Soft Computing for Groups Making Hard Decisions

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Introduction

Hard decisions for a management team are those decisions which will have significant economic, financial, political and/or emotional consequences for the team and the company they serve. Hard decisions are normally difficult to make and this is made even harder if the decision situation is complex (i.e. there are many interdependent elements), the information about the decision alternatives and their consequences is imprecise and/or uncertain and the environment (or the context) unstable, dynamic and not well known. If a team or a group should make the decisions the group members may have different opinions about the alternatives and the risks or outcomes of the consequences. In the modern business world, which is dominated by real-time information readily available in abundance through the World Wide Web and by the notion that decisions need to be made quickly as otherwise the competition (or opposition, or whatever antagonistic force) will prevail, there is a growing tendency to make *fast and bad decisions*. In this chapter we will take another route – we will try to show that groups can make *fast and good decisions* with the help of some recent and fairly exciting analytical tools that are imbedded in good and easy to use software (cf. Shim et al., 2002).

We will support our argument with data and experiences from a real world case – the hard decision on the closing/not closing of a paper plant in the UK where there are several opposing and competing views: the responsibility to the shareholders is a good argument for closing the plant, the responsibility to the employees and the community where the plant has been operating for nearly a century is a good argument for not closing the plant. Then we have the overall market situation and the profitability development for the European forest industry, the differences in management styles in Finland and the UK, the different results skilful people get with different analytical tools and the different market trends people believe in (with or without the use of foresight methods). Still the management team needs to find a good (or preferably the best) decision to recommend to the board of directors – a good decision can be explained in logical and analytical terms with a good support of facts and can be explained with rational arguments; the best decision is simply dominating any other alternative that can be discussed or tested. The management team needs a bit more than that – they need to be able to understand all the alternatives and their consequences, they need to be able to analyse and understand the alternatives with all the data that is available, they need to have a reasonable foresight into the coming markets, they need to be able to discuss the issues and the alternatives in terms they can understand jointly and they need to come to a consensus on what they should be doing. The situation is close to the situation worked on by Ackermann and Eden (cf. this volume) where they develop ways for assisting managers who have to negotiate the

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Parts of this paper were earlier published as *A Fuzzy Real Options Model for (Not) Closing a Production Plant: An Application to Forest Industry in Finland* (Markku Heikkilä – Christer Carlsson) In Proceedings of the 12th Annual International Conference on Real Options, Rio de Janeiro, 2008

D.M. Kilgour, C. Eden (eds.), *Handbook of Group Decision and Negotiation*, Advances in Group Decision and Negotiation 4, DOI 10.1007/978-90-481-9097-3_4, © Springer Science+Business Media B.V. 2010

resolution of messy, complex and/or strategic problems. We worked with the management team during an 18 month period and both followed the processes they went through and tried to support them with good analytical tools as best we could. We gained a fairly good understanding of how management works with hard decisions and how they formed consensus as a group – this is the story we will be telling in this chapter.

Academic outsiders need a conceptual framework and a basis for forming an understanding of the processes they are going to work with. This was our starting point.

The early support for hard decisions was developed with the theory and methods of OR [*Operations (or Operational) Research*]. This was a major movement for rational decision making in the 1960'es through 1980'es but its origins go back to the late 1930'es. OR is striving for rational decision-making – it is searching for and (if possible) using the best alternative, i.e. the one maximizing/minimizing an objective function. It differed from classical economic theory by assuming that full information is not available – thus there is certainty, risk or uncertainty on available alternatives and the outcomes of selecting among the alternatives. Operational research works with the assumption that a context could change in a systematic or random manner, and that the changes in most cases will impact the set of alternatives. The context may in some cases change as a function of the decision-making process itself, i.e. the decision makers will influence the context by starting a decision process. The first target of OR was to find good methods for solving operational and tactical problems but the scope was inevitably broadened to include also strategic problems as the methods gained acceptance among senior management. The development of OR was supported by a developing theory as sets of problems were recognized and classified as generic: resource allocation, assignment, transportation, networking, inventory, queuing, scheduling, etc. Then, in the next phase, generic problems became the basis for modelling, problem-solving and decision-making theories: *guidance for better, more effective actions in a complex environment*. Then, finally, as computing power was developed the OR methods became increasingly more popular as non-professionals could use the methods for handling large, complex and difficult problems.

Russell Ackoff in 1976 (cf. Carlsson and Fullér, 2002) was the first to warn against putting too much faith in the OR. He introduced a classification in (i) *well-structured problems* that can be dealt with using OR modeling theory and (ii) *ill-structured problems* – the rest, i.e. all the problems in real life decision-making. Then he concluded that there are no problems, only abstract constructs to bring OR modeling theory into play; his conclusion was that *problem-solving theory* is not useful for any practical purposes if it is building on OR.

Bellman-Zadeh had actually shown similar results in their 1970 paper (cf. Carlsson and Fullér, 2002). They assume that all the elements which define a decision context are not strictly given and may evolve during the decision process, which gives a more flexible approach than the one used in OR. Then they developed a variation of the traditional optimization models with the proposal that there need not be any strict differences between constraints and objective functions. Their conclusion is that if we want to support an evolving decision process we need new and other tools than OR – but we should keep the focus and the power of a theory which have been tested and proved many times over the years.

Zadeh in a later paper (1976) introduced *soft decision-making* (cf. Carlsson and Fullér, 2003): at some point there will be a trade-off between precision and relevance: if we increase the precision of our methods and models we will reach a point where the results we get will be irrelevant as guidance for practical decision making – on the other hand, if we need to get relevant guidance for decision making we will also reach some point where we will have to give up on precision. There are several reasons for this conclusion which may appear paradoxical for users of classical OR theory: (i) the facts about the problem and its context are normally not completely known; (ii) the data is imprecise, incomplete and/or frequently changing; (iii) the core of the problem is too complex to be adequately understood with OR theory; (iv) the dynamics of the problem context requires a problem solving process in real time (or almost real time); and, (v) knowledge and experience (own or developed by others) are necessary for building a theory to deal with ill-structured problems. Mathematical models are also used as part of the negotiation support systems Kersten works on (in this volume). The precision/relevance trade-off started the development of *soft computing* which is where we now work on building new and better theory to cope with hard problems with smart computing methods and intelligent computing technology. As we now have introduced *soft computing* we will next describe a context – the forest industry.

The forest industry, and especially the paper making companies, has experienced a radical change of market since the change of the millennium. Especially in Europe the stagnating growth in paper sales and the resulting overcapacity have led to decreasing paper prices, which have been hard to raise even to compensate for increasing costs. Other drivers to contribute to the misery of European paper producers have been steadily growing energy costs, growing costs of raw material and the Euro/USD exchange rate which is unfavourable for an industry which still has to invoice a large part of its customers in USD and to pay its costs in Euro. The result has been a number of restructuring measures, such as closedowns of individual paper machines and production units. Additionally, a number of macroeconomic and other trends have changed the competitive and productive environment of paper making. The current industrial logic of reacting to the cyclical demand and price dynamics with operational flexibility is losing edge because of shrinking profit margins. Simultaneously, new growth potential is found in the emerging markets of Asia, especially in China, which more and more attracts the capital invested in paper production. This imbalance between the current production capacity in Europe and the better expected return on capital invested in the emerging markets represents new challenges and uncertainties for the paper producers that are different from traditional management paradigms in the forest products industry.

The Finnish forest industry has earlier enjoyed a productivity lead over its competitors. The lead is primarily based on a high rate of investment and the application of the most advanced technologies. Investments and growth are now curtailed by the long distance separating Finland from the large, growing markets as well as the availability and price of raw materials. Additionally, the competitiveness of Finnish companies has suffered because costs here have risen at a faster rate than in competing countries. The paper plant in UK – which is owned by a Finnish forest industry multinational – has a somewhat different situation: advanced technology was brought in a number of years ago which improved the cost structure and the plant is in the middle of its domestic market with export a very small part of the revenue but the plant has not been profitable for a number of years.

Finnish energy policy has a major impact on the competitiveness of the forest industry. The availability and price of energy, emissions trading and whether wood raw material is produced for manufacturing or energy use will affect the future success of the forest industry. If sufficient energy is available, basic industry can invest in Finland. The UK does not differ significantly from Finland in terms of the investment climate for the basic industry.

We have now outlined the context; let us turn to the decision problems we will have to tackle.

In decisions on how to use existing resources the challenges of changing markets become a reality when senior management has to decide how to allocate capital to production, logistics and marketing networks, and has to worry about the return on capital employed. The networks are interdependent as the demand for and the prices of fine paper products are defined by the efficiency of the customer production processes and how well suited they are to market demand; the production should be cost effective and adaptive to cyclic (and sometimes random) changes in market demand; the logistics and marketing networks should be able to react in a timely fashion to market fluctuations and to offer some buffers for the production processes. Closing or not closing a production plant is often regarded as an isolated decision, without working out the possibilities and requirements of the interdependent networks, which in many cases turn out to be a mistake.

Profitability analysis has usually had an important role as the threshold phase and the key process when a decision should be made on closing or not closing a production plant. Economic feasibility is a key factor but more issues are at stake. There is also the question of what kind of profitability analysis should be used and what results we can get by using different methods. Senior management worries – and should worry – about making the best possible decisions on the close/not close situations as their decisions will be scrutinized and questioned regardless of what that decision is going to be. The shareholders will react negatively if they find out that share value will decrease (closing a profitable plant, closing a plant which may turn profitable, or *not* closing a plant which is not profitable, or which may turn unprofitable) and the trade unions, local and regional politicians, the press etc. will always react negatively to a decision to close a plant almost regardless of the reasons.

The idea of optimality of decisions comes from normative decision theory (cf. Carlsson and Fullér, 2002). The decisions made at various levels of uncertainty can be modelled so that the ranking of various alternatives can be readily achieved, either with certainty or with well-understood and non-conflicting measures of uncertainty. However, the real life complexity, both in a static and dynamic sense, makes the optimal decisions hard to find many times. What is often helpful is to relax the decision model from the optimality criteria and to use sufficiency criteria instead. Modern profitability plans are usually built with methods that originate in neoclassical finance theory. These models are by nature normative and may support decisions that in the long run may be proved to be optimal but may not be too helpful for real life decisions in a real industry setting as conditions tend to be not so well structured as shown in theory and – above all – they are not repetitive (a production plant is closed and this cannot be repeated under new conditions to get experimental data).

In practice and in general terms, for profitability planning a good enough solution is many times both efficient, in the sense of smooth management processes, and effective, in the sense of finding the best way to act, as compared to theoretically optimal outcomes. Moreover, the availability of precise data for a theoretically adequate profitability analysis is often limited and subject to individual preferences and expert opinions. Especially, when cash flow estimates are worked out with one number and a risk-adjusted discount factor, various uncertain and dynamic features may be lost. The case for good enough solutions is made in fuzzy set theory (cf. Carlsson and Fullér, 2002): *at some point there will be a trade-off between precision and relevance, in the sense that increased precision can be gained only through loss of relevance and increased relevance only through the loss of precision.*

In a practical sense, many theoretically optimal profitability models are restricted to a set of assumptions that hinder their practical application in many real world situations. Let us consider the traditional Net Present Value (NPV) model – the assumption is that both the microeconomic productivity measures (cash flows) and the macroeconomic financial factors (discount factors) can be readily estimated several years ahead, and that the outcome of the project is tradable in the market of production assets without friction. In other words, the model has features that are unrealistic in a real world situation.

Having now set the scene, the problem we will address is *the decision to close – or not to close – a UK production plant in the forest products industry sector*. The plant we will use as an example is producing fine paper products, it is rather aged, the paper machines were built a while ago, the raw material is not available close by, energy costs are reasonable but are increasing in the near future, key domestic markets are close by and other (export) markets (with better sales prices) will require improvements in the logistics network. This is how the decision problem was described to us – the management team did not use precise figures and did not have them readily available, which made us believe that the *joint understanding* was formed in these imprecise terms.

The intuitive conclusion is, of course in the same imprecise terms, that we have a sunset case and senior management should make a simple, macho decision and close the plant. On the other hand we have the UK trade unions, which are strong, and we have pension funds commitments until 2013 which are very strict, and we have long-term energy contracts which are expensive to get out of. Finally, by closing the plant we will invite competitors to fight us in the UK markets we have served for more than 50 years and which we cannot serve from other plants at any reasonable cost. We learned that intuitive decision making gives inferior results to systematic analytical decision processes – we found out that the possibilities formed with analytical models simply were not known before and that they represented solutions with surprising and positive consequences. We will also show that these decision processes will not be possible without effective information systems support. Finally, we will show that group consensus can be formed with the help of analytical support tools using the results from the real option valuation as input.

Fuzzy Real Option Valuation: The Analysis Instrument

In traditional investment planning investment decisions are usually taken to be *now-or-never*, which the firm can either enter into right now or abandon forever.

The decision on to close/not close a production plant (a disinvestment decision) has been understood to be a similar *now-or-never* decision for two reasons: (i) to close a plant is a hard decision and senior management can make it only when the facts are irrefutable; (ii) there is no future evaluation of *what-if* scenarios after the plant is closed. Nevertheless, as we will show, it could make sense to work a bit with *what-if* scenarios as closing the plant will cut off all future options for the plant.

Common managerial wisdom is to look at some "irrefutable" facts, to evaluate and judge them as much as possible, using experience and intuition, the senior manager alone or he/she in cooperation with a group of trusted co-workers, and if there is consensus in the group or in the mind of the manager to take a decision. New executives often seem to earn their first spurs by closing production plants; they are quite often rewarded by the shareholders who think that decisive actions is the mark of an executive who is going to build good shareholder value. Nevertheless, the exact outcomes in terms of shareholder value of the decision are uncertain as a consequence of changing markets, changes in raw material and energy costs, changes in the technology roadmap, changes in the economic climate, etc. In some cases the outcome is positive for the executive and the shareholders, in other cases it is not so positive (and is explained away); *we want to make the point that the outcome need not be random; we can estimate it with some confidence.*

Only very few decisions are of the type *now-or-never* – often it is possible to postpone, modify or split up a complex decision in strategic components, which can generate important learning effects and therefore essentially reduce uncertainty. If we close a plant we lose all alternative development paths which could be possible under changing conditions. These aspects are widely known – they are part of managerial common wisdom – but they are hard to work out unless we have the analytical tools to work them out and unless we have the necessary skills to work with these tools.

We gradually understood that the *now-or-never* situation was the major reason for dissent and frustration in the management team and there were also some differences in Finnish and British management approaches to the decision problem. This is why we started work with real options models as a possible analytical tool to support a close/no close decision for the paper plant. The rule we will work out, derived from option pricing theory, is that *we should only close the plant now if the net present value of this action is high enough to compensate for giving up the value of the option to wait*. Because the value of the option to wait vanishes right after we irreversibly decide to close the plant, this loss in value is actually the opportunity cost of our decision (cf. Alcaraz Garcia, 2006; Borgonovo and Peccati, 2004; Carlsson and Fullér, 2001). This is the understanding in academic terms but it turned out that the principle was well understood by the management team as well as soon as it was illustrated with some of the own numbers. The mathematics involved in working with real options modelling is fairly advanced but we were able to work it out with the managers in a series of workshops where we also introduced and demonstrated the software (actually Excel models) we were using – the key turned out to be that we used the management team's own data to explain the models step by step. They could identify the numbers and fit them to their own understanding of the close/no close problem and the possible problem solving paths shown by the real options models.

Let us now work out the real options models first in academic terms and then we will demonstrate how they are used in section "The Production Plant and Future Scenarios". The basic understanding of real options modelling is that we have options on the future of real assets (like production plants); real options differ from the financial options which have become standard tools in the stock markets in one significant way: in most cases there are no effective markets for the assets (in the sense of the stock market) which make all the valuation procedures challenging for finding out the future value of an asset (cf. Luehrman, 1988). This was one of the key questions for the management team – what is the future value of the production plant?

The value of a real option is computed by (cf. Black and Scholes, 1973; Carlsson et al., 2003)

$$\mathrm{ROV} = S_0 e^{-\delta T} N(d_1) - X e^{-rT} N(d_2),$$

where

$$d_1 = \frac{\ln\left(S_0/X\right) + \left(r - \delta + \sigma^2/2\right) T}{\sigma\sqrt{T}},$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

Here, S_0 denotes the present value of the expected cash flows, X stands for the nominal value of the fixed costs, r is the annualized continuously compounded rate on a safe asset, δ is the value lost over the duration of the option, σ denotes the uncertainty of the expected cash flows, and T is the time to maturity of the option (in years). The interpretation is that we have the difference between two streams of cash flow: the S_0 is the revenue flow from the plant and the X is the cost generated by the plant; both streams are continuously discounted with a chosen period of time T and the streams are assumed to show random variations, which is why we use normal distributions N. In the first stream we are uncertain about how much value we will lose δ if we postpone the decision and in the second stream we have uncertainty on the costs σ.

Analytical people want to make things precise: the function $N(d)$ gives the probability that a random draw from a standard normal distribution will be less than d, i.e. we want to fix the normal distribution,

$$N(d) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{d} e^{-x^2/2} dx.$$

Facing a deferrable decision, the main question that a company primarily needs to answer is the following: *how long should we postpone the decision – up to T time periods – before (if at all) making it?*

With the model for real option valuation we can find an answer and develop the following natural decision rule for an optimal decision strategy 2; again this requires a bit of analytical modelling (cf. Carlsson and Fullér, 1999, 2002; Carlsson et al., 2005).

Let us assume that we have a deferrable decision opportunity P of length L years with expected cash flows $\{cf_0, cf_1, \ldots, cf_L\}$, where cf_i is the cash inflows that the plant is expected to generate at year $i (i = 0, \ldots, L)$. We note that cf_i is the anticipated net income (revenue – costs) of decision P at year i. In these circumstances, if the maximum deferral time is T, we shall make the decision to postpone for t' periods (which is to exercise the option at time t', $0 < t' < T$) for which the value of the option, $ROV_{t'}$ is positive and gets its maximum value; namely (cf. Carlsson and Fullér, 2003 for details),

$$\begin{aligned} ROV_{t'} &= \max_{t=0,1,\ldots,T} ROV_t \\ &= \max_{t=0,1,\ldots,T} V_t e^{-\delta T} N(d_1) - X e^{-rT} N(d_2) > 0, \end{aligned}$$

If we make the decision now without waiting, then we will have

$$ROV_0 = V_0 - X = \sum_{i=0}^{L} \frac{cf_i}{(1+\beta_P)^i} - X.$$

That is, this decision rule also incorporates the net present valuation of the assumed cash flows; β_P stands for the risk-adjusted discount rate of the decision. In this way we have worked out a decision rule for how long we can postpone the decision to close/not close the production plant which is anchored in solid economic theory (thus we can give a rational motivation for the decision). The reason for postponing is that we expect or can get more information on some of the parameters deciding the future cash flows, which will have an impact on the decision. The real option model actually gives a value for the deferral which makes it possible to find the optimal deferral time. In this way the management team will now have an additional instrument for the hard decision.

Having got this far we will now have to face another problem: the difference between academic modelling and what is possible with the data that is available in a real world case. Real options theory requires rather rich data with a good level of precision on the expected future cash flows. This is possible for financial options and the stock market as we have the effective market hypothesis which allows the use of models that apply stochastic processes and which have well known mathematical properties. The data we could collect on the expected future cash flows of the production plant were not precise and were incomplete and the management team was rather reluctant to offer any firm estimates (for very understandable reasons, these estimates can be severely questioned with the benefit of hindsight). It turns out that we can work out the real options valuation also with imprecise and incomplete data, the method is known as fuzzy real options modelling. We will have to use some more academic theories to properly explain this approach.

Let us now assume that the expected cash flows of the close/not close decision cannot be characterized with single numbers (which should be the case in serious decision making). With the help of possibility theory (cf. Dubais and Prade, 1988; Carlsson and Fullér, 2003 for details; possibility theory is an axiomatic theory which now is starting to replace the theory of subjective probabilities) we can estimate the expected incoming cash flows at each year of the project by using a trapezoidal possibility distribution of the form

$$\overline{V_i} = (s_i^L, s_i^R, \alpha_i, \beta_i), \quad i = 0, 1, \ldots, L,$$

that is, the most possible values of the expected incoming cash flows lie in the interval $[s_i^L, s_i^R]$ (which is the core of the trapezoidal fuzzy number describing the cash flows at year i of the production plant); $(s_i^R + \beta_t)$ is the upward potential and $(s_i^L - \alpha_t)$ is the downward potential for the expected cash flows at year i, ($i = 0, 1, \ldots, L$). In a similar manner we can estimate the expected costs by using a trapezoidal possibility distribution of the form

$$\overline{X} = (x^L, x^R, \alpha', \beta'),$$

i.e. the most possible values of the expected costs lie in the interval $[x^L, x^R]$; $(x^R + \beta')$ is the upward potential and $(x^L - \alpha')$ is the downward potential for the expected fixed costs (this is of course a simplification, there should be different costs for each year, but the management team stated that they do not change much and that the trouble of estimating them does not have a good trade-off with the accuracy of the model).

By using possibility distributions we can extend the classical probabilistic decision rules for an optimal decision strategy to a possibilistic context.

The reasons for using fuzzy numbers are, of course, not self-evident. The imprecision we encounter when judging or estimating future cash flows is in many cases not stochastic in nature, and the use of probability theory gives us a misleading level of precision and a notion that consequences somehow are repetitive. This is not the case; the uncertainty is genuine as we simply do not know exact levels of future cash flows. Without introducing fuzzy numbers it would not be possible to formulate this genuine uncertainty. Fuzzy numbers incorporate subjective judgments and statistical uncertainties which may give managers a better understanding of the problems with assessing future cash flows.

We will now revisit our decision rule when the model is built with fuzzy numbers. Let P be a deferrable decision opportunity with incoming cash flows and costs that are characterized by the trapezoidal possibility distributions given above. Furthermore, let us assume that the maximum deferral time of the decision is T, and the required rate of return on this project is β_P. In these circumstances, we should make the decision (exercise the real option) at time t', $0 < t' < T$, for which the value of the option, $C_{t'}$ is positive and reaches its maximum value. That is,

$$\begin{aligned}\overline{FROV_{t'}} &= \max_{t=0,1,\ldots,T} \overline{FROV_t} \\ &= \max_{t=0,1,\ldots,T} \overline{V_t} e^{-\delta t} N(d_1^{(t)}) - \overline{X} e^{-rt} N(d_2^{(t)}) > 0,\end{aligned}$$

where

$$\begin{aligned}d_1^{(t)} &= \frac{\ln\left(E(\overline{V_t})/E(\overline{X})\right) + \left(r - \delta + \sigma^2/2\right) t}{\sigma\sqrt{t}}, \\ d_2^{(t)} &= d_1^{(t)} - \sigma\sqrt{t} \\ &= \frac{\ln\left(E(\overline{V_t})/E(\overline{X})\right) + \left(r - \delta - \sigma^2/2\right) t}{\sigma\sqrt{t}}.\end{aligned}$$

Here, E denotes the possibilistic mean value operator and

$$\sigma = \sigma(\overline{V_t})/E(\overline{V_t})$$

is the annualized possibilistic variance of the aggregate expected cash flows relative to its possibilistic mean (and therefore represented as a percentage value). Furthermore,

$$\begin{aligned}\overline{V_t} &= \mathrm{PV}(\overline{cf_0}, \overline{cf_1}, \ldots, \overline{cf_L}; \beta_P) \\ &\quad - \mathrm{PV}(\overline{cf_0}, \overline{cf_1}, \ldots, \overline{cf_{t-1}}; \beta_P) \\ &= \mathrm{PV}(\overline{cf_t}, \ldots, \overline{cf_L}; \beta_P) \\ &= \sum_{i=t}^{L} \frac{\overline{cf_i}}{(1 + \beta_P)^i}\end{aligned}$$

computes the present value of the aggregate (fuzzy) cash flows of the project if this has been postponed t years before being undertaken.

To find a maximizing element from the set

$$\left\{\overline{FROV_0}, \overline{FROV_1}, \ldots, \overline{FROV_T}\right\}$$

we need to have a method for the ordering of trapezoidal fuzzy numbers. This is one of the partially unsolved problems with the use of fuzzy numbers as we do not have any complete models for ranking intervals (cf. Carlsson and Fullér, 2003, for details), which is why we have to resort to various ad hoc methods to find a ranking. Basically, we can simply apply some value function to order fuzzy real option values of trapezoidal forms

$$FROV_t = (c_t^L, c_t^R, \alpha_t', \beta_t'), \quad t = 0, 1, \ldots, T.$$

$$\nu(FROV_t) = \frac{c_t^L + c_t^R}{2} + r_A \cdot \frac{\beta_t' - \alpha_t'}{6},$$

where $r_A \exists 0$ denotes the degree of the manager's risk aversion. If $r_A = 1$ then the manager compares trapezoidal fuzzy numbers by comparing their pure possibilistic means (cf. Carlsson and Fullér, 2001). Furthermore, in the case $r_A = 0$, the manager is risk neutral and compares fuzzy real option values by comparing the centre of their cores, i.e. he does not care about their upward or downward potentials.

Thus we have a basis for working out the best time for making a decision on the close/not close issue for the production plant also with imprecise and incomplete data. The fuzzy sets theory is of course much richer than can be seen from the sketches we have provided but the details on that and how it will give additional guidelines for decision making will have to wait for another forum for discussion and evaluation.

In this way we have now demonstrated that we can deal with the close/no close decisions with the help of analytical models. We have simply translated the understanding we have of the problem to an analytical framework which helps us to work out the logic of the various alternatives we could consider. An analytical framework is helpful because it offers a number of mathematical tools we can use to refine our understanding and to work out the possible consequences of the alternatives we have (cf. Benaroch and Kauffman, 2000, and also Heikkilä and Carlsson, 2008). We had some doubts that the management team would be willing to share our conceptual framework or that the team would be able to follow our reasoning, but we were wrong on that account (cf. a similar discussion by Ackermann and Eden, this volume). We did, of course, not work with the mathematical modelling as we have done in this section – which we had to build in order to check the correctness of the models – but we implemented the models as part of a decision support system (cf. Saaty, 1986 for a review of decision support systems) and used this to work interactively with the management team (cf. a similar process developed by Kersten for his negotiation support system (in this volume)). As we were able to work with the actual figures the management team could follow how the models worked and how we reached the recommended decisions; we will work through this part in the next section (the company-specific figures have been changed for reasons of confidentiality). We will address the building of a group consensus in Section "Group Consensus", which is why we should point out that one of the key findings was that the members of the management team need to be reasonably good at using the models in order to be able to communicate their understanding of the alternatives and the consequences with their peers. If one of the members cannot follow the reasoning he/she will rather quickly represent an odd position in the group decision making and will not contribute to the forming of consensus.

The Production Plant and Future Scenarios

The production plant we are going to describe is a paper mill in UK, the numbers we show are realistic (but modified) and the decision process is as close to the real process as we can make it. We worked the case with the fuzzy real options model in order to help the management team to decide if the plant should (i) be closed as soon as possible, (ii) not closed, or (iii) closed at some later point of time (and then at what point of time).

The production plant suffers from the same reasons for an unsatisfactory profitability development as the Finnish paper products industry in general: (i) fine paper prices have been going down for 6 years, (ii) costs are going up (raw material, energy, chemicals), (iii) demand is either declining or growing slowly depending on the markets, (iv) production capacity cannot be used optimally, and (v) the €/USD exchange rate is unfavourable (sales invoiced in USD, costs paid in €). The standard solution for most forest industry corporations is to try to close the old, small and least cost-effective production plants.

The analysis carried out for the production plant started from a comparison of the present production and production lines with four new production scenarios with different production line setups. In the analysis each production scenario is analyzed with respect to one sales scenario assuming a match between performed sales analysis and consequent resource allocation on production. Since there is considerable uncertainty involved in both sales quantities and sales prices the resource allocation decision is contingent to a number of production options that the management has to consider, but which we have simplified here in order to get to the core of the case.

There were a number of conditions which were more or less predefined. The *first* one was that no capital could/should be invested as the plant was regarded as a *sunset plant*. The *second* condition was that we should in fact consider five scenarios: the current production setup with only maintenance of current resources and four options to switch to setups that save costs and have an effect on production capacity used. The *third* condition is that the plant together with another unit has to carry considerable administrative costs of the sales organization in the country and if the plant is closed these costs have to be covered is some way (but not clear how). The *fourth* condition is that there is a pension scheme that needs to be financed until 2013. The *fifth* condition is the power contract of the unit which is running until 2013. These specific conditions have consequences on the cost structure and the risks that various scenarios involve. The existence of these conditions make the decision making complex as they can eliminate otherwise reasonable alternatives – and it is not known if they are truly non-negotiable.

Each scenario (cf. Fig. 1) assumes a match between sales and production, which is a simplification; in reality there are significant, stochastic variations in sales which cannot be matched by the production. Since no capital investment is assumed there will be no costs in switching between the scenarios (which is another simplification). The possibilities to switch in the future were worked out as (real) options for senior management. The option values are based on the estimates of future cash flows, which are the basis for the upward/downward potentials.

In discussions with the management team they (reluctantly) adopted the view that options can exist and that there is a not-to-decide-today possibility for the close/not close decision. The motives to include options into the decision process were reasoned through with the following logic:

- New information changes the decision situation
- Consequently, new information has a value and it increases the flexibility of the management decisions
- The value of the new information can be analyzed to enable the management to make better informed decisions

In the workshops we were able to show that companies fail to invest in valuable action programs because the options embedded in a program are overlooked and left out of the profitability analysis. The real options approach shows the importance of timing as the real option value is the opportunity cost of the decision to wait in contrast with the decision to act immediately.

We were then able to give the following practical description of how the option value is formed:

$$\begin{aligned}&\textit{Option value} = \textit{Discounted cash flow}^{*}\ \textit{Value of}\\&\textit{uncertainty}\,(\textit{usually standard deviation}) -\\&\textit{Investment}^{*}\ \textit{Risk free interest}\end{aligned}$$

If we compare this sketch of the actual work with the decision to close/not close the production plant with the theoretical models we introduced in Section "Fuzzy Real Option Valuation: the Analysis Instrument", we cannot avoid the conclusion that things appear to be much simplified. There are two reasons for this: (i) the data available is scarce and imprecise as the scenarios are more or less ad hoc constructs; (ii) senior management will distrust results of an analysis they cannot evaluate and verify with numbers they recognize or can verify as "about right". In reality the

			Scenario 1	*Scenario 2*	*Scenario 3*	*Scenario 4*
	Production lines		2	1	1	
	Products		Product 1 Product 2 Product 3	Product 1 Product 3	Product 1 Product 3	Product 2 Product 3
Scenario 1	Optimistic sales volume	***200000***				
Scenario 2	Sales volume as today	***150000***				
Scenario 3	Pessimistic sales volume	***125000***				
Scenario 4	Joker	***105000***				

Fig. 1 Production plant scenarios

models we built and implemented were the fuzzy real options models we introduced in Section “Fuzzy Real Option Valuation: the Analysis Instrument” (actually using the binomial form instead of the Black-Scholes formula) but the interpretations and the discussions were in terms of the more practical decisions.

Closing/Not Closing a Plant: Information Systems Support

Closing a production plant is usually understood as *a decision at the end of the operational lifetime of the real asset*. In the aging unit considered here the two paper machines were producing three paper qualities with different price and quality characteristics. The newer Machine 2 had a production capacity of 150, 000 tons of paper per year; the older Machine 1 produced about 50,000 tons. The three products were:

- *Product 1*, an old product with declining, shrinking prices
- *Product 2*, a product at the middle-cycle of its lifetime
- *Product 3*, a new innovative product with large valued added potential

As background information a scenario analysis had been made with market and price forecasts, competitor analyses and the assessment of paper machine efficiency. Our analysis was based on the assumptions of this analysis with four alternative scenarios to be used as a basis for the profitability analysis (cf. Fig. 1).

After a preliminary screening (a simplifying operation to save time) two of the scenarios, one requiring sales growth and another with unchanged sales volume were chosen for a closer profitability assessment. The first one, Scenario 1 (sales volume 200,000 ton) included two sub options, first 1A with the current production setup and 1B with a product specialization for the two paper machines. The 1B would offer possibilities for a closedown of a paper coating unit, which will result in savings of over 700,000 €. Scenario 1A was chosen for the analysis illustrated here. Scenario 2 starts from an assumption of a smaller sales volume (150,000 ton) which allows a closedown of the smaller Machine 1, with savings of over 3.5 M€.

In addition to operational costs a number of additional cost items needed to be worked out and estimated by the management. There is a pension scheme agreement which would cause extra costs for the company if Machine 1 is closed down. Additionally, the long term energy contracts would cause extra cost if the company wants to close them before the end term.

The scenarios are summarised here as production and product setup options, and are modelled as *options to switch a production setup*. They differ from typical options – such as options to expand or postpone – in that they do not include major capital commitments; they differ from the option to abandon as the opportunity cost is not calculated to the abandonment, but to the continuation of the current operations (cf. Collan, 2004 for a systematic discussion of the various option alternatives).

In order to simplify the analysis and to be able to use Excel as the modelling platform we used the binomial version of the real options model (the continuous distributions used for the Black-Scholes are cumbersome to handle with Excel). For our case the basic binomial setting is presented as a setting of two lattices (we need to be a bit precise again but we have simplified the notations in order to show the principles), the underlying asset lattice and the option valuation lattice. In Fig. 2 the weights u and d describe the random movement (typically assumed to be completely random, a so-called Geometric Brownian Motion, but this is rarely the case for real assets) of an asset value S over time, *q* stands for a movement up and *1–q* movement down, respectively. The value of the underlying asset develops in time according to probabilities attached to movements *q* and *1–q*, and weights *u* and *d*, as described in Fig. 2.

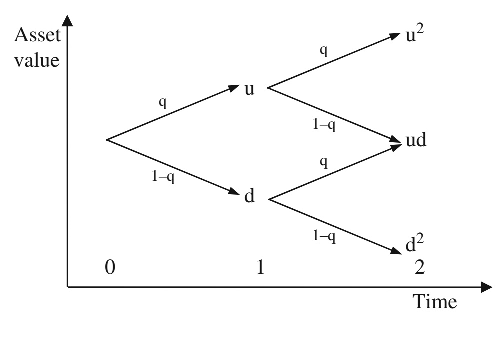

Fig. 2 The asset lattice of two periods

The input values for the lattice are approximated with the following set of formulae:

$$u = e^{\sigma\sqrt{\Delta t}}\,(movement\ up)$$
$$d = e^{-\sigma\sqrt{\Delta t}}\,(movement\ down)$$
$$q = \tfrac{1}{2} + \tfrac{1}{2}\frac{(\alpha - \frac{1}{2}\sigma^2)}{\sigma}\sqrt{t}\,(probability\ of\ movement\ up)$$

The option valuation lattice is composed of the intrinsic values *I* of the latest time to decide retrieved as the maximum of present value and zero, the option values *O* generated as the maximum of the intrinsic or option values of the next period (and their probabilities *q* and *1–q*) discounted, and the present value *S–F* of the period in question (this is worked out in detail in Fig. 3).

This formulation describes two binomial lattices that capture the present values of movements up and down from the previous state of time *PV* and the incremental values *I* directly contributing to option value *O*. The relation of random movements up and down is captured by the ratio $d = 1/u$. The binomial model is a discrete time model and its accuracy improves as the number of time steps increases.

In the Excel models we used these principles to work out the fuzzy real option values based on the cash flows estimated (as fuzzy numbers) for the scenarios.

Cash flow estimates for the binomial analysis were estimated for each of the scenarios from the sales scenarios of the three products and accounting for the changes in the fixed costs caused by the production scenarios. Each of the products had their own price forecast that was utilised as a trend factor. For the estimation of the cash flow volatility there were two alternative methods of analysis. Starting from the volatility of sales price estimates one can retrieve the volatility of cash flow estimates by simulation (the Monte Carlo method) or by applying the management team's opinions directly to the added value estimates. In order to illustrate the latter method the volatility is here calculated from added value estimates (*AVE*) (with fuzzy estimates: a: *AVE* *–10%, b: *AVE* *%, α: *AVE* *–20%, β: *AVE* *20%) (cf. Fig. 4).

It turned out that the added value estimates (AVE) are more robust for planning purposes than individual revenue and cost estimates that could be allocated to the products (Products 1–3). Calculating the AVE requires access to the actual revenue and cost data of the plant; this data cannot be shown as it is highly confidential. This is another reason for using AVE – which we here also have modified in order not to reveal the actual state of the plant.

It turned out that the management team was both rather good at making the estimates and willing to make them as there was an amount of flexibility in using the (trapezoidal) fuzzy numbers.

The annual cash flows in the option valuation were calculated as the cash flow of postponing the switch of production from which was subtracted the cash flows of switching now. The resulting cash flow statement of switching immediately is shown (Fig. 5). The cash flows were transformed from nominal to risk-adjusted in order to allow risk-neutral valuation (this refinement was asked for by the plant controller who wanted to make a point). The management team could trace and intuitively validate the numbers as "reasonable".

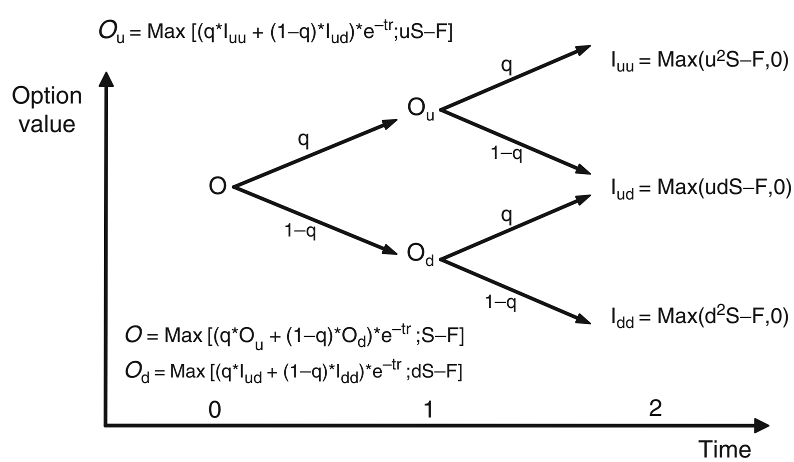

Fig. 3 The option lattice of two periods

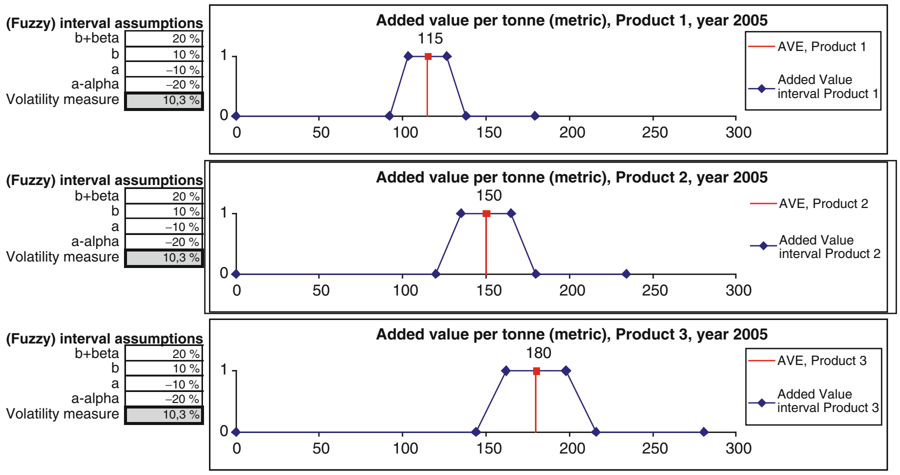

Fig. 4 Added value estimates, trapezoidal fuzzy interval estimates and retrieved volatilities (STDEV)

Year	*0*	1	2	3	4	5
Fixed Cost Total , Scenario 1A	*0*	*−5 620 750*	*−5 757 269*	*−5 899 200*	*−6 056 180*	*−6 257 835*
Added Value Total , Scenario 1A	*0*	*6 465 000*	*7 358 000*	*7 913 000*	*8 881 000*	*8 902 000*
EBDIT , Scenario 1A	*0*	*844 250*	*1 600 731*	*2 013 800*	*2 824 820*	*2 644 165*
Risk-neutral valuation parameter	1,000	0,955	0,911	0,870	0,830	0,792
EBDIT	0	805 875	1 458 518	1 751 484	2 345 185	2 095 423
NPV, no delay	*7 174 624*	8 148 015				

Fig. 5 Incremental cash flows and NPV with no delay in the switch to Scenario 1A

The switch immediately to Scenario 1A seems to be profitable (cf. Fig. 5). In the following option value calculation the binomial process results are applied in the row "EBDIT, from binomial EBDIT lattice". The calculation shows that when given volatilities are applied to all the products and the retrieved Added Value lattices are applied to EBDIT, the resulting EBDIT lattice returns cash flow estimates for the *option to switch*, adding 24 million of managerial flexibility (cf. Fig. 6).

The binomial process is applied to the Added Value Estimates (AVEs). The binomial process up and down parameters, u and d, are retrieved from the volatility (σ) and time increment (dt).

The fuzzy interval analysis allows management to make scenario-based estimates of upward potential and downward risk separately. The volatility of cash flows is defined from a possibility distribution and can readily be manipulated if the potential and risk profiles of the project change. Assuming that the volatilities of the three product-wise AVEs were different from the ones presented in Fig. 4 to reflect a higher potential of Product 3 and a lower potential of Product 1, the following volatilities could be retrieved (cf. Fig. 7).

Year	*0*	1	2	3	4	5	6
Fixed Cost Total, Scenario 1A	*0*	*−5 620 750*	*−5 757 269*	*−5 899 200*	*−6 056 180*	*−6 257 835*	*−6 390 171*
Added Value Total, Scenario 1A	*0*	*6 465 000*	*7 358 000*	*7 913 000*	*8 881 000*	*8 902 000*	*8 786 900*
EBDIT, Scenario 1A	*0*	*844 250*	*1 600 731*	*2 013 800*	*2 824 820*	*2 644 165*	*2 396 729*
Risk-neutral valuation parameter	1,000	0,955	0,911	0,870	0,830	0,792	0,756
EBDIT	0	805 875	1 458 518	1 751 484	2 345 185	2 095 423	1 813 003
NPV, no delay	*7 174 624*	8 148 015					
NPV at year 2006		7 777 651					
NPV,delay: 1 year(s)		603 027					
EBDIT, from binomial EBDIT lattice		3 711 963	6 718 118	8 067 557	10 802 222	9 651 783	12 064 213
Option to switch, value at year 2006		33 047 232					
Option to switch		31 545 085					
Flexibility		24 370 461					

Fig. 6 Incremental cash flows, the NPV and Option value assessment when the switch to Scenario 1A is delayed by 1 year

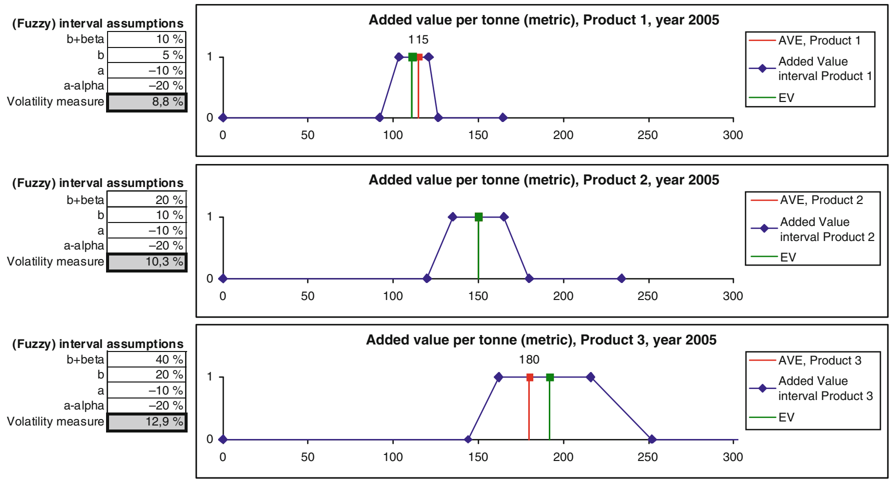

Fig. 7 Fuzzy added value intervals and volatilities

Note that the expected value with products 1 and 3 now differs from the AVEs.

The fuzzy cash flow based profitability assessment allows a more profound analysis of the sources of a scenario value. In real option analysis such an asymmetric risk/potential assessment is realised by the fuzzy ROV (cf. Section "Fuzzy Real Option Valuation: the Analysis Instrument"). Added values can now be presented as fuzzy added value intervals instead of single (crisp) numbers. The intervals are then run through the whole cash flow table with fuzzy arithmetic operators. The fuzzy intervals described in this way are trapezoidal fuzzy numbers (cf. Fig. 8).

With the fuzzy intervals for added value of the three products and assumptions on incremental sales volumes (this is an alternative to guess at or estimate total sales volumes) for the 6 years we get the results shown in Fig. 8 (here only Product 1 is shown; the added values for Products 2–3 are calculated in the same way).

In the case of the risk-neutral valuation the discount factor is a single number. In our analysis the discounting is done with the fuzzy EBDIT based cash flow estimates by discounting each component of the fuzzy number separately. The expected value (EV) and the standard deviation (St. Dev) are defined as follows (cf. Fig. 9, cf. also Section "Fuzzy Real Option Valuation: the Analysis Instrument"), the illustration is now of the whole plant instead of one product (cf. Fig. 8):

In the Excel models we decided to calculate the net present value (NPV), which is the standard way of comparing scenarios which are built around

Sales volume Product 1, incremental		**0**	37000	22000	12000	7000	7000
Sales volume Product 2, incremental		**0**	3000	3000	3000	8000	3000
Sales volume Product 3, incremental		**0**	10000	25000	35000	40000	45000
Sales volume total, incremental		***0***	***50000***	***50000***	***50000***	***55000***	***55000***
Added Value Product 1, Crisp	–1,0%	***115***	114	113	112	111	109
Added Value Product 1, Supportup	10,0%	**126,50**	125,40	124,30	123,20	122,10	119,90
Added Value Product 1, Coreup	5,0%	**120,75**	119,70	118,65	117,60	116,55	114,45
Added Value Product 1, Coredown	–10,0%	**103,50**	102,60	101,70	100,80	99,90	98,10
Added Value Product 1, Supportdown	–20,0%	**92,00**	91,20	90,40	89,60	88,80	87,20
Added Value Product 1, FuzzyEV		**111,17**	110,20	109,23	108,27	107,30	105,37
Added Value Product 1, St.Dev.		**9,80**	9,71	9,63	9,54	9,46	9,29
Added Value Product 1, St.Dev.%		**8,8%**	8,8%	8,8%	8,8%	8,8%	8,8%

Fig. 8 Fuzzy interval assessment, applying interval assumptions to Added Value

Risk-neutral valuation parameter	0.955	0.911	0.870
EBDIT, risk neutral	805875	1458518	1751484
EBDIT, risk neutral , Support up	2040102	2799376	3127935
EBDIT, risk neutral , Core up	1422989	2128947	2439710
EBDIT, risk neutral , Core down	188761	788088	1063258
EBDIT, risk neutral , Support down	–428352	117659	375032
EBDIT, risk neutral , Fuzzy EV	805875	1458518	1751484
EBDIT, risk neutral , St. Dev.	634024	688801	707085
EBDIT, risk neutral , St. Dev. %	78.7%	47.2%	40.4%

Fig. 9 Fuzzy interval assessment, discounting a fuzzy number

assumptions of future cash flows. This proved to be a good way to improve the understanding of how the fuzzy real option valuation (ROV) is built and used.

As a result from the analysis a NPV calculation now supplies the results of the NPV and fuzzy ROV as fuzzy numbers. Also flexibility is shown as a fuzzy number.

For illustrative purposes this comparative analysis is made by applying a standard volatility (10.3%) for each product, scenario and option valuation method. Figure 10 shows that the NPV does not support postponing the decision but the fuzzy ROV recommends a delay of 2 years. This obvious contradicting recommendation was hotly debated – the NPV is a much used and trusted method – but gradually it was accepted that there is value in having the flexibility to adjust to changes in sales, prices, cost structures, competition, etc. when deciding about the closing/not closing of the production plant. Then there were the settlement costs for the pension scheme and the energy contracts, which are both significant and not easily absorbed by the corporation (at least not in the present budget year).

We then worked out a simple model to allow the management team to experiment with switching to Scenario 1A at different years (cf. Fig. 11). This improved the understanding of how the relationships work (it was then repeated for all the scenarios).

	2004	2005	2006	2007
Present value at delay		7,174,624		6,494,629
Present value at delay, Support up		9,834,912		14,886,532
Present value at delay, Core up		7,552,125		11,824,291
Present value at delay, Core down		2,986,552		5,699,809
Present value at delay, Support down		703,765		2,637,568
Present value at delay, Fuzzy EV		6,410,732		10,293,171
Present value at delay, St. Dev.		2,345,340		3,146,154
Present value at delay, St. Dev. %		36.6%		30.6%
NPV at present year, 2005	Flexibility			
Delay value without flexibility	–1,283,804	7,174,624		5,890,820
Delay value with flexibility, Support Up	3,667,612	9,834,912		13,502,524
Delay value with flexibility, Core Up	3,172,855	7,552,125		10,724,981
Delay value with flexibility, Core Down	2,183,343	2,986,552		5,169,895
Delay value with flexibility, Support Down	1,688,587	703,765		2,392,352
Delay value with flexibility, Fuzzy EV	2,925,477	6,410,732		9,336,209
Delay value with flexibility, St. Dev.	508,314	2,345,340		2,853,654
Delay value with flexibility, St. Dev. %	17.4%	36.6%		30.6%
Delay	2			

Fig. 10 Fuzzy interval assessment, NPV and fuzzy Real Option Value (ROV)

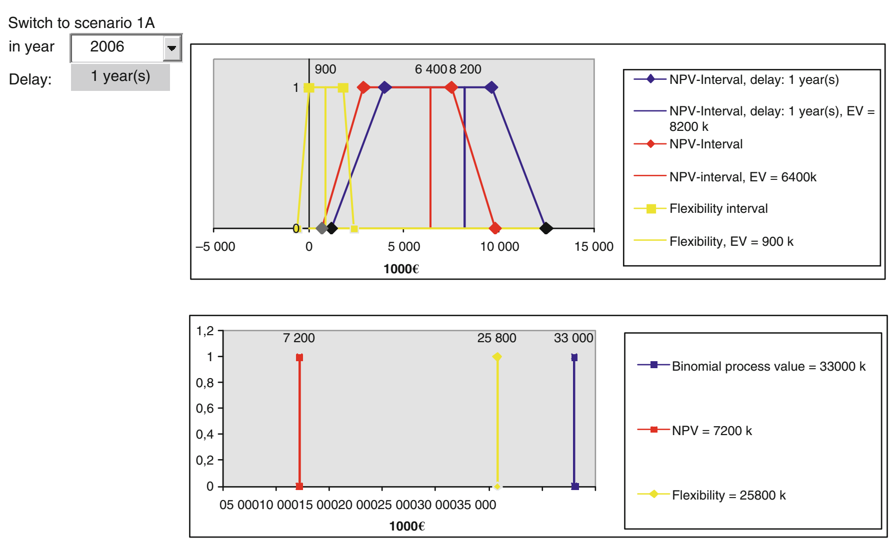

Fig. 11 Comparing the results graphically, the option to switch to Scenario 1A at 2006

Fig. 12 Results comparison

Time of action		NPV 2005	NPV with option to switch 2006	2007	2008	2009	2010
Binomial price process analysis (5 timesteps)							
Option 1	Switch from present to 1A		33 000	22 000	19 500	14 800	18 300
	Difference to NPV	7 200	25 800	14 800	12 300	7 600	11 100
Option 2	Switch from present to 2		7 900	7 000	6 300	2 800	5 100
	Difference to NPV	–21 000	28 900	28 000	27 300	23 800	26 100
Cash flow inteval analysis							
Option 1	Switch from present to 1A		8 200	9 300	9 900	10 300	10 200
	Difference to NPV	7 200	1 000	2 100	2 700	3 100	3 000
Option 2	Switch from present to 2		–19 700	–15 900	–13 500	–11 500	–9 700
	Difference to NPV	–21 000	1 300	5 100	7 500	9 500	11 300

The following Fig. 12 summarizes the results from the binomial process and the cash flow interval analysis when planning to switch from Scenario 1 ("present") to either Scenario 1A or Scenario 2.

In this way we worked through all the combinations of Products 1–3 and Scenarios 1–4, and even tested some variations like Scenario 1A and 1B, and finally came to the conclusion that there is a positive option value in delaying the closing of the production plant at least until the year 2010. This contradicted the results we got with the NPV methods which recommended closing the plant in the next 1–3 years for all scenarios. This may be one of the reasons why we have had quite a few decisions to close production plants in the forest industry in several countries in the last 5–6 years.

Overall it is fair to say, that the analysis shows that there are viable alternatives to the ones that result in an immediate closing of the production plant and that there are several options for continuing with the current operations. The uncertainties in the added value processes, which we have modelled in two different ways, show significantly different results when, on the one hand, both risk and potential are aggregated to one single number in the binomial process (which is the traditional way) and, on the other hand, there is a fuzzy number that allows the treatment of the downside and the upside differently. In this close/no close situation management is faced with poor profitability and needs to assess alternative routes for the final stages of the plant with almost no real residual value. The specific costs of a closedown (the pension scheme and the energy contracts) are a large opportunity costs for an immediate closedown.

The developed models allow for screening alternative paths of action as options (cf. see the chapter by Ackermann and Eden (cf. this volume). We found out that the binomial assessment, based on the assumptions of the real asset tradability, overestimates the real option value, and gives the management flexibilities that actually are not there. On the other hand, the fuzzy cash flow interval approach allows an interactive treatment of the uncertainties on the (annual) cash flow level and in that sense gives the management powerful decision support. With the close/not close decision, the fuzzy cash flow interval method offers both rigor and relevance as we get a normative profitability analysis with readily available uncertainty and sensitivity assessments.

Here we have shown one scenario analysis in detail and sketched a comparison with a second analysis. For the real case we worked out all scenario alternatives – as mentioned above – and found out that it makes sense to postpone closing the paper mill at least until 2010.

The a paper mill was closed on January 31st, 2007 at significant cost according to our analysis; this year (2009) we found out that the senior manager – the head of the management team with which we worked – was able to negotiate a more reasonable deal with the trade unions and the power companies and the actual cost was not as high as our analysis showed (he used our results as a benchmark for the negotiations).

Group Consensus

We noted in Section "Closing/Not Closing a Plant: Information Systems Support" that there were sometimes different opinions on how to interpret and use the results from the fuzzy ROV models. There was also a debate on what to trust more – the NPV everyone knows or the ROV which is a new and "rather mathematical" method. There were discussions of how to generate the scenarios and the numbers going into the scenarios (the use of fuzzy numbers helped this process) and there were some debate on how to calculate the added value estimates (AVE). These were, however, technical issues that can be settled with discussions, experiments and careful validation tests.

The management team had three UK members and two Finnish members; the senior manager came from the Finnish corporation. We expected there to be more heated debate as the time came to come to a conclusion on the closing/no closing of the paper mill.

The analysis was done; the Excel tables and the graphics showed some clear action alternatives and a decision should be made. We expected the process to be one of seeking consensus and commitment. The actual process went somewhat differently: the senior manager simply summarized all the arguments that had been used for the analysis and the results of the fuzzy ROV models, then he asked if there was anything missing in his summary. Everybody was satisfied and he stated: "we will postpone closing the production plant until 2010" – and that was that. The senior manager had spoken and in the Finnish corporate tradition this is then the consensus decision (cf. an alternative process and outcome described by Kersten, this volume).

The research group was not very satisfied with this decision process as it had developed a set of models to find consensus among disagreeing managers; we will next briefly work through a way to find consensus among dissenting members of a management team.

The management team has five members: M1, M2 and M3 are the UK managers; M4 and M5 are the Finnish managers; M5 is the senior manager.

The managers should agree on the best alternative from a set of alternatives (here limited to three for illustrative purposes; in the actual case the number was larger):

A1 Do nothing and stay with the present sales-production Scenario 1
A2 Switch to scenario 1A in 2010
A3 Switch to Scenario 2 in 2011

In order to carry out this selection the managers have agreed on four criteria that should decide which alternative will be the best choice:

C1 Fuzzy ROV
C2 Fuzzy EBDIT
C3 Flexibility
C4 Risk level

We decided to work this out with the Analytical Hierarchical Process (AHP, cf. Saaty, 1986) as this allows the managers to judge both the importance of the criteria C1–C4 and how good the alternatives A1–A3 are relative to the criteria. The judgements build on systematic pair wise comparisons of all the criteria and all the alternatives relative to each one of the criteria; the judgements can be carried out with linguistic, graphical or numerical comparisons; the AHP will summarize the judgments for all the managers and provide a ranking of the alternatives and then produce an overall consensus coefficient. Here we will again summarize the details and simplify the presentation as much as possible.

The basic, individual AHP model is built as shown in Fig. 13:

Level 0	select the best alternative			
Level 1	C1	C2	C3	C4
Level 2	A1	A1	A1	A1
	A2	A2	A2	A2
	A3	A3	A3	A3

Fig. 13 The basic individual AHP model

The summarization of the judgements given by the managers (in AHP these are called the global priorities) were as follows (cf. Fig. 14, we have left out the individual judgments to save space):

Manager	M1	M2	M3	M4	M5
A1	0.311	0.186	0.447	0.574	0.515
A2	0.217	0.302	0.292	0.259	0.235
A3	0.472	0.513	0.261	0.167	0.250
	1.000	1.000	1.000	1.000	1.000

Fig. 14 The global priorities for level 2 relative to the level 0 goal

From this summary we can see that there is some disagreement among the managers and we should find some systematic way to turn the disagreement into consensus.

Let us introduce the following function to represent a 2-party consensus: (i) $K(d, d) = 0$ and (ii) $K(d_1, d_2) = K(d_2, d_1)$ where d is a distance measure between judgements. We will call $K(d_1, d_2)$ the degree of consensus between d_1 and d_2 give it some properties. If $K(d_1, d_2) = 0$ then we have complete consensus; if $K(d_1, d_2) = 1$ then we have complete disagreement on the judgements (this is a different approach from the consensus measure used in the AHP). A suitable metric for working out the consensus degrees from the global priorities is the geometric mean – we get the following matrix of degrees of consensus (cf. Fig. 15):

	M1	M2	M3	M4	M5
M1	0.000	0.111	0.185	0.286	0.214
M2	0.111	0.000	0.257	0.369	0.301
M3	0.185	0.257	0.000	0.114	0.063
M4	0.286	0.369	0.114	0.000	0.074
M5	0.214	0.286	0.063	0.074	0.000

Fig. 15 Matrix for degrees of consensus

The degree of consensus for all five managers *K(D)* is 0.369, which is the max value in the matrix. If we are satisfied with a 4-manager majority then the *K(D4)* is 0.286 if M2 is excluded; if we are satisfied with a 3-manager majority then the *K(D3)* is 0.114 if also M1 is excluded. This will of course be a rather unkind process – the likeminded managers go together and form a majority after having looked at the matrix. Another thing is that the majority is formed by the two Finnish managers with one UK manager; the majority includes the Finnish senior manager. Thus the outcome would not be surprising.

The senior manager could, however, insist that all five managers should find a way to be closer to a consensus because they have to deal with a hard decisions and it is not advisable that it becomes public knowledge that the management team could not find a consensus and that the issue was forced by a majority that was formed by two Finnish managers and a consenting UK manager (who will probably get nailed in the press). If we look at the matrix we can see that M2 is the main driver of the disagreement and the senior manager could advise him of this fact and encourage him to take a new look at the AHP model and revise the priorities he has given the various criteria; the AHP is rerun and the consensus matrix is recalculated – if the *K(D)* now is ~ 0 then a sufficient consensus has been reached. If M2 is a true dissenter and adventurous he can try to move "closer" to M1 in his opinions and thus increase the minority; this new minority could then try to get M4 to move "closer" to the two in his opinions (this tactics can be derived from the matrix) and then the consensus would be formed with some new combination of priorities for the criteria. In the actual case this would not work as the Finnish senior manager already stated his decision and this will never change according to old Finnish management practice.

Discussion and Conclusions

The problem we have addressed is *the decision to close – or not to close – a production plant in the forest products industry sector*. The plant was producing fine paper products, it was rather aged, the paper machines were built a while ago, the raw material is not available close by, energy costs are reasonable but are increasing in the near future, key markets are close by and other markets (with better sales prices) will require improvements in the logistics network. The intuitive conclusion was, of course, that we have a sunset case and senior management should make a simple, executive decision and close the plant.

We showed that real options models will support decision making in which senior managers search for the best way to act and the best time to act. The key elements of the closing/not closing decision may be known only partially and/or only in imprecise terms; then meaningful support can be given with a fuzzy real options model. We found the benefit of using fuzzy numbers and the fuzzy real options model – both in the Black-Scholes and in the binomial version of the real options model – to be that we can represent genuine uncertainty in the estimates of future costs and cash flows and use these factors when we make the decision to either close the plant now or to postpone the decision by *t* years (or some other reasonable unit of time).

We showed that we can deal with the close/no close decisions with the help of analytical models by translating the understanding we have of the problem to an analytical framework and then working out the logic of the various alternatives we could consider. An analytical framework is helpful because it offers a number of mathematical tools we can use to refine our understanding and to work out the possible consequences of the alternatives we have. We also showed that the case we have been working in involves genuine uncertainty, i.e. we cannot defend using probabilistic modelling to represent future cash flows, and that fuzzy real options modelling helps us to work out both the course of uncertainty and the consequences in terms of the variations of future cash flows. Taken together, this represents a more effective way to handle uncertainty than the classical approach with discounted cash flows that have been predicted with a trend model based on historical time series. We have also shown that information systems help us to handle complex interactions of the key factors in the close/no close decision both in their interaction over time and with numerical details that can be checked and verified. Finally, we worked through a method for finding group consensus which we could not implement in the actual case as the senior manager told the group what the consensus was and made the decision.

Analytical models and information systems are key parts of modern management research – as the close/no close case shows; without these instruments we would have missed the core of the problem, we would not have been able to work out the options available and we would not have been able to work out the numbers to test the viability of the options. In our mind this represents a significant improvement over common wisdom, experience and intuition – and over group consensus derived from some joint belief or some wishful thinking.

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