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Supplier ranking by multi-alternative proposal analysis for agile projects

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Abstract

Changing requirements and on-going decision making along the entire project life cycle are well handled by Agile methods. However Agile projects still use evaluation methods during the RFP stage that do not fulfill the flexibility mandated by the Agile manifesto.

Current evaluation methods assume a single development alternative, and thus a fixed cost–benefit tradeoff. The proposed model provides a more realistic approach by relaxing this assumption. It assumes that a supplier can propose several different alternatives (Multi-Alternative Proposal) reflecting diverse potential cost-benefit tradeoffs. The model makes it possible to rank the suppliers of these Multi-Alternative Proposals at the RFP stage.

The ideas behind the method combine concepts from both the Agile approach and Data Mining. Thus suppliers who provide multi-alternative proposals can be ranked in an objective, but very intuitive manner.

Keywords: IT projects; RFP; Proposal analysis; Agile; ROC curve; Cost–benefit curve

1. Introduction

Request for proposals (RFP) and proposal analysis are significant milestones in information technology (IT) projects, regardless of the management and development approaches that are implemented. In current tender procedures, suppliers are required to submit their proposals according to predefined specifications. These specifications explicitly ask bidders to state system requirements, timetables and deliverables. The latter usually define intermediate milestones for system subproducts. The participants present their proposals in detail, covering both quality related items (i.e., the functional aspects) as well as cost related issues (i.e., budgetary issues) in what is supposed to be a clear and unequivocal format.

Despite the clear definitions in both the RFPs and the suppliers' proposals, practical experience shows that functional specifications and deliverable schedules may not be rigid. Academic studies on IT project success, such as those discussed in Molkken and Jrgensen (2003), pinpoint significant discrepancies in many projects in terms of functionality, schedule and budget. These findings are supported by analyses of commercial firms such as the Standish Group[1] (Standish Group, 2004), as well as theoretical studies (Agarwal and Rathod, 2006; Madpat, 2005).

The high percentage of projects which suffer from significant functional, budget and schedule related deviations has led to the development of a wide range of software engineering and development management methods. These include the Agile approaches. The concept behind these approaches differs fundamentally from "traditional" methods such as the Waterfall. The Agile approaches assume that clients' needs and requirements are likely to change during the development phase. Such changes can be the result of environmental forces (e.g., new competition, new legislation, etc.), or erroneous interpretations of the original requirements (Cockburn, 2007;

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[1] The Standish Group reported that 18% of ICT projects failed (i.e., projects that were cancelled at some point during development), 53% of the projects were challenged (i.e., the project was completed and operational but failed to meet budget, time or functionality criteria), and that only 29% were successful on all three performance measures (Standish Group, 2004).

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Highsmith, 2002; Schwaber and Beedle, 2002). This prompted the Agile approaches to formulate the following principle: “Welcome changing requirements, even late in development. Agile processes harness change for the customer’s competitive advantage” (Beck et al., 2001). Approaches such as Scrum anchor this principle in formal indices and metrics to evaluate the progress of IT project development. These measures include Stories, Sprints, and Velocity. The metrics allow for dynamic changes in the requirements along an incremental development process.

The significance of the different perspectives of the Agile approaches lies in acknowledging that an IT development project is a dynamic collection of requirements which are not known clearly and unequivocally in advance. This reality, and the fact that the scope of the work cannot be determined in a foolproof manner until the end of the development phase, effectively makes static RFPs ineffective for complex and lengthy development projects. In order to cope with this reality, Agile approaches view RFPs as dynamically changing sets of needs and requirements. Consequently, the formal contractual agreement between the parties involved in the project must be adjustable to allow for the expression of new indices-metrics which deal with dynamically changing requirements.

As an example of an Agile approach, Stevens, for instance, proposed ten possible contracts (Stevens, 2009): (1) the “Sprint Contract” — an agreement for one sprint between a supplier and the client. (2) Fixed Price/Fixed Scope — the supplier and the client agree on specific deliverables and their price. (3) Time and Materials — the supplier and the client agree on price with no specific time limits, but the client is liable for changes. (4) Time and Materials with Fixed Scope and a Cost Ceiling — similar to Fixed price/Fixed scope, but only actual effort is invoiced. (5) Time and Materials with Variable Scope and Cost Ceiling — similar to Time and Materials, except that the cost ceiling limits the client’s financial liability. (6) Phased Development — the product version is delivered periodically, and additional funds are approved after each successful release. (7) Bonus/Penalty Clauses — the supplier receives a bonus or pays a penalty depending whether the project is completed earlier or after an agreed -upon due date. (8) Fixed Profit — the supplier and the client agree on the profit margin in advance, regardless of the project’s actual completion date. (9) “Money for Nothing, Changes for Free” — the client can stop the project when he/she realizes that no further development is necessary after a certain amount of functionality has been delivered. And (10) Joint Venture — Both the supplier and the client make an investment, and share the liabilities and profits. Stevens’ contracts always adhere to one of these forms.

The Agile approaches deal not only with possible changes in requirements during the project, but also with flexibility in project management (Olsson, 2006). The present study expands the Agile framework to the tender-RFP stage, and suggests a method for bid evaluation, in which each bid can be composed of several contract formats. Each bid is in fact a *Multi-Alternative Proposal*. Here, each potential supplier can present several (i.e., different) alternatives. For example, one bidder can submit ten different proposals, each reflecting one of Stevens’ ten contracts. Moreover, any supplier can submit several variations of a contract, thus allowing the client to choose from a variety of alternative support methods, programmer experience, etc. The situation described above creates conditions similar to those in Prospect Theory (Kahneman and Tversky, 1979), where any participant’s suggestion is in fact a collection of prospects (i.e., alternatives). According to this theory, an increase in prospects can create a situation of limited rationality.

The current study does not deal with the various values and beliefs regarding the Agile forms and concepts. Rather, it focuses on the mechanism for rational, optimal and objective evaluation of RFP proposals, in which any proposal can contain a wide range of different prospects/alternatives. What is suggested in this work is, in fact, a Multi-Prospect Proposal analysis, referred to here as *multi-alternative proposal* analysis.

In *multi-alternative proposal analysis* each potential supplier can submit various proposals. This situation enables each bidder to present a variety of alternatives, thus expressing his / her competitive advantage. An option presented by one supplier is not necessarily offered by all of them. The client’s task is to compare and evaluate the suppliers’ multi-alternative proposals across a variety of options, and to select the supplier who tailors the contractual suite that best fits the client’s objectives, as a function of the situations that may occur during the project’s life cycle. The proposed method has an added value when at least one of the suppliers submits a multi-alternative proposal. This situation is very common in the current dynamic IT market. In this case clients need to rank the various suppliers and not individual proposals, since one cannot anticipate with absolute certainty which proposal will actually emerge as preferable as the project progresses (sometimes a combination of several proposals from a single supplier is the best choice). However, when every supplier submits a single-alternative proposal our method has no added value over existing ones.

RFPs in which each supplier submits several, not necessarily identical alternatives require the development of a new method for ranking the various suppliers. Clearly the client can rate each proposal using a weighted scoring function, by taking into account all the alternatives suggested in each proposal. The weights, in this case, are estimated according to probabilities ascribed by the client to each possible situation, tradeoffs and terms. However such a scoring scheme may be subjective, because there can be non-uniformity in the proposals presented by different suppliers. Hence, the probabilities assigned by the client may be superficial. Under such circumstances the entire tender may be cancelled or delayed by lengthy legal battles.

The current study proposes a new method for objective *multi-alternative proposal analysis*. The approach taken here combines the concept of Multi-Objective Utility Functions suggested by Keeney and Raiffa (Keeney, 1974; Keeney and Raiffa, 1993), with an index which is used in signal processing, machine learning and data mining for ranking the performance of classifiers and other kinds of decision-making automata models. This index is the Area Under Receiver Operating Characteristic Curve, commonly known as the AUC-index. The concepts are implemented in a visualized form, enabling the evaluation of multi-alternative proposals and the rankings of the suppliers.

The proposed method is an extension of the graphical cost–benefit approach developed by Shoval and Lugasi (1988). However, in contrast to their approach, which only ranks single proposals, our method can rank suppliers in multi-alternative proposal situations (e.g., select the 'best' one). Each alternative typically has a unique cost and benefit. Similar to Shoval and Lugasi (1988), our method does not deal with benefit calculation and/or added value evaluation using different methods like the Additive Weight, AHP, etc. (which are reviewed in the Related Work section). It works on top of these evaluation methods, and is not designed to replace them.

The Cost–Benefit approach as well as its graphical representation assume that all the criteria fall either into the cost or the benefit categories. It is composed of several straight lines. Each line refers to one proposal by one supplier. In the complex reality to which the current study refers, each proposal is multi-alternative , and therefore cannot be represented as a single linear line. Therefore finding the most attractive supplier is not straightforward. We innovate by suggesting a simple index, called the *Area Under Cost–Benefit Curve (AUCB)*, for ranking the various suppliers.

The AUCB enables clients to choose not only the best proposal (current methods do this very well already), but more importantly to identify the supplier who offers the most attractive set of alternatives for various situations which may occur during project's life cycle. Specifically, the method ranks the various suppliers without requiring the alternatives to be identical, and is free of subjectivity biases. The proposed model anchors the flexibility of Agile concepts in the RFP stage (tender and contract), thus creating a better fit between formal contracts and actual reality.

2. Related Work

Although IT project management has been discussed in the academic literature for over three decades, there is still no standard accepted method for supplier selection at the RFP stage. However, the subject is of utmost importance for both practitioners as well as for the academic community.

The evaluation of bids and the selection of the best one is usually viewed in the MIS literature as a *Multi-Stage Multi-Attribute / Multi-Criteria Decision process* (Lee and Kim, 2000, 2001; Sarkis and Sundarraj, 2003; Shoval and Lugasi, 1988). Stamelos et al. (2000), for example, developed an expert system for software evaluation based on a seven-stage decision process.

In the process of evaluation and selection, comparisons should relate to the estimated benefits and costs (Keeney, 1974). The traditional cost-benefit analysis suggests calculating the net present value (NPV) of each proposal and selecting the one with the highest value. Weill (1993) presented empirical evidence that the NPV method is not used in practice, in particular because of difficulties in determining model parameters (Tam, 1992). Taudes et al. (2000) suggested a cost method based on real options. Using a real-life case, they showed that an NPV estimate represents the lower bound of a project's actual value to the firm, since it does not account for the value inherent in allowing managers to intervene during the project trajectory.

Since benefits which derive from an IT project are often difficult to express in monetary terms, several methods of ranking have been put forward over the years. Most of these methods involve the generation of a list of criteria or attributes, which specify the quantifiable and intangible benefits, and then a formula to determine the weights of the attributes/criteria and their scores or ranks for each alternative. The total score / rank of the proposal is calculated as an aggregated sum. In contrast to simultaneous comparisons as in the Additive Weight or the Weighted Average Sum methods (see, for example, Buss, 1983; Lucas and Moore, 1976), Saaty's (1980) Analytic Hierarchy Process (AHP) method suggests pair-wise comparisons of the project alternatives as well as pair-wise comparisons of the multiple criteria. Muralidhar et al. (1990) applied the AHP to IT project evaluation and selection. Saaty (1996) later presented another method, the Analytical Network Process (ANP), or the Super matrix approach, which deals with interdependencies among criteria and project alternatives. The two AHP and ANP methods differ from each other as regards the number and types of pair-wise comparisons, and in the way the weights are computed. Sarkis and Sundarraj (2003) used both methods for the evaluation of complex systems. Lee and Kim (2000, 2001) integrated the ANP with goal programming for interdependent IT project selection problems. Mulebeke and Zheng (2006) applied the ANP method to the selection of software for product development processes. Liang and Li (2008) used the ANP for project selection with regard to opportunities and risks.

Costs are often included in scoring and ranking methods as one of the attributes/criteria (see, for example, Lee and Kim, 2000, 2001; Liang and Li, 2008; Stamelos et al., 2000). Sometimes they are not (see, for example, Mulebeke and Zheng, 2006; Sarkis and Sundarraj, 2003). In this case, the costs must then be incorporated in the final stage of the evaluation process. The simplest way is to compare the aggregated scores of the benefits with the costs of the proposals and choose the alternative with the highest benefit-to-cost ratio (see, for example, Sarkis and Sundarraj, 2003). Shoval and Lugasi (1988) developed a graphical cost-benefit approach which is more flexible and allows the user to vary the weights of benefits and costs in different situations. They suggested calculating the normalized benefits and costs of each proposal first. Regardless of the transformation method employed, the most advantageous and least costly proposals have higher scores on the corresponding 0–1 scales. The different proposals are presented graphically in a clear and intuitive manner. The two vertical axes express the normalized benefits and costs, respectively. The horizontal axis expresses the relative importance of benefits versus costs on a 0–1 scale. The lines which connect the points on the benefit and cost axes represent different alternatives. For any given point on the weights axis, the best proposal, which is represented by the highest line, can be easily identified and chosen.

Selection methods, supported with graphical-visual presentation, can be used for identifying the best out of many alternatives. However, the actual goal here is to rank the suppliers and not the individual proposals, since a single supplier can propose many alternatives. This goal cannot be achieved by using any of the methods mentioned above. In the next section we present how a *multi-alternative proposal analysis* can do this effectively.

3. The proposed model for supplier ranking

The main objective of the method proposed here is to enable a decision maker to rank two or more suppliers, each of whom has presented several (not necessarily identical) alternatives, without being committed to a particular tradeoff between costs and benefits. As discussed earlier, this is a typical real-world situation in many IT projects, in particular complex projects which span a long period of time.

The suggested model can be applied on top of any method mentioned in the previous section. Purely for illustrative purposes, we used Shoval and Lugasi (1988)'s approach as a starting point to illustrate our concepts, due to its simple and clear graphical interpretation.

A relatively straightforward example is shown in Table 1, where each of the two suppliers submits four alternatives for a certain IT project. The decision-maker's task is to rank the suppliers without having to commit him/herself to any particular cost-benefit tradeoff. Bear in mind that the goal is not to rank the individual proposals (see Related Work), but rather to rank the suppliers.

The net present value of each alternative's cash flow is given in the Cost row in Table 1. The next row indicates the normalized benefit, where higher values indicate more beneficial proposals and vice versa. Both the cost and the benefit may represent an aggregate of an arbitrary number of attributes. A proposal's benefit calculation, for instance, can be made by using methods such as those described in the Related Work section (e.g. the Additive Weight, AHP, etc.). The reader can therefore choose one of the abovementioned or any other method.

Shoval and Lugasi (1988) presented several alternative transformation formulas. Table 1 presents two of these optional transformations, labeled Transformation A and Transformation B respectively. Transformation A applies the following formulas:

$$NC(min) = Benefit(max);$$
$$NC(i) = NC(min)*Cost(min)/Cost(i)$$

Thus, Transformation A assigns a normalized-cost value to the least costly alternative which equals the value of the most beneficial alternative, and the normalized cost of any other alternative is decreased proportionally. Using the cost and benefit values of alternatives A1–A4 of Supplier A yields:

$$NC(A1) = 0.9*400/700 = 0.51; \quad NC(A2) = 0.9;$$
$$NC(A3) = NC(A4) = 0.9*400/500 = 0.72$$

These results are shown in Table 1 in the row labeled Transformation A for Supplier A. The values on the same row for Supplier B were calculated in a similar way.

Alternatively, Transformation B reflects the following formula:

$$NC(max) = Benefit(min);$$
$$NC(i) = NC(max)*Cost(max)/Cost(i)$$

Transformation B assigns a normalized-cost value to the most costly alternative which equals the value of the least beneficial alternative, and the normalized cost of any other alternative is increased proportionally. For the same four alternatives (A1–A4) of Supplier A, the following values are obtained:

$$NC(A1) = 0.5; \quad NC(A2) = 0.5*700/400 = 0.87;$$
$$NC(A3) = NC(A4) = 0.5*700/500 = 0.7$$

These values are shown on bottom row of Table 1 for Supplier A alone. The values for Supplier B can be calculated in a similar way (not shown to simplify presentation).

As mentioned above, a variety of formulas can be used for the normalized cost transformation. However, regardless of the transformation method chosen, calculating NC from 'Cost' involves two major steps:

(a) Normalization of the costs on a 0–1 scale irrespective of their respective benefits. Here, an alternative with a higher score is more expensive and vice versa (not shown).
(b) Normalization of the results of step (a) with the normalized benefits. This step transforms the costs into a scale which is identical to the benefits. After this step is completed, higher NCs represent cheaper costs and vice versa. The results of step (b) are shown in the NC row of Table 1.

Since our analysis is conducted on top of whatever transformation has been applied (i.e., the current research is not focused on any specific transformation), we arbitrarily chose Transformation A to exemplify the approach.

After the normalized costs and the normalized benefits have been calculated using similar 0–1 scales, a visual presentation

Table 1
Cost/benefit of two potential suppliers (eight alternatives).

Factors	Supplier A				Supplier B			
	A1	A2	A3	A4	B1	B2	B3	B4
Cost	700	400	500	500	1000	350	650	750
Benefit	**0.9** [a]	**0.5** [b]	0.8	0.6	**0.95** [a]	0.6	0.7	0.75
Normalized Cost (NC) Transformation A	0.51	**0.9** [a]	0.72	0.72	0.333	**0.95** [a]	0.512	0.443
Normalized Cost (NC) Transformation B	**0.5** [b]	0.87	0.7	0.7				

[a] The value of the most beneficial alternative is assigned to the least costly alternative.
[b] The value of the least beneficial alternative is assigned to the most costly alternative.

of the various alternatives can be generated. Fig. 1 and Fig. 2 present the cost-benefit graphs for Supplier A and Supplier B respectively. The horizontal axis expresses the relative importance of cost versus benefits on a 0–1 scale. When the weight of the benefit is, say, *w*, the weight of the cost is *1-w*, so each straight line in Fig. 1 presents the normalized cost-benefit curves of the four alternatives suggested by Supplier A. Fig. 2 presents the normalized cost-benefit curves of the four alternatives suggested by Supplier B. Some points and regions of interest in the graphs are indicated in parentheses and arrows respectively. A detailed explanation of both Fig. 1 and Fig. 2 is provided below.

Fig. 1 graphically illustrates the values of the Normalized Cost (NC) and the Benefit of the four alternative proposals submitted by Supplier A (A1, A2, A3, A4). The second row in Table 1 refers to the Benefit values, and the third row refers to NC values. Each alternative is represented in Fig. 1 by a straight line drawn between two Y-axes. The left Y-axis refers to NC values, while the right Y-axis refers to the Benefit. The Benefit of alternative A1, for example, scores 0.9 (as indicated in the left cell of the Benefit row in Table 1, as well as by point 1–8 on the right Y-axis of Fig. 1). The NC score of alternative A1 is 0.51 (as indicated in the left cell of the NC row of Table 1, as well as in point 1–1 on the left Y-axis of Fig. 1). Therefore, the A1 line in Fig. 1 is drawn between 0.51 on the left Y-axis (the point labeled 1–1), and 0.9 on the right Y-axis (the point labeled 1–8). The lines representing the other three alternative proposals made by Supplier A (A2, A3, A4) were drawn in a similar way. Fig. 2 does the same for the four alternative proposals submitted by Supplier B (B1, B2, B3, B4). The values are taken from the Benefit and NC rows of Transformation A in Table 1 for Supplier B.

So far we have re-introduced what has been proposed in previous studies for selecting the most attractive alternative, given that the cost-benefit tradeoff (*w*) is known in advance. These steps can include sensitivity analysis (on cost and benefits alike). Under the assumption that the cost-benefit tradeoff (*w*) is known in advance it is possible to find the best proposal by picking the highest line for that value of *w*. Here we assume, for reasons discussed earlier, that the value of *w* is unknown at the time a decision has to be made regarding the best supplier. We also assume that every value of *w* is equally likely. This

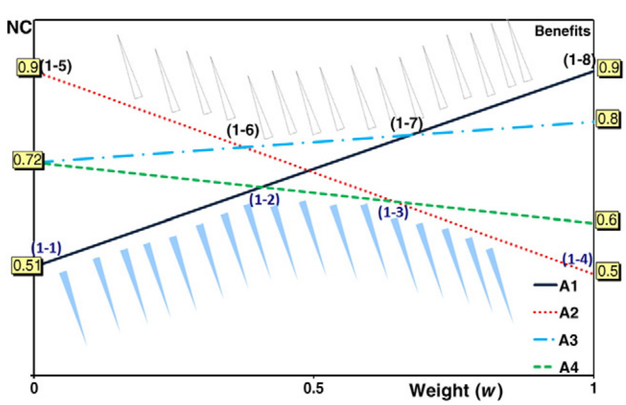

Fig. 1. Cost–benefit graph for Supplier A.

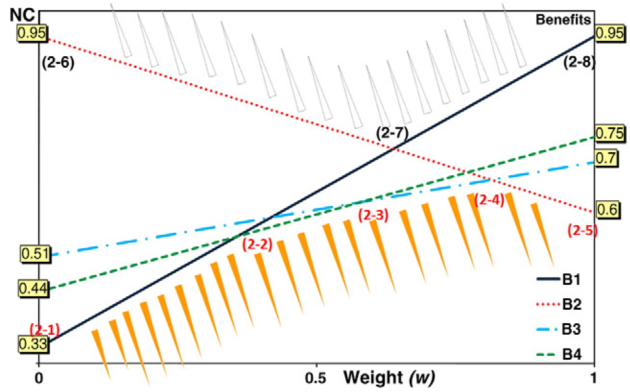

Fig. 2. Cost–benefit graph for Supplier B.

assumption enables the ranking of the various suppliers. Note that assigning a probability distribution other than uniform to *w* is illegal in many countries since it may be interpreted as a bias which favors certain suppliers over the others. A more comprehensive discussion of this issue is given in the Discussion and Future Work section.

The curve that represents the higher bound of the area included in all the supplier's proposals is called the *Least-Assured*, and the curve for the higher bound of the area that subtends the most attractive sections of the supplier's proposals is called the *Efficiency-Frontier*. The sequence of the intersection points in Figs. 1 and 2 starts with the lowest intersection point on the left Y-axis, to the lowest intersection point on the right Y-axis, along the lowest crossovers of the diverse alternatives determines the supplier's Least-Assured curve. Hence, the sequence (1–1)–(1–2)–(1–3)–(1–4) in Fig. 1 presents the Least-Assured curve of Supplier A, while the sequence (2–1)–(2–2)–(2–3)–(2–4)–(2–5) in Fig. 2 presents the Least-Assured curve of Supplier B. These curves bound the areas from above in Figs. 1 and 2 which are marked with downward arrows. The sequence of the intersection points in Figs. 1 and 2, starting with the highest intersection point on the left Y-axis to the highest intersection point on the right Y-axis, along the highest crossovers of the diverse alternatives determines the supplier's Efficiency-Frontier: the sequence (1–5)–(1–6)–(1–7)–(1–8) in Fig. 1 presents this curve of Supplier A and (2–6)–(2–7)–(2–8) in Fig. 2 that of Supplier B. The suppliers' Efficiency-Frontiers bound the areas in Figs. 1 and 2 which are marked with upward arrows from below.

Fig. 3 was formed from the curves presented in Figs. 1 and 2. It shows, on a single graph, the Least-Assured curves of both Supplier A and Supplier B. By the same token we could have drawn, on a single graph, the Efficiency-Frontiers of the two suppliers. To illustrate the model we used the "Least-Assured" curves, but a similar method of calculation could have been implemented for the "Efficiency-Frontiers" curves as well.

We have argued that in the RFP phase of a real life IT project one typically has only a very vague idea of the actual value of *w* during the project's life-cycle. However let us assume for purposes of illustration that this value can be determined with absolute certainty. This assumption will help explain Fig. 3. Consider a hypothetical case where the value

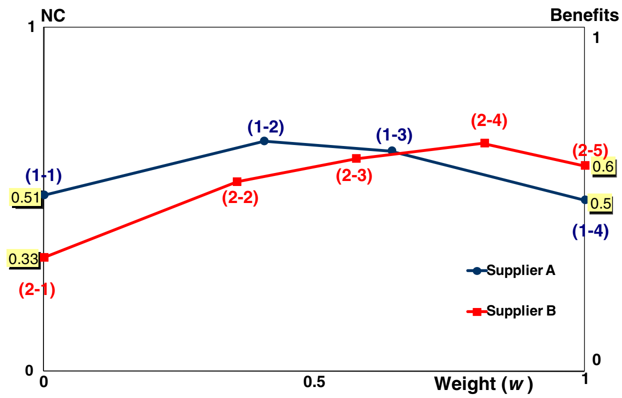

Fig. 3. Cost–benefit (Least-Assured) curves of two suppliers.

of the weight w was known with absolute certainty, say $w=0.2$. In this case the immediate conclusion that should be drawn from Fig. 3 is that the Supplier A is preferable to Supplier B. However if, for instance, the value of w was 0.8 the immediate conclusion from Fig. 3 would be that Supplier B is preferable. Furthermore, one can also conclude from Fig. 3 that for values of w left of the intersection of the two curves of Suppliers A and B, the alternatives given by Supplier A are preferable, and that the opposite is true up to that intersection point. But which supplier is preferable? The ranking of the two suppliers for all values of w is not straightforward when the curves intersect (as in this example). For this case, and in particular when many suppliers are involved, one needs some objective measure to rank the suppliers.

Since it is assumed here that all values of weights (w) are equally likely (otherwise they may be considered subjective and unlawful; see Discussion and Future Work section), the area which is bounded by each supplier's Least-Assured curve (or the Efficiency-Frontier if chosen) gives a good indication of this supplier's rank. The larger the area is, the better, and vice versa. We call this measure of the overall quality of all the alternatives presented by a single supplier the *Area Under the Cost-Benefit* curve (or AUCB for short). The AUCB is fairly simple to calculate.

The AUCB measure for Supplier A is obtained by a summation of the areas under Supplier A's cost-benefit curve in Fig. 3, corresponding to the line segments from left to right:

$$\int_0^{0.407}(0.514+0.386w)dw+\int_{0.407}^{0.643}(0.72-0.12w)dw$$
$$+\int_{0.643}^{1}(0.9-0.4x)dw=0.6003.$$

The AUCB of Supplier B is calculated in a similar way:

$$\int_0^{0.357}(0.3325+0.6175w)dw+\int_{0.357}^{0.577}(0.4433+0.3067w)dw$$
$$+\int_{0.577}^{0.814}(0.5115+0.1885w)dw$$
$$+\int_{0.814}^{1}(0.95-0.35w)dw=0.557.$$

The reader can verify these results using basic geometry. Since $AUCB_{SupplierA}>AUCB_{SupplierB}$, Supplier A is ranked as better than Supplier B. Clearly, using the suppliers' Efficiency-Frontiers instead of the Least-Assured curves (as we did here) could have lead to a different ranking. This is similar to the different optimal solutions that can be obtained by profit-maximization and by cost-minimization, which are also interpreted in different ways. Using the Least-Assured curves, the client chooses the supplier that suggests more in all his/her proposals than the other suppliers, whereas the Efficiency Frontiers ensure the supplier's ranking according to their most ambitious proposals.

The idea of using the areas which are bounded under functions that express tradeoffs for ranking is not new. Receiver Operating Characteristic (ROC) curves, for instance, were used during WWII in signal processing for calibrating radar equipment. ROC curves are two-dimensional graphs of true positives (TPs; i.e., justified or true alarms) versus false positives (FPs; i.e., false alarms). A classifier that generates high TPs but low FPs is preferable to one that does the opposite. However, in reality these two goals are often in conflict with each other. By varying the value of some parameter, or a threshold of a classifier (e.g., the sensitivity of a signal detector), one can tune up the equipment (or a model) in such a way that the operating point (i.e., the actual TP and FP values) is considered optimal in the context of a particular application.

The above example can be generalized to a case where there are several suppliers, each submitting several alternative proposals for a certain IT project. Let S be is a finite set of suppliers, $S=\{1, 2, \ldots, s\}$. Supplier i submits several alternatives, $A_i=\{A_{i_1}, A_{i_2}, \ldots, A_{i_k}\}$. Each alternative j of supplier i is characterized by the two values, (NC_j, NB_j), the normalized cost and the normalized benefits, and can be represented by the linear function $NC_j+(NB_j-NC_j)w$. The intersection points of these lines can be calculated using basic geometry principles, and the lowest (i.e., the most 'cost effective,' or 'promising') sections can identified. The area bounded by the graph of alternative j, the w-axis, and the vertical lines $w=0$ and $w=1$, is described by the definite integral $\int_0^1\left[NC_j+\left(NB_j-NC_j\right)w\right]\ dw$. Thus, the AUCB measure of supplier i can be calculated as the intersection of the areas bounded by the graphs of all the supplier's alternatives. Formally,

$$AUCB_i=\bigcap_{j=i_1}^{i_k}\int_0^1\left[NC_j+\left(NB_j-NC_j\right)w\right]\ dw.$$

The supplier for which the AUCB measure is maximal, $\max_{i\in S}AUCB_i$, is ranked as better than the others.

As mentioned earlier, the AUCB measure was inspired by the way many researchers compare the performance of data mining and machine learning models. Provost et al. (1998) suggested that ROC curves could be successfully applied to data mining as well, and these have become increasingly popular in that field. It turns out that ROC curves can be very effective tools for ranking classifiers. ROC curves often cross each other, making the ranking non-trivial. When many ROC curves cross each other it is usually the Area Under the ROC curve (known as the AUC-index) which is used for determining the ranking of the models (Provost and Fawcett, 2001). The AUC-index is a scalar, and as such, when using it for ranking instead of the ROC curves, valuable information may be lost. However in many cases one needs an objective measure of the performance of several models, for instance for selecting the best performing model (analogous to the selection of the best supplier in our case), or for performing statistical ranking tests as described in (Demsar, 2006). In such cases the AUC-index is very frequently used.

4. Discussion and future work

Uncertainty, changing requirements and on-going decision making along the entire IT project period are well-known concepts in Agile methods. Nevertheless, when it comes to the RFP stage, Agile projects use evaluation methods that do not take the uncertainty of cost-benefit tradeoffs into account. Instead (and similar to 'traditional' approaches) they assume that the cost-benefit weight (w) is known at the RFP stage. We argue that this assumption runs counter the Agile manifesto, and present a simple method which overcomes this difficulty by relaxing this assumption. The method proposed here is both objective and consistent with the Agile approach.

The method combines concepts from the Agile approach with notions applied in signal processing and data mining. The result is a simple and intuitive method for supplier ranking in which each supplier can present several (not necessarily identical) alternatives, and the m*ulti-alternative proposal analysis* introduces ranks the suppliers at the IT project's RFP phase.

The simple AUCB-index example depicted a situation where there was a preference for one supplier over the other. It should be noted, however, that supplier ranking is not straightforward and requires a metric, in particular when more suppliers are involved. The calculation itself is easy since only straight lines are involved, which reduces it to simple sums of areas of trapezoids. The future development of adequate automated tools (even spreadsheet macros) should alleviate the need for manual calculation.

Preferred cost-benefit curves can cross each other, and their areas may be identical. In this case the AUCB-index indicates a tie between the two suppliers. Furthermore, when the values of two or more AUCB-indices are very close to each other, one must be very cautious when using the AUCB-index as the sole metric for rankings. Some kind of what-if-analysis may be helpful in this situation. When two cost-benefit curves do not intersect each other, calculating the AUCB-index is not required at all, since one dominates the other over all values of cost-benefit weights (w). In reality more complicated scenarios than what was shown in Fig. 3 are likely, in which case the use of the AUCB-index may be very helpful indeed. This is true in particular when many suppliers need to be ranked, when each of them submits several non-identical alternatives, and / or when many cost-benefit curves cross each other over the range of the cost-benefit weights (w) scale.

We have shown that once the normalized costs and the normalized benefits are known for every proposal of each supplier, calculating the AUCBs is fairly simple. All one has to do is to compute the total area which is bounded within the 'best' polygon of each supplier, and the supplier's ranking is determined by these areas. Clearly, the GIGO (Garbage In Garbage Out) universal rule also applies here. Depending on the method used for calculating the values of the normalized costs and the normalized benefits, subjective influences may (and often do) occur. However, it is important to note that the AUCB calculation in itself does not introduce any additional degree of subjectivity to the supplier's ranking, if (as we did) the assumption of equally likely values of w is adopted.

Several extensions to the proposed model can be suggested. One involves assigning some sort of qualitative or quantitative measure of belief or probability distribution of the cost-benefit weights (w). The assumption of equal probability of w is analogous to the assumption of equal class probabilities in data mining when calculating the AUC. In data mining this assumption is often violated whenever a dataset has an uneven class distribution. Some remedies have been suggested by various data mining researchers over the years, most notably Hand's (2009) H-index. The H-index assumes a Beta probability distribution of loss functions (which is analogous in our case to assuming some, and possibly another, probability distribution function of w). Hand's H-index has been criticized for being much more complicated to compute and less intuitive than the AUC. More crucially, there are doubts whether its underlying assumptions (i.e. specific distributions of loss function) can be considered universal. Thus the H-index might be considered subjective (i.e., dependent on the specific distribution of loss function). This has prevented the H-index and other alternatives to the AUC from garnering wider acceptance within the data mining community. The interested reader is also referred to a recent paper by Flach et al. (2011) which discusses this controversy in depth.

Throughout this paper we have assumed equal probabilities of w, so the intriguing questions that naturally arise are: (1) Should one relax this assumption in the first place? and, if so, (2) What happens if this assumption is relaxed? We argue that the answer to (1) in the context of Agile project management is negative. There are several reasons why: (A) Assuming a non-uniform probability distribution of the weights (w) may lead to serious legal problems. This is because such a probability distribution of w is likely to influence the AUCBs of the various suppliers. This may be interpreted as a bias or an unfair practice that favors one supplier over the others (this is against the law in many countries). (B) Since different IT projects may have different probability distributions of w, the AUCB will no longer be regarded as an objective meter. (C) It is unclear whether even experienced decision-makers are capable of explicitly predicting reasonably accurate distribution functions of the cost-benefit weights at the RFP phase of lengthy and complex IT projects. (D) The experience gained by the H-index proposal (see above) shows that an integration of w into the AUCB calculation will make the computation much more complex and the outcome will be less intuitive.

A simple and intuitive solution to the ranking of multi-alternative proposals for Agile projects has been presented here. The method ensures the existence of safeguards such that the decision makers will not be exposed to allegations of subjectivity with all its concomitant legal problems.

References

Agarwal, N., Rathod, U., 2006. Defining ‘success’ for software projects: an exploratory revelation. International Journal of Project Management 24 (4), 358–370.

Beck, K., et al., 2001. Principles behind the Agile Manifesto. Retrieved July 2010, from Agile Manifesto Org site: http://agilemanifesto.org/principles.html.

Buss, M.D.J., 1983. How to rank computer projects. Harvard Business Review 61, 118–125.

Cockburn, A., 2007. Agile Software Development: The Cooperative Game, 2nd Edition. The Addison Wesley Agile Software Development Series.

Demsar, J., 2006. Statistical comparisons of classifiers over multiple datasets. Journal of Machine Learning Research 7, 1–30.

Flach, P., Hernandez-Orallo, J., Ferri, C., 2011. A coherent interpretation of AUC as a measure of aggregated classification performance. *Proceedings of the 28th International Conference on Machine Learning*, Bellevue, WA, USA.

Hand, D.J., 2009. Measuring classifier performance: a coherent alternative to the area under the ROC curve. Machine Learning 77, 103–123.

Highsmith, J., 2002. Agile software development ecosystems. The Addison Wesley Agile Software Development Series.

Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk. Econometrica 47, 263–291.

Keeney, R., 1974. Multiplicative utility functions. Operations Research 22, 22–34.

Keeney, R., Raiffa, H., 1993. Decisions with Multiple Objectives. Cambridge University Press.

Lee, J.W., Kim, S.H., 2000. Using analytic network process and goal programming for interdependent information system project selection. Computers and Operations Research 27, 367–382.

Lee, J.W., Kim, S.H., 2001. An integrated approach for interdependent information system project selection. International Journal of Project Management 19, 111–118.

Liang, C., Li, Q., 2008. Enterprise information system project selection with regard to BOCR. International Journal of Project Management 26, 810–820.

Lucas, H.C., Moore, J.R., 1976. A multiple-criterion scoring approach to information system project selection. Infor 14, 1–12.

Madpat, S., 2005. Bridging organizational strategy & projects — an OPM3 insiders perspective. PMI Journal 5 (10), 16–20.

Molkken, K., Jrgensen, M., 2003. A review of surveys on software effort estimation. Proceedings of the International Symposium on Empirical Software Engineering, pp. 223–231.

Mulebeke, J.A.W., Zheng, L., 2006. Analytical network process for software selection in product development: a case study. Journal of Engineering and Technology Management 23, 337–352.

Muralidhar, K., Santhnanm, R., Wilson, R.L., 1990. Using the analytic hierarchy process for information system project selection. Information Management 18, 87–95.

Olsson, N.O.E., 2006. Management of flexibility in projects. International Journal of Project Management 24, 66–74.

Provost, F., Fawcett, T., Koavi, R., 1998. The case against accuracy estimation for comparing classifiers. Proceedings of the Fifteenth International Conference on Machine Learning, ICML-98.

Provost, F., Fawcett, T., 2001. Robust classification for imprecise environments. Machine Learning 4, 203–231.

Saaty, T.L., 1980. The Analytic Hierarchy Process. McGraw-Hill, NY.

Saaty, T.L., 1996. Decision making with dependence and feedback: the analytic network process. RWS Publications, Pittsburgh, PA.

Sarkis, J., Sundarraj, R.P., 2003. Evaluating componentized enterprise information technologies: a multiattribute modeling approach. Information Systems Frontiers 5, 303–319.

Schwaber, K., Beedle, M., 2002. Agile software development with Scrum. The Addison Wesley Agile Software Development Series.

Shoval, P., Lugasi, Y., 1988. Computer systems selection: the graphical cost–benefit approach. Information Management 15, 163–172.

Stamelos, I., Vlahavas, I., Refanidis, I., Tsoukias, A., 2000. Knowledge based evaluation of software systems: a case study. Information and Software Technology 42, 333–345.

Standish Group, 2004. The Chaos Report. The Standish Group International, Boston, MA.

Stevens, P., 2009. 10 Contracts for your next Agile Software Project. Retrieved July 2010, from Agile Software Development site: http://agilesoftwaredevelopment.com/blog/peterstev/10-agile-contracts.

Tam, K.Y., 1992. Capital budgeting in information systems development. Information Management 23, 345–357.

Taudes, A., Feurstein, M., Mild, A., 2000. Option analysis of software platform decisions: a case study. MIS Quarterly 24, 227–243.

Weill, P., 1993. The role and value of information technology infrastructure: some empirical observations. In: Banker, R.D., Kauffman, R.J., Mahmood, M.A. (Eds.), Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage. Idea Publishing Group, Harrisburg, PA.