

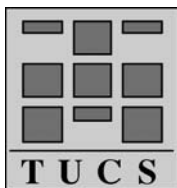
Improving Investment Decision–Making by Expanding Key Knowledge with Real Option Tools

Francisco Augusto Alcaraz Garcia

Turku Centre for Computer Science TUCS
IAMSR (Institute for Advanced Management Systems Research)
Åbo Akademi University
Lemminkäinenengatan 14 B FIN-20520 Åbo, FINLAND
falcaraz@abo.fi

Markku Heikkilä

IAMSR (Institute for Advanced Management Systems Research)
Åbo Akademi University
Lemminkäinenengatan 14 B FIN-20520 Åbo, FINLAND
maheikki@abo.fi



Turku Centre for Computer Science
TUCS Technical Report No 467
July 2002
ISBN 952-12-1027-3
ISSN 1239-1891

Abstract

Assessment of investment profitability with discounted cash flows has proven insufficient when industry structures change. Managers need an extended flexibility in decision-making that DCF analyses cannot offer. *Real Option* valuation as a method for improving flexibility in investment decisions has been widely researched but less used in business. With good support tools it is possible for managers to cross the threshold to Real Option methods and thinking. Real Option spreadsheet tools support both decision-making processes and business learning. They utilise the flexibility that new key knowledge brings to volatile industry situations and lead to better investment decisions.

Keywords: Flexibility in investment, Real Option tools, DSS

1 Introduction

In investment planning and management the basic business rationale is to improve the profitability and productivity of the planned or managed asset. In a corporate context this logic is further developed into the strategic management of a portfolio of business units [22], [20].

The corporate board typically makes strategic capital budgeting decisions. In the strategic portfolio management model fixed industrial assets are managed according to their economic performance [21, Ch.8]. In order for an additional asset to be added to the portfolio, or an existing asset to be replaced by a new one, it has to prove its value with respect to both profitability, according to corporate rate of capital return, and corporate strategy. Alignment to corporate strategy can be understood as a constraint that effectively discards unfeasible investment alternatives during the various phases of the investment planning process. What is left in the final board-level decision phase are the final few alternatives (or only one alternative to be accepted or rejected) that compete in the internal market of scarce corporate resources (also industrial and human, but in this case capital resources). The final decision is then made as a capital budgeting decision.

To evaluate competing projects, most companies use a mix of approaches that can be grouped between formal (theories and models) and informal (rules of thumb or leadership). A clear trend toward more formal-quantitative methods has been observed when facing uncertainty over future conditions. Traditionally, corporate investment decisions are guided by the rule of *net present value (NPV)* maximization, among other methods such as *internal rate of return (IRR)*, *payback*, etc. While using the first method, the stream of expected cash flows the investment will generate must be discounted (*discounted cash flows - DCF*) to present value at a discount rate, as well as the stream of expenditures required to undertake the project at the risk-free interest rate. By calculating the difference between the two we obtain the *NPV*, and the project with the highest positive value should be exercised.

$$NPV = - \sum_{t=0}^n \frac{I_t}{\prod_{j=0}^t (1 + r_{f_j})} + \sum_{t=0}^n \frac{E(CF)_t}{\prod_{j=0}^t (1 + k_j)} \quad (1)$$

where

t = time

I_t = Investment at time t

r_{f_j} = Risk-free interest rate at time j

$E(CF)_t$ = Expected cash flow at time t

k_j = Discount rate at time j

During the calculation process we need to forecast the expected future cash flows for the life-time of the different projects, the expected stream of costs, and also the discount rate. As with anything involving future projections, there is not a unique and best way to obtain the project's cash flows and costs and it is quite common in practice to use favourable, intermediate and worst scenarios.

The discount rate is the opportunity cost of capital for the specific project, i.e. the expected rate of return an investor would require from an investment of similar risk. The opportunity cost reflects the systematic risk associated with the particular project, the non-diversifiable risk. The widely used discount rate is the *weighted-average cost of capital (WACC)*, that is a tax-adjusted discount rate including the value of interest tax shields. *WACC* is a good approximation of the opportunity cost of capital if the company's projects have a similar systematic risk.

$$WACC_j = \frac{E_j}{V_j} * r_{e_j} + \frac{D_j}{V_j} * r_{d_j} * (1 - T_{c_j}) \quad (2)$$

where

E_j = Market value of the firm's equity at time j

D_j = Market value of the firm's debt at time j

$V_j = E_j + D_j$

r_{e_j} = Cost of equity at time j

r_{d_j} = Cost of debt at time j

(E_j/V_j) = Percentage of financing that is equity

(D_j/V_j) = Percentage of financing that is debt

T_{c_j} = Corporate tax rate at time j

Another alternative for evaluating value business operations is the *adjusted present value (APV)* [6]. It applies the previous *DCF* method to two main cash flow categories and then sums up the present values. The two categories are: 1) real cash flows, associated with the business operation; and 2) side effects cash flows, associated with its financing programme. The added value with respect to the *NPV* is the greater information that can be obtained by breaking the valuation problem into several sub-problems. In this case, management can identify different sources of value, how the different parts add value to the total project, and design tailored corrective actions in those areas affecting negatively the overall performance.

2 Limitations of DCF

Though these techniques are widely applied, their limitations for adequately evaluating investment projects have become more evident during recent years [6], [8], [4]. We can group their limitations into two categories:

- *Intrinsic limitations*
- *Valuation limitations*

2.1 Intrinsic Limitations

We have pointed out earlier that in order to obtain the *NPV* we need to estimate the future expected cash flows and costs. The task is not straightforward and different methods and approaches about what will happen in the future may be taken depending on who does the calculations. Different scenarios can be considered in order to cover the different future situations. However, though they give management slightly more information, they are based on assumptions about uncertain cash flows. Moreover, it is implicitly assumed that the project begins and ends at a fixed point of time (*static*) and does not take into account the possible managerial actions affecting the project during its life-cycle (*dynamic*).

For the expected investment costs the situation is similar. Though this factor may vary less and can be better estimated than its counterpart, it is often difficult to determine them accurately in projects involving high investment and a certain degree of technical complexity. If much investment expenditure is required over time, we need to choose their specific discount rate, r_f , per period and this is not an easy task since r_f is one of the factors included in the governments' monetary policy, changing according to the economic situation of the country.

Another factor we referred to before is the selection of an appropriate discount rate. Low discount rates give more weight to the cash flows farther away in the future, while high ones give distant cash flows less weight in the evaluation process. It often happens that the opportunity cost of capital is difficult to measure, and companies, for simplification, choose an arbitrary discount rate they consider appropriate. Benchmarks for the appropriate opportunity cost can be obtained from capital markets when similar risks are priced, but it is not always possible to find correspondence if we consider that much investment is company or industry-specific. *WACC*, as an approximation of the correct discount rate, is not free of criticism. *WACC* is more suitable for static capital structures; otherwise it needs to be adjusted for tax shields, issue costs, subsidies, hedges, exotic debt securities,

and dynamic capital structures. These adjustments must be made period by period and for every project [6]. Therefore, the more complex the financial structure, the easier it is to misestimate.

2.2 Valuation Limitations

In most cases, investment projects are irreversible, i.e., they are specific to a company or industry, and therefore, it is difficult to recover expenditure during unfavourable market conditions. Even if they are not specific, they are partly irreversible because of the difficulty external investors face when evaluating the real value of assets. At other times irreversibility may come from government regulations or institutional agreements. *NPV*, when dealing with irreversible investment, assumes that it is a *now-or-never* proposition in the sense that if the company does not invest now it will lose the opportunity. But the recognition that capital investment can be irreversible opens the opportunity for *proactive project management*. Strategic considerations change the management's passive commitment to a static operating strategy (static life-cycle) into a dynamic one where there exists the *flexibility* to alter decisions and generate new opportunities as new information becomes available. Flexibility is a valuable commodity and usually the more associated with a project the better; companies must find out how to exploit their opportunities and flexibilities in the most effective way.

		<i>Uncertainty</i>	
		<i>(Likelihood of new information)</i>	
		Low	High
<i>Managerial flexibility</i>	<i>High</i>	Moderate flexibility value	High flexibility value
<i>(Ability to respond)</i>	<i>Low</i>	Low flexibility value	Moderate flexibility value

Flexibility increases by:

- High possibilities of receiving new information
- High managerial flexibility, proactiveness
- When $NPV \simeq 0$, flexibility to change future is more valuable

Table 1: Managerial flexibility, adapted from [4]

Since opportunities are options, the concept of *Real Options* has been developed as a way to quantitatively measure the value of flexibility. *DCF*

fails to capture the added value that management can incorporate into the project in several ways [8], [1], [3]:

- Following the criterion of a positive *NPV* to accept a project, worthwhile investments may be rejected since most capital investment is irreversible. In practice, as a rule of thumb, a project is accepted only if its discounted cash flows are double its costs.
- When an irreversible investment is made, the option to invest is exercised and, therefore, the opportunity to do so at a future date is lost. In this case, the possibility of delaying the investment and waiting for new information is given up. This information may also affect the decision for the timing of the option.
- *DCF* tends to overlook the strategic reasons for an investment since it ignores other sources of value than the discounted cash flows. An investment may create future growth opportunities because of its characteristics, even though its *NPV* is not as high as with other investment.
- *DCF* do not include the value of active management. During the life-cycle of the investment, management can change the input and output mixes, shut down and restart the project later on, adjust maintenance investments, etc.
- If market conditions become unfavourable, management can abandon a project permanently. *DCF* ignores the value associated with the opportunity to abandon the project.
- *NPV* also ignores the value of creating options. Some investment, as in R&D, can lead to patents and new technologies that open up possibilities of investing in the future if market conditions become favourable.

All these different types of flexibilities define different types of options that can be valued. We shall explain them briefly in the next section.

2.3 Types of Options

The flexibility of management to modify its future actions according to new situations increases the investment value by expanding its upside potential and reducing downside losses. This value can be assessed using *Real Option* methods and leads to different types of real options depending on the existing opportunities for management [1], [5], [4], [10].

- *Option to Defer.* An important type of managerial flexibility is the ability to defer the investment and benefit from the resolution of uncertainties when new information becomes available. This option acquires more importance if the project is totally or partially irreversible. Waiting has a value because the project can be reversed by undertaking the investment at a future date. The greater the uncertainty over the future profitability of the investment, the greater value the option to wait has, i.e., if there is some probability of a loss when proceeding with the project, the decision of keeping the option alive has a value greater than 0. The question that remains is when to exercise the option and invest. The solution to the optimal timing of an *American call option* on the investment gives the answer.

When a company makes an irreversible investment now, it *exercises* or *kills* the option and, therefore, it cannot be reversed any more. Since *NPV* fails to assess the value of flexibility, it is net of any premium of the timing option. When the expected *DCF* exceeds the initial outlay by an amount greater than the option premium associated with waiting, the investment should be made immediately.

- *Time-to-Build Option.* Usually, the required expenditure of a project can be made in stages. The arrival of information may cause the investor to ignore, accelerate or decelerate future expenditure. Each stage can be seen as a *call option* on the next stage forming a set of consecutive call options. This set of nested options can be valued similarly to the valuation of compound options. We can find this idea in the sequencing of product development. By investing in a base product, the company can observe how it evolves on sales, market penetration, brand name, etc. and decide whether to develop new releases or not.
- *Option to Expand.* When market conditions become more favorable, management can expand the scale of production by investing in new facilities. The investment opportunity can be considered as a basic investment plus a *call option* on a future investment. The initial outlay allows development of the future project, usually by assuming higher initial costs. This could be the case of an industry with an initially more flexible technology that helps to expand production if demand increases, or the case of a factory with the space and infrastructure already built for the installation of new production units in the future. The option to expand will be exercised if future market conditions become favourable so that the option premium may be outweighed by the opportunity lost due to not investing. The option to expand may

be strategic if it enables a firm to capitalize on future growth options.

- *Growth Options.* When the option to expand has considerable strategic importance, we may have corporate growth options. This could be the case of a power plant based on a new technology for biofuel processing that is developed and tested at a pilot plant. Although the investment may appear to be a sunk cost, it might be the first of a series of similar units in Scandinavia. The value of the first investment does not come from the *DCF* but from the ability to open future growth opportunities and future strategic positioning. The infrastructure and experience may facilitate the development of lower-cost, more efficient future units, or the generation of new application into other areas; but if the first investment is not undertaken the future potential will be dismissed. Growth options are considered as options on options, i.e., *compound options*.
- *Option to Contract.* Contrary to the option to expand, the option to contract consists of the possibility of reducing capacity or scale of operations if market conditions become worse than expected, thus saving part of the expected investment expenditure. The flexibility to reduce losses is modelled as a *put option* on part of the initial project.
- *Option to Shut Down/Produce.* Traditional budgeting analysis assumes that a project will be operated every year during its life-cycle. But in real life the project does not have to be operative in every period. When revenues are not enough to cover variable operating costs for the period, production can cease temporarily. If the market situation changes and cash flows increase enough, operation can start again. We can see the firm's productive capacity as a *call option* to produce that expires in each period.
- *Option to Abandon.* The flexibility to abandon a project before its life-time expires is another potential source of value. If profitability of the project is low, management can decide to stop incurring the fixed and variable costs permanently in exchange for the salvage value of the project. Since the abandonment alternative limits losses, its payoff is similar to that of an *American put option*. When to abandon is assessed by solving the corresponding optimal stopping problem.
- *Option to Alter Input/Output Mix.* The wider the choice of input, output or both, the more valuable must be the options to alter the production mix. Technology providing process flexibility allows the maxi-

mization of the cash flows by modifying the output mix, and the minimization of the costs by modifying the input mix according to market conditions. The company would not be reluctant to invest in such a technology to obtain that flexibility, but it can also be obtained by maintaining relationships with different suppliers so that it is possible to change the mix according to variations on prices. This type of option can be seen as a *compound call option* in the different inputs and outputs that maximize revenues and minimize costs. An example of an option to change input is a metal-refining process that accepts two or more raw material mixes as process inputs. Refinery management can consequently change the mix according to the market situation of the final product or the availability of the raw materials.

3 Real Options versus Financial Options

We have introduced the concept of (American) call/put options in the previous section for different types of flexibilities. In general, a *call option* gives you the right but not the obligation to buy a security at a given price (*exercise price*) during a certain period of time (*time to expiry*). If the market price of the security is higher than the exercise price, the holder of the option will exercise it and will buy from the writer (the issuer) the underlying asset at the exercise price, obtaining, therefore, a profit for the difference. Conversely, a *put option* gives the holder the right but not the obligation to sell a security at the *exercise price* during the *time to expiry*. If the market price of the security is lower than the exercise price, the holder will exercise the option and sell the security at the exercise price to the writer. He obtains, therefore, a profit for the difference.

An *American* option allows the holder to exercise the right on or before the expiry date, and an *European* one can only be exercised on the expiry date. When dealing with American options we also have the task of determining the *optimal exercise time*.

Real Options are like financial options but have as an underlying asset a non-financial or real one. An irreversible investment opportunity is like a financial call option. A company with an investment opportunity has the option to spend money either today or within the time to expiry (the exercise price) in return for a real asset, the project. Since the future profitability of the project is uncertain and several contingencies may occur, the option to invest has a value to the *NPV*. This additional value is an estimate of the opportunity's worth. Also, an opportunity to shut down, downsizing or abandon may be considered as a financial put option. Because of the

analogy between financial options and corporate investment, we can borrow the theory behind financial options and establish a correspondence between the project's characteristics and the variables determining the value of an option.

In 1973 Black and Scholes derived a differential equation that the price of any derivative security dependent on a non-dividend paying stock must satisfy. This formula was modified by Robert Merton to incorporate dividend-paying stocks in the valuation, being the formula for estimating the price of a financial call option as follows [2], [7], [10]:

$$\begin{aligned}
 Call &= Se^{-\delta t}N(d_1) - Xe^{-r_f t}N(d_2) \\
 d_1 &= \frac{\ln(\frac{S}{X}) + (r_f - \delta + \frac{\sigma^2}{2})t}{\sigma\sqrt{t}} \\
 d_2 &= d_1 - \sigma\sqrt{t}
 \end{aligned} \tag{3}$$

where

- S . This is the value of the underlying security on which an option is purchased. The equivalent in real terms is the sum of the expected discounted cash flows of the project.
- X . Exercise price, the value at which the security will be bought or sold if the option is exercised. In real terms it is the sum of the investment costs.
- σ . Uncertainty about the future movements of the stock price measured as the standard deviation of the growth rate of the stock price. In real terms it represents the riskiness of the project, i.e., the uncertainty about the future value of the project's cash flows.
- t . Time to expiry, time interval where we have the right to exercise the option. In real terms this is the period we can delay the investment without losing the opportunity.
- r_f . Risk-free interest rate, the annualized continuously compounded rate on a safe asset with the same maturity as the expiry of the option.
- δ . Dividend, sums paid regularly to stockholders. In real terms is the leakage in value, i.e. costs incurred to preserve the option, rental, licence, royalty income, convenience yield, etc. δ is considered as a constant percentage of the value of the underlying asset.
- $N(d)$. Cumulative normal distribution.

- $N(d_1)$. Proportion of shares required to replicate the call option.
- $N(d_2)$. Probability that the call option will be exercised on expiry.

<i>INVESTMENT OPPORTUNITY</i>	<i>VARIABLE</i>	<i>CALL OPTION</i>
Present value of a project's operating cash flows	S	Stock price
Investment costs	X	Exercise price
Length of time the decision may be deferred	t	Time to expiry
Time value of money	r_f	Risk-free interest rate
Riskiness of the project	σ	Standard deviation of returns on stock

Table 2: Table of equivalences [7]

NPV and option value are identical when the investment cannot be deferred, i.e., if $t=0$ we are in the situation of *invest now or never* which value is reflected in the *NPV* and, therefore, both results must coincide. By using this procedure we can determine the value of flexibility as the difference between the traditional *NPV* and the value of the option contained in the investment opportunity. If there is no flexibility, we are in the previous situation. The greater the value of the opportunity the greater the incentive to wait and to keep the option alive rather than exercise it by investing now (as *NPV* would suggest).

But under this framework and despite all the criticism *NPV* has received, the methods are not opposed but complementary since several inputs for the Black–Scholes formula come from the analysis performed to obtain the *DCF* and *NPV*. We need the discounted cash flows as the value of *S*, the investment costs as the value of *X* and, if the project requires considerable investment expenditure over time, the r_f interest rate is also necessary for the *NPV*. So, we could say that *NPV* is the first stage in the real option calculation and a high degree in the accuracy of the flexibility value comes from the accuracy attained in its calculation.

4 Real Option–Enabled Decision Support Systems

Real option valuation methods have gained attention as methods of real asset and investment valuation. Industrial investment that is typically built for operational life-times of more than ten years includes a relatively large unique risk due to a considerable one-time sunk capital cost. In order to deal with unique risk, decision–makers of industrial corporations routinely run careful risk analyses. Unique, non-diversifiable risks are then treated as scenarios of *DCF* analysis. Scenarios, however, do not take into account the flexibility that changing market situations bring the value of the project [17]. In order to introduce the flexibility of the project to investment decision–making, there needs to be a new approach to capturing key knowledge of the changing market in quantitative investment analyses. Real option valuation methods clearly offer this capacity when applied appropriately in decision support.

The investment decision–making process requires a lot of high–quality information. There is a constant need for a flow of adequate, timely information that enables the initiation of possible alternatives, facilitates discussions and comparisons concerning the qualitative features of existing assets and new alternatives, as well as supports the generation of key figures to show the expected economic performance of each of the possible ways of action.

4.1 The Unexpected

One of the most important features in strategic management is to be prepared for the unexpected. Indeed, it can be regarded as the basis for all planning and management. Traditional *DCF* analysis reacts slowly to the unexpected. If a market situation changes, the changes can be incorporated in the calculation by modifying the corresponding decision variable, but the change in inherent flexibility is not captured in this static mode of investment management.

If instead, we apply a dynamic real option–enabled profitability analysis, the changes of flexibility are readily available as the change of the key knowledge is automatically updated to the calculation. In order to show the needs for information in real option–enabled decision support systems (*RO–DSS*) we will first present the general *requirements of information* for a set of decision modes to be supported. Then we will show construction guidelines for a *RO–DSS design* supporting a group of organic corporate investment decision–makers (as defined by the applied investment decision–

Investment management

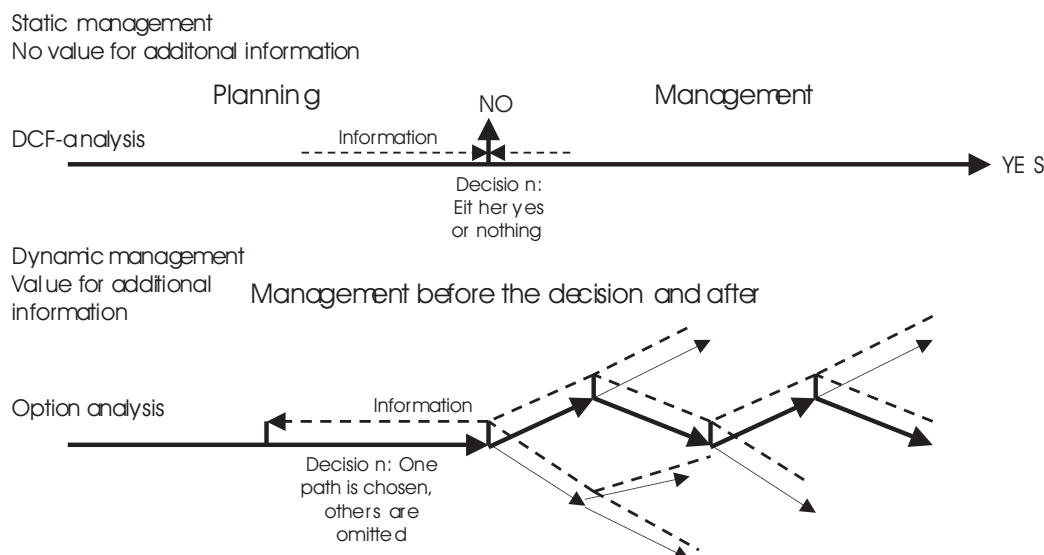


Figure 1: Investing management

making process) responsible for assigning of corporate resources. Features of the guidelines will follow three existing functional *RO-DSS* prototypes that we have built for a Finnish metals producer and a Finnish energy supplier.

4.2 Information Requirements

Information requirements are here classified as five organic decision support modes: strategy, process, consensus, learning and profitability.

- *Strategy*
Following the line of logic of investment planning where the strategy is seen as a tool for eliciting the feasible investment alternatives from all existing alternatives, support for strategic decisions is dominated by qualitative, investment-specific knowledge. Due to the nature of strategic decisions per se, i.e. of being the result of a qualitative decision-making process, there is a need for a comprehensive but compact set of qualitative knowledge for each proposed alternative. This information should be updated in a common knowledge base when the variables of strategic environment, or any other independent variable, change. This should enable the decision-maker to see if the change in the environment actually has made the alternative obsolete or maybe opened up new prospective sources of strategic value. Due to elimination of un-

feasible alternatives in the process of strategic decision-making, there should also be room in the system for including new investment proposals. Otherwise, the efficient elicitation could replace the use of expertise and judgement in the initiation of new alternatives.

- *Process*

Corporate investment planning typically includes various stages, when decision-makers of the various levels of organization process information. Results of this processing are then used by the following stages. A decision process model of this type sets a quality requirement on the reliability of the information. An *RO-DSS* should support the identification of various sources of real option information by assigning to them data about the source, owner, process stages and current state (static or dynamic) of the piece of information. This is especially important since real options as tools for assessing investment potential show the results as measured by currency units. This may lead a decision-maker to expect the result to be an expected value of cash flow instead of the value of the real option potential. In practical cooperation with corporate partners it has proven necessary for the authors to show the meaning of various variables of real option valuation in order to facilitate understanding and increase the acceptance of the real option method.

- *Consensus*

A hierarchical corporate structure enables the use of a portfolio model, and it also enables the use of politics for the manipulation of opinion and preference in decision-making. In order for the best possible decision-making process to take place, there needs to be a common ground for negotiation. This is supported primarily by the formalization of the decision process that gives to all participants a common understanding of rules and preferences set for the investment planning. All such information can be included in the help facility of the *RO-DSS*. In addition, by showing the source of each item of information an *RO-DSS* can support the negotiation by facilitating trust among the parties in negotiation. This approach presupposes high confidence in the system used, which may be a hard task. It is a common rule that a system should be as transparent as possible, in order to support negotiation function.

- *Learning*

Due to the novelty of the real option approach in business there is a constant need for expertise in the education of business practitioners.

Expertise can also be modelled in an *RO-DSS*. A knowledge base and a rule base for ensuring the consistency of decision-making logic can facilitate learning and support real option-enabled decision-making of less *real option-able* managers.

- *Profitability calculations*

The results of real option valuation are the results of the use of management models and mathematical formulae. The most important support for the user in any *RO-DSS* is the support for understanding the results of real option valuation, the variables of applied real option models and the conditions of the applied real option formulae. This is the area where the usability and applicability of each *RO-DSS* are ultimately tested. The design guidelines here follow a multiple format knowledge representation scheme. Any single piece of information, showing either the potential of an investment, a decision variable or an environmental value should be shown at least in a graphical as well as the numerical way. It should also be possible for industry practitioners to follow the specific logic of analysis in a way that directly integrates the potentiality of a real option with the conditions of the analysis and the terms of the decision model. A clear logic of the interpretation of the business situation as well as a recommended course of action should also be included.

Results of the information requirements are shown in Table 3.

4.3 RO-DSS Design

We have developed three *RO-DSS* prototypes for the analysis of real options in various industrial investment situations. The experiences gathered from these applications with the requirements for information in the decision situations suggest some guidelines to be applied in *RO-DSS* design. We apply a process-centred design approach, where the requirements of the process guide the design of the desired system. We also apply the integrative concept of support that sets the role of the system to be a tool to aid the generation of decision outcomes, to facilitate the decision-making process, and to support learning according to the requirements of user capability [15].

The core of the system in our approach is built to follow the structure of hyperknowledge, which is a knowledge-rich decision environment with system support consisting of hyperlinks linking various knowledge concepts to each other. This approach allows for the use of a variety of concepts, models and data sources [11], [12], [18], [14]. The basic concepts in our

DECISION SUPPORT REQUIRED FOR:		DECISION SUPPORT MODE	DSS OPERATION REQUIRED
STRATEGY	←	INFORM	QUALITATIVE KNOWLEDGE MONITORING
PROCESS	←	INFORM	DATA AND PROCESS KNOWLEDGE CONTROL
CONSENSUS	←	INFORM	CONSTRUCTION AND CONTROL COMMON KNOWLEDGE BASE
LEARNING	←	STIMULATE	INDIVIDUAL LEARNING WITH KNOWLEDGE FUNCTIONS
PROFITABILITY CALCULATION	←	AUTOMATE	KEY-FIGURE GENERATION WITH QUANTITATIVE CALCULATIONS

Table 3: Decision support modes according to general RO-DSS information requirements

approach include real option valuation, linear programming, knowledge visualization, knowledge-intensive learning and knowledge-based support facility with fuzzy logic approach.

Carriero and Gelernter have presented their model of *coordination* as languages that integrate communication between various *computational* processes that are separate from each other in time, location and interface [13], [16]. The process of real option-enabled investment decision-making is clearly a process of coordination that facilitates computations, and vice versa. What we need in order to coordinate the two types of processes is a hyperknowledge environment.

5 Examples of Real Option Tools

In the research consortium *WAENO* we have built several real option decision tools using a prototyping approach. We have developed a learning platform with an example of an *option to expand*, and two case applications, one for a copper-producing unit with a copper smelter and a copper refinery

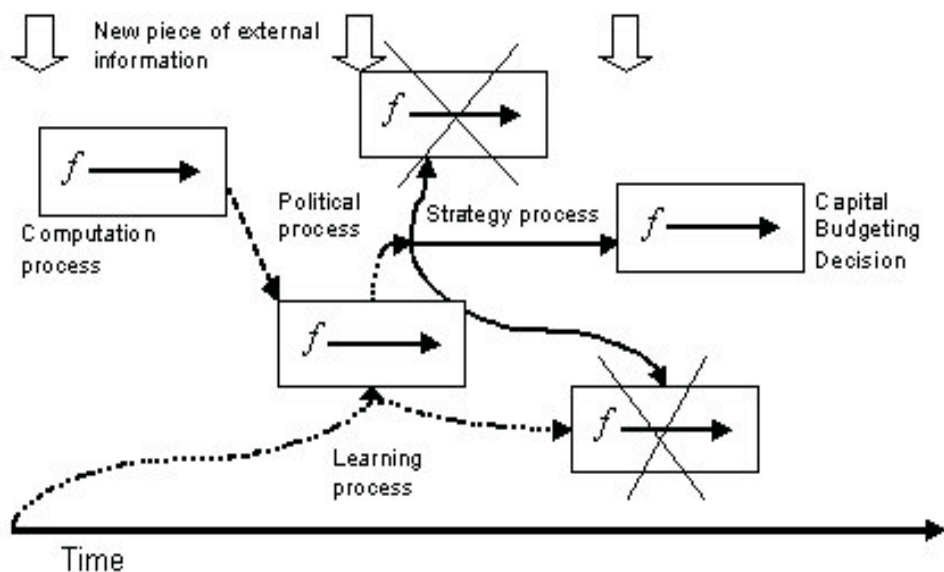


Figure 2: Modes of investment decision support with real option tools (both computation and coordination processes)

and another for an electricity company with several development options regarding the use of biofuel and natural gas. We have also developed several ad-hoc platforms for specific purposes for both the previous companies and two other enterprises that participate in *WAENO-consortium*.

In this section we will show some examples of real options utilisation in a corporate planning context. Due to corporate secrecy demands all figures have been modified or replaced with artificial ones. What a decision maker often requires is the ability to adjust decision variables of a decision model in order to see the sensitivity of the result to the change in the decision variable. Such a sensitivity analysis can be developed for a real option calculation as well. For financial options the sensitivities are captured by partial derivative functions called *the Greeks*. This is one possible approach also for real option calculation. However, we have chosen a representation form that is slightly different in content, but quite different in representation. Our *graphical sensitivity analysis* captures the value changes in decision variables to the real option value and to the inherent flexibility of the project. By showing the information both numerically and graphically, we aim at supporting both visual and mathematical knowledge acquisition modes. Due to the fact that the cash flows are imported from standard *DCF* calculations, the possibilities to manipulate decision variables can be taken one step further to the *DCF tables*.

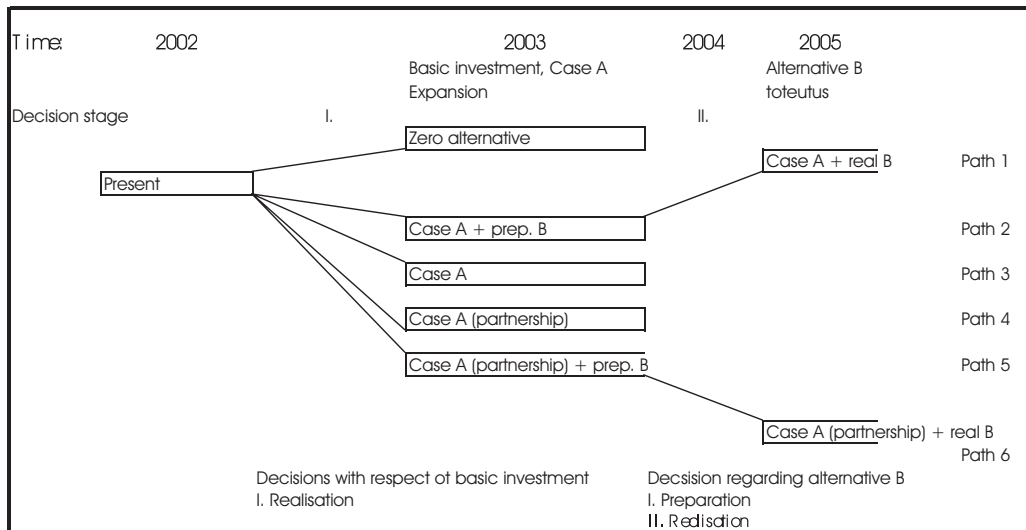


Figure 3: Decision tree to facilitate the plotting of various alternatives and decision paths

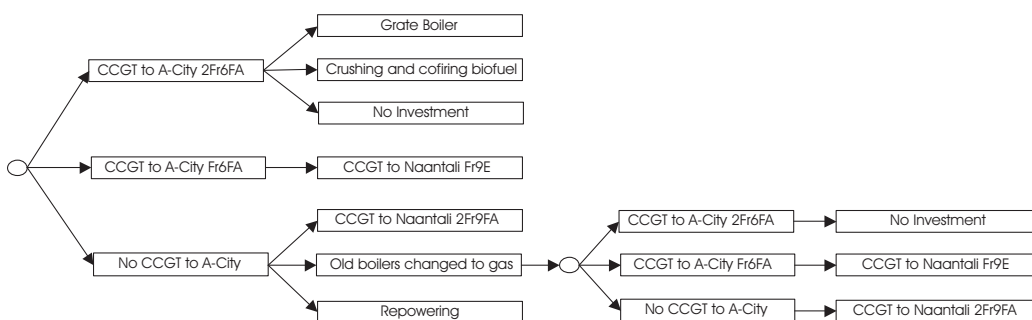


Figure 4: Decision tree with external factors and decision paths

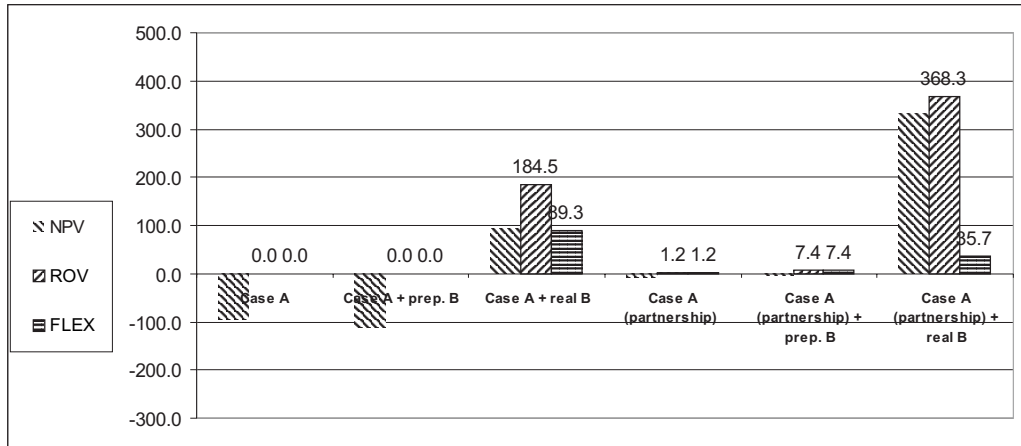


Figure 5: Comparison of NPV, ROV and flexibility of each decision path

SENSITIVITY ANALYSIS:

Case: Case A (partnership)		Simulation assumptions				
Currency: No currency effect		Original Values	Change (-)	No change	Change (+)	
TC/RC: Lognorm		Give Change				
S	PV of cash flow (S), MEUR	10%	87	78	87	95
X	Investment (X), MEUR	0%	130	130	130	130
	Riskfree interest rate	0%	5.0 %	5.0 %	5.0 %	5.0 %
d	Lost value	0%	0.0 %	0.0 %	0.0 %	0.0 %
s	St. deviation of cash flow	0%	27.0 %	27.0 %	27.0 %	27.0 %
T	Years to expiry	0	1.0	1.0	1.0	1.0
NPV	NPV		-9.1			
			-1.17832	-1.56854	-1.17832	-0.82532
			-1.44832	-1.83854	-1.44832	-1.09532
			0.11934	0.05838	0.11934	0.20460
			0.07376	0.03299	0.07376	0.13669
C	Real option value (Call), MEUR		1.2	0.5	1.2	2.6
NPV	NPV	0%	-9.1	-9.1	-9.1	-9.1
	Flexibility		1.2	0.5	1.2	2.6

Figure 6: Numerical sensitivity analysis (both manipulation and its results)

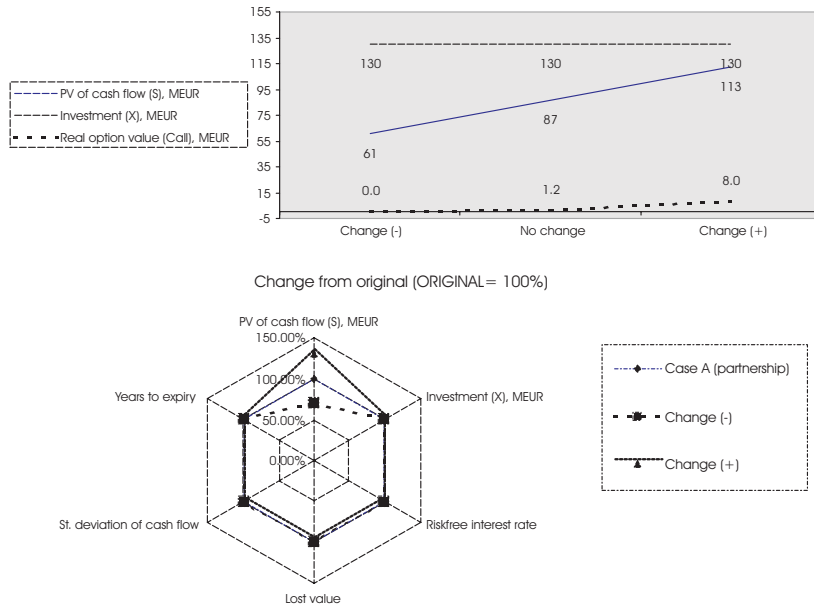


Figure 7: Graphical sensitivity analysis (results of manipulation)

The *fuzzy logic* approach to real option valuation provides additional features. Fuzzy logic is a formal method for dealing with imprecise information, reducing the need for precise forecasts and expressing uncertain future values by means of possibility distributions. In the fuzzy approach, cash flows can be fuzzified and converted to fuzzy numbers, usually of the triangular or trapezoidal types. In this way, the real value of cash flow is specified as lying within an interval. Values below or over the interval have a lower possibility of occurrence (trapezoidal fuzzy number), and no precise cash flow estimation is required. From the fuzzy cash flows we can obtain some of the inputs for the fuzzy real option value, such as the possibilistic mean value and the possibilistic variance. These values, together with the other crisp (non-fuzzy) inputs, allow the calculation of a *Fuzzy Real Option Value* which contains the value of flexibility from the real option approach and mitigates forecast inaccuracy [19].

6 Real Options and Investment Planning

6.1 Real Options in Investment Planning

The applicability of the real option approach can be further illustrated in the context of the case studies carried out in the *WAENO* project. The

PRODUCTION UNIT X, Scenario A, Fuzzy Cash Flows				
Date	a	b	Alpha	Beta
Jan-03	-26,134,139	20,534,935	53,003,733	35,695,303
Jan-04	-15,183,139	32,498,565	36,989,972	21,502,943
Jan-05	-19,230,839	29,074,788	45,028,901	29,198,830
Jan-06	-12,330,997	39,897,877	40,432,788	30,069,056
Jan-07	-8,561,617	46,859,094	38,435,182	29,131,851
Jan-08	-6,355,051	54,177,394	34,367,051	28,684,737
Jan-09	5,340,783	62,645,892	25,197,262	27,119,757
Jan-10	9,942,717	71,134,773	20,869,916	34,902,036
Jan-11	11,719,778	72,349,979	19,941,320	37,202,234
Jan-12	12,209,701	77,741,638	22,278,200	36,887,183
Jan-13	14,206,546	80,652,185	20,974,803	36,758,845
Jan-14	16,351,789	83,908,172	18,918,088	36,272,603
Jan-15	18,665,980	92,073,821	16,019,312	61,167,212
FROV	31,359,339	489,413,406	216,502,435	273,598,277

Figure 8: Fuzzy cash flows for the life-cycle of an investment

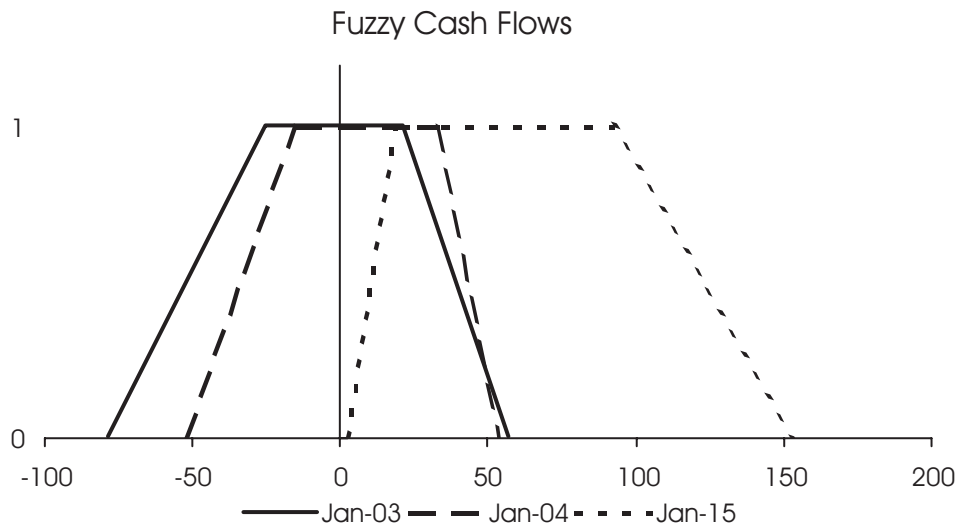


Figure 9: Graphical representation of trapezoidal cash flows

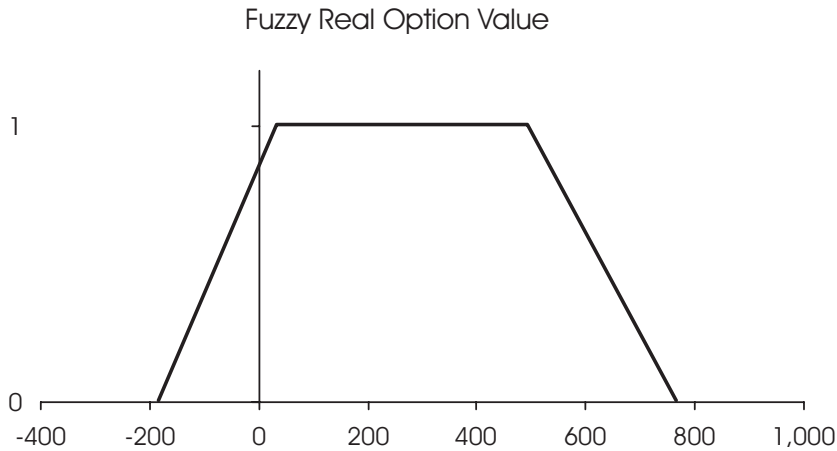


Figure 10: Fuzzy Real Option Value

cases were qualitatively ranging from a green field investment project in the production chain of paper to a modification in a set of power turbines in a power station park. In a total of nine cases there were several cases where real option approach could support decision-making. The overall objective of the *WAENO* project was to examine the profitability and productivity of capital in very large industrial “gigainvestments”. The method of real options valuation was originally introduced to explain the development of profitability when the original planning figures of the investments were retrospectively compared to the realised investment project life cycle profitability. The methodological question was whether the real option approach could give better support for investment planning than traditional *DCF*-approach.

A green field pulp mill was partially founded due to reasons of social welfare and regional policy, but mainly with logistical considerations of better utilising the regional supply of wood suitable for pulp production. In a retrospective case study of this investment project it was found that the process of investment planning and asset maintenance followed the logic of incremental development closely related to the real option approach [23].

The project had undergone a severe market downswing with large economic losses right after the completion of the initial investment project, and a question was arising whether the operations should be closed. However, the project management team and the managing director were convinced that the market trend would turn up soon. That is why they started to persuade the corporate board to issue more funds for a project that would enable the maximum benefits from an expected bull market. Members of the board strongly argued against the request on the grounds of the conventional market logic that the funds invested in the existing projects should be recovered

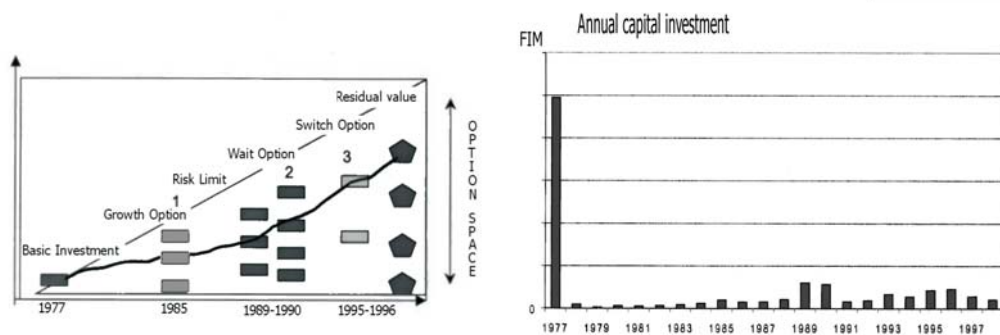


Figure 11: Identification of real options in the investment life-cycle of the case project. Annual capital investment. Adapted from [23]

before going for follow-on projects. Finally, the motion of the management was accepted and the additional project was finished in right time to take advantage of a market upswing that fully covered the previous losses and the capital costs of the projects. Also, the productivity of the plant was continuously improved by means of a few larger maintenance investments with almost optimal timing (See Figure 11 for a sequence of basic and maintenance projects). It seems reasonable to claim that the management applied the real option approach by using the educated intuition. They mentally valued the future potential of the investment projects, since it could not be done with the traditional valuation tools implemented in the planning process.

The options applied during the life cycle of the investment were:

1. Ability to wait for the experience from implementing a new technology in another pulp mill owned by the corporation (Technology implemented in 1985, experiences gathered in a few years, an option to wait)
2. Ability to utilise the development program of a few new technologies (1987-1993, growth option)
3. Ability to switch the production (1995, option to switch output)

In the cyclical pulp market the timing of investment can be the very source of either profit or loss. In the following graphic (Figure 12) it can be seen clearly how the investment timing enabled the company to take advantage of market volatility.

All the planning during the over 20-year history of the plant (1977-2000) was done with traditional investment planning tools *NPV*, *IRR*, payback time, etc. and the results were achieved without explicitly modeling capital investment flexibility or real option value. However, the results show

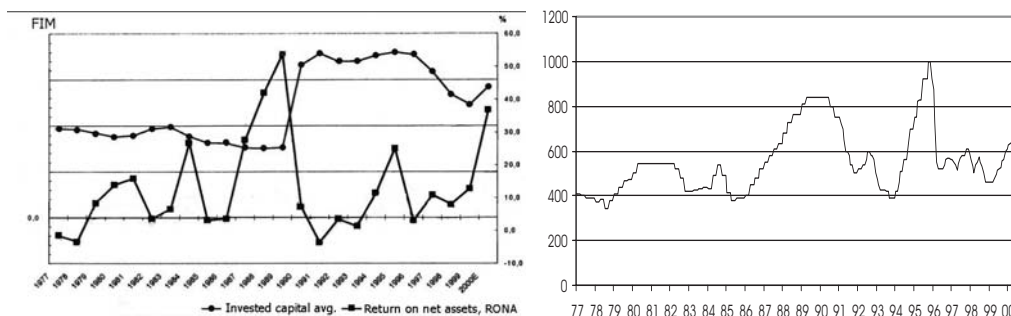


Figure 12: Key figures of the investment projects (numbers denote the exercise time of options mentioned in the text) and average monthly pulp price, *USD/tonne*, during 1977-2000

how understanding an investment in a continuum of project life cycle with preceding and subsequent investments gives better results than using only time-independent discounted cash flows. Thus, it is only logical to model such an investment as an incremental development process with real options rather than as a one-time “now or never decision” typical to *DCF*-methods.

What *RO-DSS* can improve in the investment process are the capital flexibility values of real option analysis and the improved information about the dynamic effects of time on decisions and decisions on subsequent decisions. On the other hand it seems that the managers of the case investment can learn only some quantitative features of real options with *RO-DSS*, not the improved business logic since they possess it already. Thus *RO-DSS* in this case has a limited potential as a tool for adaptation and learning of the business. If we follow the sequence of decisions, we can conclude that the “educated intuition” of the managers played a very central role. A question if this intuition could be incorporated in a formal *RO-DSS* and whether the decisions could be further improved remains to be unanswered. It seems reasonable to assume that in this case the knowledge and use of real option valuation would probably have given similar decisions to those actually made by the management.

To be able to fully assess the usefulness of real option valuation and *RO-DSS*, we would need to study an investment project underway. However, the educated intuition says that in order for a company to manage its assets in the (decades) long perspective of a gigainvestment, there are clearly advantages with the tools that give the management an opportunity to “wait-and-see” instead of acting upon the short-term market fluctuations.

A more formal motivation behind the use of real options can be retrieved

from the comparison of the financial stochastic processes of the Geometric Brownian Motion (*GBM*, a process with independent increments) and the Mean–Reverting Process (*MRP*, a process with increments depending on some normal value). With *GBM* the price of the asset follows a random walk process of geometric incremental change (e.g. the sequentially independent cash flows of the neoclassical *NPV*). In the *MRP* the incremental change is reverted to a normal level of the asset value with a fixed speed of reversion, and random walk is thus excluded. The marginal cost of producing one unit of a certain product is a typical example of a normal value that defines a *MRP*.

Tests with market data show that the longer the forecast perspective is, the better results *MRP* shows compared to *GBP* in terms of expected market value [9]. Nevertheless, the fact that tests usually show the change in favour of *MRP* with forecast perspectives exceeding a certain threshold¹ makes it more complicated to see if the benefits of an approach using dependent increments with slow reversion speed are true also for shorter periods. But, if one assumes positive marginal adjustment effects due to increased productivity from a gain investment project with 10-30 years of operational life cycle, the marginal unit cost decreases while the speed of reversion remains the same and *MRP* becomes more favourable also with shorter forecast perspectives.

Geometric Brownian Motion (with drift):

$$dx = \alpha x dt + \sigma x dz$$

where α is the drift parameter and σ is the variance parameter

Ornstein–Uhlenbeck Mean–Reverting Process:

$$dx = \alpha \eta (\bar{x} - x) dt + \sigma x dz$$

where η is the speed of the reversion and \bar{x} is the normal level of x ; α and σ as in *GBM*.

6.2 How Can *DSS* Enable the Use of Real Options in Investment Planning?

If the corporate management knew for sure when an upswing in the market is going to take place, there would be very few decisions to support. If a piece of information is available for everyone in the market, the marginal value of this information becomes very small. Then it is enough for a *DSS*

¹E.g. for copper the threshold is 30 years.

to support the basic calculation functions that automate the generation of analysis outcomes. Moreover, it is always easier to communicate potentials explicitly to the corporate board and to obtain its approval, if there is a DSS available to identify and analyse market information.

In practice, market experiences various levels of inefficiencies when the supply changes due to a gaininvestment project. In order for the planners to anticipate the adjustment effects they need, in addition to the knowledge about the present market variables, the knowledge about the dynamic effects of the gaininvestment that are not explicit at the moment. This makes the decision-making process substantially different and requires the utilisation of trend and uncertainty information that in turn requires a dynamic, adaptive decision-making process.

Such a process resembles closely to the present corporate practices of investment planning where several experts and managers work together to understand the potentials and risks of the investment project. In such an environment there is a need for showing the potentials of various alternative paths of the business development instead of only planning for a single outcome investment. To support decision-making process dynamics and learning the *RO-DSS* must have features that also enable the communication of qualitative knowledge and even intuition. In the sense of the negotiation process, a *RO-DSS* could also be considered as a group *DSS* (*GDSS*) where different individuals from different areas of organisation would approach and modify their opinions. Such a *DSS* would be helpful in communicating the strategic considerations to the decision-making process.

7 Summary and Conclusions

The *DCF* analysis has been the standard method used in capital budgeting, but limitations in the calculation process and in the value assessed have been pointed out during the last few years. The technique relies on future estimations of cash flows, investment costs, risk-free interest rates and discount rates. Though different scenarios may be considered, the procedure is based on assumptions about uncertain factors. Moreover, it is a static model since it does not consider proactive project management actions during the life-cycle of the investment that can alter substantially the overall performance. Nor does the technique cover any strategic reasons or built-in flexibility for undertaking an investment because it ignores other sources of value than the discounted cash flows.

The *Real Option* valuation procedures try to overcome the shortcomings of the *DCF* method. Relying on the similarities between financial options

and the managerial flexibility in investment planning, option pricing models attempt to value these types of flexibility. Under this framework, some of the inputs for the real option analysis come from the *DCF* calculations and, therefore, the methods should not be considered to be competing but to be complementary. Since several actions or *options* are available in proactive project management, we find different types of real options, such as: options to defer, to build, to expand, to contract, to abandon, etc.

The investment decision-making process requires a flow of adequate, timely information to evaluate and manage the different ways of action. A real option-enabled decision support system (*RO-DSS*) can efficiently handle the dynamic managerial flexibilities, so that changes in flexibility are readily available when new sources of information are updated to the calculation. By updating a common knowledge base whenever a variable changes, the decision-maker can identify the source of real option information and how it affects the performance. A *RO-DSS* builds and supports an understanding of the results of real option valuation, the variables involved in the real option models and the conditions for using them.

A new technique, *Fuzzy Real Option Valuation*, has been developed to better deal with imprecise information in capital budgeting. By means of fuzzy numbers, no exact cash flow estimates are required and the value of flexibility is captured.

References

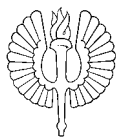
- [1] Lenos Trigeorgis. *Real Options in Capital Investment*. Praeger Publishers. Westport, CT. 1995.
- [2] Keith J. Leslie and Max P. Michaels. The real power of real options. *The McKinsey Quarterly*. Number 3. 1997. Pages 4-22.
- [3] Jerry Flatto. Using Real Options in Project Evaluation?. *The Magazine for Life Insurance Management Resource*. Life Office Management Association (LOMA). 1996.
- [4] Thomas E. Copeland and Philip T. Keenan. How much is flexibility worth?. *The McKinsey Quarterly*. Number 2. 1998. Pages 38-49.
- [5] Joseph K. Cheung. Managerial Flexibility in Capital Investment Decisions: Insights from the Real-Options Literature. *Journal of Accounting Literature*. Volume 12. 1993. Pages 29-66.

- [6] Timothy A. Luehrman. What's It Worth? A General Manager's Guide to Valuation. Harvard Business Review. May - June 1997. Pages 133-142.
- [7] Timothy A. Luehrman. Investment Opportunities as Real Options: Getting Started on the Numbers. Harvard Business Review. July - August 1998. Pages 51-67.
- [8] Avinash K. Dixit and Robert S. Pindyck. The Options Approach to Capital Investment. Harvard Business Review. May - June 1995. Pages 105-115.
- [9] Avinash K. Dixit and Robert S. Pindyck. Investment Under Uncertainty. Princeton University Press. Princeton, New Jersey. 1994.
- [10] Michael J. Mauboussin". Get Real. Using Real Options in Security Analysis. CREDIT SUISSE FIRST BOSTON CORPORATION. Equity Research. Number 10. Jun 1999.
- [11] A. Chang and C. W. Holsapple and A. B. Whinston. Model Management: Issues and Directions. Decision Support Systems. Number 9(1). 1993. Pages 19-39.
- [12] A. Chang and C. W. Holsapple and A. B. Whinston. A hyperknowledge Framework for Decision Support Systems. Information Processing and Management. Number 30(4). 1994. Pages 473-498.
- [13] D. Gelernter and N. Carriero. Coordination Languages and Their Significance. Communications of the ACM. Volume 35. Number 2. 1992. Pages 96-107.
- [14] C. Carlsson and P. Walden. More Effective Strategic Management with Hyperknowledge: The Woodstrat Case. Journal of Decision Systems. Volume 6. Number 1. 1997. Pages 23-44.
- [15] S. Dutta and B. Wierenga and A. Dalebout. Designing Management Support Systems Using an Integrative Perspective. Communications of the ACM. Volume 40. Number 6. 1997. Pages 70-79.
- [16] D. Gelernter and N. Carriero. A Computation Model of Everything. Communications of the ACM. Volume 44. Number 11. 2001. Pages 77-81.
- [17] S. Pender. Managing incomplete knowledge: Why risk management is not sufficient. International Journal of Project Management. Number 19. 2001. Pages 79-87.

- [18] C. Carlsson and P. Walden. Strategic Management with a Hyperknowledge Support System. HICSS-27 Proceedings. Los Alamitos. 1994. IEEE Computer Society Press. Pages 241-250.
- [19] C. Carlsson and R. Fuller. Real option evaluation in fuzzy environment. Proceedings of the International Symposium of Hungarian Researchers on Computational Intelligence. Budapest. 2000. Pages 67-77.
- [20] M. S. Allen. Business Portfolio Management. John Wiley & Sons. 2000.
- [21] R. A. Brearley and S. C. Myers. Principles of Corporate Finance. McGraw-Hill Higher Education. 2000.
- [22] M. E. Porter. From Competitive Advantage to Corporate Strategy. Harvard Business Review. May - Jun 1987. Pages 49-52.
- [23] Jukka Bodman". Gigainvestointien elinkaartuottoihin vaikuttavien tekijöiden arviointi. Tampere University of Technology, Pori. Industrial Economics. Diploma Thesis. 2000.

Turku Centre for Computer Science
Lemminkäisenkatu 14
FIN-20520 Turku
Finland

<http://www.tucs.fi>



University of Turku

- Department of Information Technology
- Department of Mathematics



Åbo Akademi University

- Department of Computer Science
- Institute for Advanced Management Systems Research



Turku School of Economics and Business Administration

- Institute of Information Systems Science