example, in the National Scorecard workstream (Figure 4), at the conclusion of analysis of growth in new housing a decision should be made about the value of incorporating sustainability provisions in the Building Code.

Timing of Workstream Outcomes

The impact of the timing of research outcomes is handled by discounting in real options analysis. This requires that the sustainability impact of research and interventions be expressed in economic terms (see *Data Requirements* below for further discussion).

Project and Market Uncertainties

One of the strengths of real options analysis is its ability to consider project and market uncertainties (Amram and Kulatilaka 1999, Poh et al. 2001). Using decision trees to perform options analysis, uncertainties are represented as probabilities of different outcomes. By considering uncertainty, options analysis identifies opportunities to mitigate negative outcomes. For example, in the Consumer Research workstream (Figure 3), industry capacity research mitigates a potential negative outcome from demonstration homes, by ensuring industry capability exists to meet demand for sustainable housing.

Data Requirements

Real options analysis requires the following data for each workstream:

- i) magnitude of sustainability impact
  - a) number of houses impacted
  - b) sustainability change per house
- ii) timing of impact
- iii) likelihood of successfully achieving impact
- iv) cost of workstream, and timing of costs
- v) cost of implementing recommended interventions, and timing of costs
- vi) dependency on other workstreams, describes in terms of how dependency affects
  - a) likelihood of success, and/ or
  - b) magnitude of sustainability impact.

As previously mentioned real options analysis requires the sustainability impact to be expressed as an economic value. This would need a value to be attached to the sustainability change per house. Real options analysis also requires that all inputs be quantified; it cannot incorporate qualitative data.

Dependencies on other workstreams can be described, and their impact on workstreams valued, with real options analysis. However, as the number of dependencies increases, the complexity of the problem to be analysed increases exponentially. Realistically the most dependencies that could be considered within a workstream would be two.

Cost and Ease of Application
Real options analysis is a costly (in terms of time) method for evaluating projects. This cost is associated with the setting up of a problem for analysis; the description of workstreams, and their representation as a decision tree. Preparation and analysis of the example Beacon programme in Figure 3 and Figure 4 took one day. Adding to the cost is the interaction with researchers needed to organise a workstream into a decision tree.

Information Provided
The higher cost associated with real options analysis is reflected in the additional information provided from the method. Key information is the valuation of options created by underpinning workstreams, which indirectly impact on sustainability. For example, in the National Scorecard workstream (Figure 4), the value of investing $50,000 on analysis of new housing growth is in the option to not invest in the Building Code intervention if new housing growth is predicted to be low.

Extent of Historical Use
Real options analysis has been applied to valuation of R&D investment only in the last decade, with the main industry making use of the method being pharmaceuticals (Amram and Kulatilaka 1999, Copeland and Tufano 2004, Dixit and Pindyck 1995). Real options analysis has been in use for longer in the oil industry (Amram and Kulatilaka 1999, Smith and McCardle 1999). Application of real options analysis to these industries is perhaps less complicated (compared with the Beacon research programme) because decision points and options are comparatively clear, and the data required are readily available.

Generality and Applicability
Real options analysis can be applied to the same problems that discounted cash flow analysis is applied. However, only in particular circumstances does real options analysis provide benefits beyond performing a DCF analysis. Real options analysis is likely to result in higher net present values when (Faulkner 1996):

- i) the future commercialisation investment is high relative to the initial R&D investment
- ii) there is uncertainty about future impacts
- iii) the duration of the research phase is long
- iv) the availability of future information will resolve uncertainties.

Were real options analysis to be used to analyse the Beacon research programme, decision trees would be the likely method of implementation. Because the complexity of decision trees increases rapidly with an increase in the number of decisions and outcomes (Brealey et al. 2003), the use of real options analysis would be restricted to separately analysing individual workstreams, and their major dependencies. Beacon’s portfolio of workstreams would then be built up from the prioritisation of projects within workstreams, rather than prioritising the Beacon programme as a whole.

CONCLUSION AND RECOMMENDATION

The choice between the Analytical Hierarchy Process and real options analysis is a trade off between complexity of representation of the Beacon programme and ease of use of methodology. If Beacon considers uncertainties and dependencies among workstreams important the additional complexity and cost of real options analysis may be worthwhile. Given that the AHP shares most of its data with real options analysis and is easier to use, an additional option would be to use both evaluation methods.

The advantages of the Analytical Hierarchy Process are:

i) its generality and applicability to a variety of problems, which is due to its ability to incorporate a variety of criteria and qualitative as well as quantitative data
ii) makes explicit the assumptions and judgements of the decision-makers to outside observers
iii) it is a widely accepted method for prioritising projects
iv) its ease of use and low cost

These advantages of the AHP come at the cost of:

i) a simpler representation of workstream dependencies, which may lead to
ii) underpinning workstreams being assigned a low priority.

The advantages of real options analysis are:

i) considers project and market uncertainties, enabling identification of opportunities to capture the upside, without the obligation to bear the downside (Ng and Björnsson 2004)
ii) important decision points and criteria within a workstream are identified
iii) dependencies can be described and their impact on workstreams valued, allowing the valuation of options created by underpinning workstreams.

The decision to apply real options analysis to the Beacon research programme involves trading these advantages off against the greater informational demands of the method:

i) an economic value needs to be attached to sustainability impacts
ii) project teams will need to construct decision trees around the proposed workstreams, requiring identification of
    a) dependencies, and how they impact on workstream outcomes
    b) critical decision points in research process, where the decision to halt or continue the project are made
    c) clear identification of uncertainties
ii) aggregation of workstreams to form an optimal portfolio.

Before work proceeds on the next phase of the Integration project, feedback is required from other project teams as to the acceptability of the:

i) data requirements of the AHP and real options analysis, particularly the more demanding data needs of real options analysis (the need for decision trees in particular) and the need to identify uncertainties affecting projects
ii) simplifying assumptions of the AHP and real options analysis, particularly the simpler representation of dependencies in the AHP.

The next phase of work within the Integration project will be development of the processes required for operation of the evaluation method. The processes will include:

i) data and knowledge requirements
ii) methods for obtaining this data

iii) evaluation of existing software for bringing data together and carrying out the programme evaluation
iv) methods of effectively reporting outcomes to Beacon.

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