Corporate Risk Tolerance and Capital Allocation: A Practical Approach to Setting and Implementing an Exploration Risk Policy.

The model described provides the firm a systematic approach to measure corporate risk tolerance and implement a coherent risk policy, thereby improving the quality of risky decision making.

Michael R. Walls, Colorado School of Mines

INTRODUCTION

Petroleum exploration companies are regularly confronted with the issue of allocating scarce capital among a set of available exploration projects - projects generally characterized by a high degree of financial risk and uncertainty. Commonly used methods for evaluating alternative investments consider the amount and timing of the monetary flows associated with a project and ignore the firm's ability or willingness to assume the business risk of the project. The *preference theory* approach[4,15] combines the traditional means of project valuation, net present value analysis, with a decision-science based approach to risk management. This integrated model provides a means for exploration firms to measure and manage the financial risks associated with petroleum exploration, consistent with the firm's desired risk policy.

Risk management decisions associated with exploration capital allocation are among the most conceptually difficult decisions faced by managers. Exploration investment opportunities are often very different in terms of their risk characteristics. Because of these differences and the importance of evaluating competing investment alternatives, it is important for managers to utilize a formal and consistent means of evaluating projects. Setting corporate risk policy is an important component of managing the process of project evaluation. The work described here contributes to the areas of preference theory application and capital budgeting decisions by providing explicit and systematic methodologies for measuring the firm's risk tolerance. The formal use of a corporate risk policy, measured by financial risk tolerance (*RT*), coupled with a decision-science based valuation model can go a long way towards improving the quality of decisions associated with capital allocation.

CAPITAL BUDGETING UNDER UNCERTAINTY

The capital budgeting problem holds a very prominent place in both the theory and practice of corporate finance. In a world of certainty, there is widespread agreement among financial theorists that choosing among independent and mutually exclusive projects based on net present value is consistent with owner wealth maximization.[7,11] An important attribute of real-world decision making, however, is the risk and uncertainty associated with future outcomes. Modern finance theory views capital markets as the fundamental mechanism for spreading these risks. In other words, the individual investor has the ability to construct a portfolio that adequately diversifies "business-specific" risk and managers of the firm should only be concerned about non-diversifiable or "market" risk.[2] Within this theoretical framework, managers in publicly held firms should maximize shareholder value by selecting those investment opportunities which have the highest *expected* net present value.

Rigorously applied, the theory suggests that corporate resources devoted to managing the business risks associated with capital allocation are inappropriately utilized. However, corporations appear to take risk management very seriously -- recent surveys find that risk management is ranked by financial executives as one of their most important objectives (Rawls & Smithson, 1990). Observations of corporate risk management activities also suggest that there is considerable disparity between the prescriptive theory of finance and actual corporate decision making behavior. We can examine this dilemma from an empirical, a theoretical, and a behavioral perspective.

The foundation of modern finance theory has been the Sharpe, Lintner, and Black Capital Asset Pricing Model which provides the basis for determining the appropriate discount rate to adjust for the non-diversifiable risks that the ownership of a particular stock brings to the investor's diversified portfolio. Unfortunately, this theory has not been supported by empirical evidence. Fama and French[6] determined that there is no detectable relation between portfolio betas and average returns. Roll and Ross[18] raise additional challenges to the CAPM, and conclude that "...it is not of practical value for a variety of applications including the computation of the cost of capital and the construction of investment portfolios." Financial theory concludes that each capital investment project should have a unique discount rate, but no guidelines exist for determining this rate. According to the popular finance textbook by Brealey and Myers[2], "...we as yet have no general procedure for estimating project betas. Assessing project risk is therefore still largely a seat-of-the-pants matter."

Studies of risky choice within organizations show that firms display a significant degree of risk aversion. March and Shapira[12] argue that if firm performance is above some critical performance target, managers attempt to avoid actions that produce below target performance (*i.e.* risk aversion); this reflects a strong sentiment for survival. Hackett[8] noted that it is unrealistic to assume that managers are merely agents for shareholders. Instead, managers attempt to reconcile the interests of all *stakeholders*, including themselves, employees, suppliers, customers, *etc*.

Swalm[20] assessed utility functions for a group of 100 executives in a large industrial organization and found the overall attitudes toward risk to be strongly risk-averse. Spetzler[19] interviewed 36 corporate executives in a major integrated oil company and consistently found risk averse attitudes among individuals and within the managerial group as a policy making body. In a study of oil executives, Wehrung[25] found that more than half gave responses that were fully consistent with preference theory, and an additional quarter of executives were consistent within a 10% margin of error. Capital investments are often technically evaluated on the basis of expected value analysis. However, actual capital allocation decisions involving risky investments, whose consequences are significant, appear to be strongly affected by risk-averse decision behaviors.

RISK ADJUSTMENT PRACTICES

In a recent study by Dougherty and Sarkar[5] the IRR and NPV criteria were shown to be the most often used methods for project evaluation by oil companies. The technique of adjusting the discount rate to accommodate for risk is the technique utilized most often by companies. In the Dougherty/Sarkar study, analysis was based on firm size. While a little over half of medium firms and 73% of large firms relied on a combination of techniques to account for risk, the majority (55%) of small firms relied on a single technique, raising the discount rate. In terms of rankings of techniques used to account for risk, either

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separately or jointly, raising the discount rate ranked at the top (46%), followed by the use of probability factors (37%) and sensitivity analysis (32%). Shortening required payback period (23%) and subjective adjustments (15%) were fourth and fifth, respectively.

Other surveys of capital budgeting practices further support the findings in the Dougherty/Sarkar study. For example, Boyle and Schenck (1985) found that adjusting the discount rate and sensitivity analysis were the two most frequently used methods for adjusting for risk, followed by the use of probability factors for calculating expected values. Chua and Woodward[3] suggest that the hurdle rate dominates the firm's process in deciding which projects receive funding and Sinha and Poole[18] regard the expected IRR and NPV rules as the two most commonly used investment analysis methods.

ADJUSTING FOR RISK - SOME SHORTCOMINGS

When the NPV and IRR rules both or separately employ the use of a risk-adjusted discount rate to account for exploration risk, serious deficiencies exist in the valuation process. These include:

- Inappropriate separation between risk discounting and time value discounting.
- Inconsistencies with respect to risk and valuation for projects having different duration.
- Use of arbitrary methodologies for determining the risk-adjusted discount rate.
- No guidance on limiting the project's downside exposure.

We also find additional support for the existence of these deficiencies in the financial literature. Martin, Cox & Macminn[13] provide evidence demonstrating the weaknesses associated with combining time value and risk discounting into one value. They state that *"this type of combined analysis can seriously bias management against long-term projects in which the riskiness of the cash flows does not increase continuously over time"*. Robichek & Myers[17] and Hodder & Riggs[9] similarly have shown that this technique inherently biases against long-term investments. An additional complication results when firms adjust for risk by changing the firm's cost of capital. The problem with this technique is that the firm's cost of capital does not represent a single project's risk or even a specific risk class of exploration projects.

Many explorationists would say that the *expected value* (EV) concept, which weights the financial consequences by their probabilities, adequately takes risk into account. However, as March & Shapira[12] have shown, to the decision maker risk is not just a function of the probability distribution of reserve outcomes or financial payoffs, but also the magnitude of capital being exposed to the chance of loss. In theory, using the expected value criterion implies that the decision maker is totally impartial to money and the magnitudes of potential profits and losses. As evident in the example in Figure 1, where the expected value of project A equals the expected value of project B, the EV concept fails to give adequate weight to the firm's exposure to the chance of a very large financial loss. Strictly applied, a decision maker who uses the expected value rule should be indifferent between project A and project B. However, most exploration managers would readily concede that the "risk" associated with each of these projects is quite different. Though Project B has a reasonably high probability of success (0.50), the payoff structure is much less attractive than that of Project A. The expected value concept is inadequate in measuring the tradeoffs between the potential and uncertain upside gains versus downside losses for individual as well as groups of projects such as those shown in Figure 1. The traditional measures of risk valuation, such as expected NPV or IRR, may lead to inappropriate choices about competing risky investments. As a result, we observe managers using more informal procedures, rules of thumb and individual intuition as a basis for making critical capital allocation decisions.

RISK VALUATIONS - AN ALTERNATIVE APPROACH

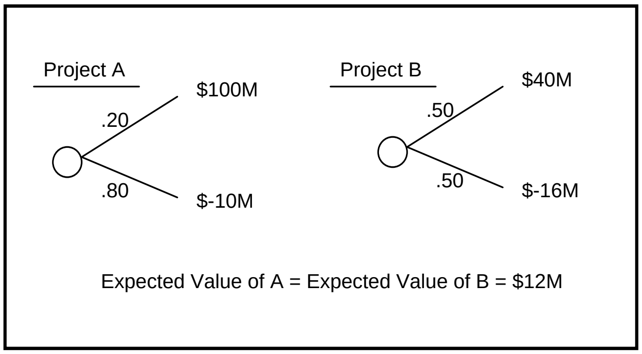


Figure 1. Though the expected value of Projects A and B are equal, the risk associated with each project is quite different. The expected value concept fails to give adequate weight to the firm's exposure to the chance of a very large financial loss.

Efforts to avoid some of the pitfalls associated with the expected net present value and internal rate of return rules leads us naturally to a discussion of a fundamental decision science model knows as *preference theory.* This theory is an extension of the expected value concept in which the firm's attitudes about money are incorporated into a quantitative decision model. The result is a more realistic measure of value among competing projects characterized by risk and uncertainty. Preference theory concepts are based on some very fundamental and reasonable concepts about rational decision making which are well-documented in the decision science literature.[14, 21]

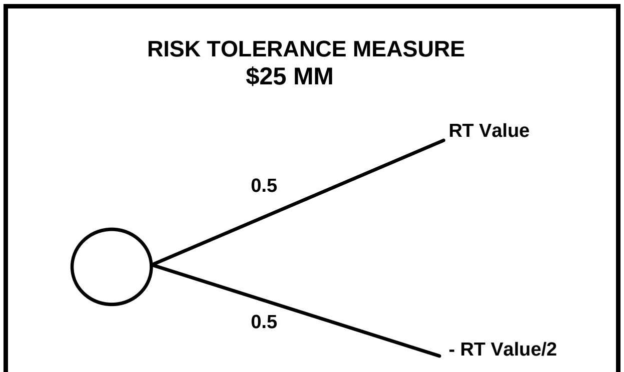
Preference theory is appealing in that it enables the exploration manager to utilize a relatively consistent measure of valuation across a broad range of risky investments. In addition, this approach provides a true measure of the financial expectation foregone when firms act in a risk averse manner. Preference analysis provides a practical way for the firm to formulate and affect a consistent risk policy. This approach provides us a means of mapping the firm's attitude about taking on risky projects in the form of a *utility function*. One functional form of utility which is dominant in both theoretical and applied work in the areas of decision theory and finance is the *exponential* utility function, and is of the form $u(x) = -e^{-x/RT}$, where RT is the *risk tolerance* level, x is the variable of interest, and e is the exponential constant. A value of $RT < \infty$ implies risk averse behavior; as the RT value approaches ∞, risk neutral behavior is implied (expected value decision making).

Understanding the Risk Tolerance (*RT*) Value

In the preference theory approach, the risk tolerance (*RT*) value has a considerable effect on the valuation of a risky project. So at this point it may be useful to provide a definition and some intuition to the term risk tolerance. *By definition, the RT value represents the sum of money such that the decision makers are indifferent as a company investment to a 50-50 chance of winning that sum and losing half of that sum*

Consider that the notion of risk involves both uncertainty and the magnitudes of the dollar values involved. The central issue associated with measuring corporate risk tolerance (*RT*) is one of assessing tradeoffs between potential upside gains versus downside losses. The decision maker's attitude about the magnitude of capital being exposed to the chance of loss is an important component of this analysis. Figure 2 provides some intuition to the *RT* measure, in terms of decisions about risky choices. Consider, for example, that the decision maker is presented three lotteries with a 50-50 chance of winning a certain sum and losing half that sum. The decision to reject Lottery #3 which has an even chance of winning $30MM versus losing $15MM implies that the firm would view this investment as too risky. Conversely, the firm's decision to accept Lottery #1 implies that the risk-return tradeoff associated with this lottery is acceptable, given the firm's risk propensity. This iterative procedure is continued until we identify the lottery such that the firm is *indifferent* between a 50-50 chance of winning a certain sum versus losing half that sum. In our example, that sum is $25MM and represents the risk tolerance of the firm.

Certainty Equivalent Valuation



Lottery	RT Value	- RT Value/2	Decision
#1	$20 MM	- $10 MM	Accept
#2	$25 MM	- $12.5 MM	*Indifferent*
#3	$30 MM	- $15 MM	Reject

Figure 2. The risk tolerance measure, *RT*, represents that sum of money such that the firm is indifferent between a 50-50 chance of winning that sum and losing half that sum.

If we know the firm's utility function, as defined by *RT*, which measures its preferences for uncertain outcomes, we can then compute a risk-adjusted valuation measure for any risky or uncertain investment. This valuation measure is known as the *certainty equivalent*; it is defined as that certain value for an uncertain event which a decision maker is just willing to accept in lieu of the gamble represented by the event. It is, in essence, the "cash value" attributed to a decision alternative which involves uncertain outcomes.

Comparisons between projects are easier because they are made between a probability distribution and a certain quantity. Once the equivalencies have been made, the choice is easy, because higher values (for desirable consequences) are preferred to lower values, which is not always the case with expected value analysis. The certainty equivalent, C_x, is equal to the expected value less a risk discount. The discount, known as the *risk premium*, is the amount of expectation the firm's management is willing to forego in order to reduce their exposure to financial risk. Using the exponential utility function, the discount is determined by the risk tolerance value, *RT*, for the firm and the risk characteristics (probability distribution on outcomes) of the investment opportunity. For discrete probability distributions, Raiffa (1968) has shown the expression for certainty equivalent to be:

$$C_x = -\frac{1}{c}\ln\left(\sum_{i=1}^{n} p_i e^{x_i/RT}\right) \qquad (1)$$

where p_i is the probability of outcome *i*, x_i is the value of outcome *i*, and *ln* is the natural log. For example, in Figure 1 we show that on an expected value basis the firm should be indifferent between Projects A and B. However, on a certainty equivalent basis, where the firm's attitude about financial risk is incorporated, we find one project is preferred to the other. For example, assume a firm with an *RT* value of $100 million, using equation (1) we find that Project A has a certainty equivalent, C_x, of $7.2MM while Project B has a certainty equivalent of $8.1MM. In this case, the firm would prefer Project B over Project A. However, another more risk averse firm with an RT value of $33 million would prefer Project A (C_x = $1.8MM) over Project B. ($C_x$ = $1.4MM). Unlike expected value analysis, the certainty equivalent valuation makes a clear distinction between the "risks" associated with each of these projects. The C_x valuation captures the tradeoffs between potential and uncertain upside gains versus downside losses with respect to the firm's risk propensity. It also provides managers a measure of the amount of expectation they forego by making certain participation choices and represents a major improvement over the ad hoc decision rules often utilized by firms.

Risk-Sharing and Diversification

Unlike expected value analysis, the certainty equivalent valuation provides guidance to the exploration firm in terms of the value of diversification and risk-sharing. Recall that if the expected value (EV) of a project is positive, then the linear EV rule suggests that to maximize EV we should participate at the maximum level that is available. The C_x valuation, however, aids the decision maker in selecting the appropriate level of participation consistent with the firm's risk propensity. This approach provides a formal means to quantify the advantages of selling down or "spreading the risk". For example, Figure 3 shows the certainty equivalent valuation for Projects A and B at different participation levels for a firm with an *RT* value of $25 million. For each Project, A and B, there is an optimum level of participation given the firm's risk attitude; in this case, both projects have an optimum of approximately 40%. Note also that at levels of participation up to 65%, the firm should prefer Project B over Project A since it has a greater certainty equivalent. However, for participation levels greater than 65%, Project A is the dominant alternative. The important implication in this analysis is that the firm has a formal means of measuring the value of diversification. Note, for example, that the certainty equivalent for either project at the optimum participation level (40%) is considerably greater than the sum of the certainty equivalents for both projects at 100% participation. Also note that participation greater than 90% in Project B has a negative certainty equivalent, which implies that this project is too risky for the firm at participation levels greater than 90%.

MEASURING CORPORATE RISK TOLERANCE

The ability to articulate and measure corporate risk preferences is an important part of both the conceptual and practical views of decision making under risk and uncertainty. Previous work (Howard, 1988 & Cozzolino,1977) suggests that there exists a relationship between certain financial measures (*i.e.*, shareholder equity, net income, capital budget size, *etc.*) and the firm's risk tolerance. Howard suggests that we might, at least in certain industries, be able to use financial statements to develop guidelines for the establishment of acceptable risk tolerance levels.

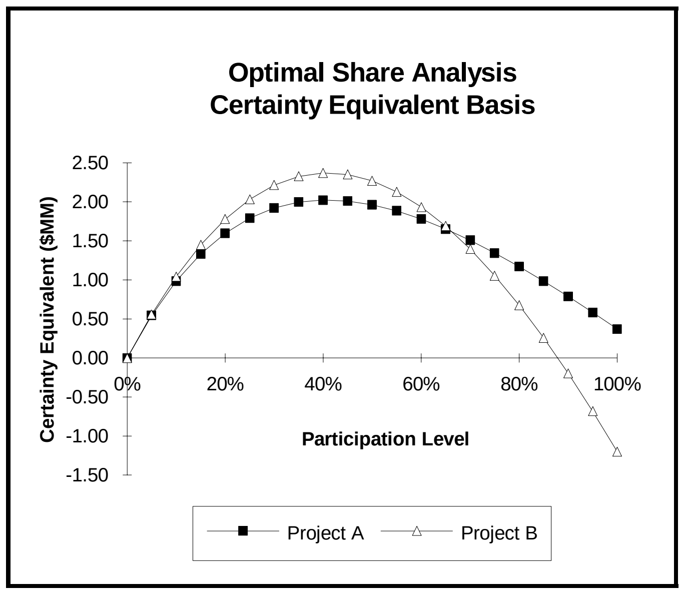


Figure 3. Optimal share analysis on a certainty equivalent basis provides guidance on the appropriate level of diversification. This analysis was based on a firm with a risk aversion coefficient, c, of 0.04 x 10^{-6}

Review of past allocation decisions under conditions of risk and uncertainty provides another means of assessing the firm's risk tolerance level. In a study[24] of an offshore bidding project by a major oil company, it was found that the company analyzed 60 investment opportunities with varying degrees of risk; all 60 investment alternatives had positive expected net present values. Due to capital limitations, the firm elected to bid on only 48 of the 60 blocks and of the 48, elected to retain a 100% interest on only 8 of these. Analysis of this data suggested that the firm's implied risk tolerance value was $33 million for this capital budgeting period. The firm's exploration budget at this time was approximately $200 million.

An empirical study by Walls and Dyer (1992) utilizes a preference theory model in order to measure the implied *RT* values of the top 50 independent and integrated oil companies over the period 1981 to 1990. This model reconstructs each firm's annual exploration budget allocations across a set of risky exploration ventures. Based on the amounts each firm was willing to pay to participate in these risky ventures an implied *RT* value for each firm in each year is estimated. Walls and Dyer found the rather intuitive result that there exists a significant positive relationship between firm size and corporate risk tolerance. In other words, in absolute terms the larger the firm the greater the risk tolerance value. The authors also developed a measure known as the *risk tolerance ratio* (*RTR*) which provides a means of controlling for size when comparing firms' risk propensities. Table 1 shows the risk tolerance ratio (*RTR*), a relative measure of risk tolerance for a sample of oil companies from that study. The motivation for this approach was to identify the appropriate risk tolerance level given a particular exploration firm's size. The study suggests that, in terms of exploration business unit performance, there is an optimal risk policy for a given firm size. This finding has important prescriptive implications for setting corporate risk policy.

RISK TOLERANCE RATIO - E&P DIVISION

	1990	1989	1988	1987	1986	1985	1984
Exxon	0.62	0.37	0.71	0.59	0.73	0.80	0.79
Chevron	0.60	0.73	0.75	0.59	0.65	0.86	0.58
Texaco	0.93	N/A	0.56	0.69	0.72	0.67	0.85
Amoco	0.18	0.35	0.99	0.80	0.46	0.78	1.85
ARCO	1.20	1.03	1.32	1.57	1.93	1.55	1.43
Conoco	3.45	2.59	3.20	3.90	3.42	3.57	3.19
Oryx	1.97	1.34	1.15	1.04	1.16	N/A	N/A
Phillips	1.16	1.24	2.58	2.60	2.03	1.78	1.58
Anadarko	2.04	1.23	1.13	1.31	1.53	1.46	1.88
Kerr-Mc.	1.83	3.09	N/A	1.97	2.26	4.00	0.86

Table 1. Risk Tolerance Ratio (RTR) indicates a firm's relative risk propensity. A firm with an RTR value greater than 1.0 implies a stronger willingness to participate in risky projects than other firms of equivalent size. An RTR less than 1.0 implies a weaker propensity or more cautious risk-taking behavior.

Another method to assess the firm's risk tolerance measure is the industry-specific questionnaire. An example of this questionnaire is shown in Table 2. The decision maker is presented five investment opportunities as part of his annual budgetary considerations. Each of these investments has a value of success and a value of failure which represents the net present value of all future cash flows net of costs; probability is the chance of occurrence of the specific outcome (success or failure). The decision maker, as agent for the firm, has a choice of six discrete participation options ranging from 100% to 0% and is asked to choose the level of participation that would be most preferred by his company. Based on the decision maker's choices for each of the risky investment opportunities, an implied *RT* value is approximated assuming the exponential form of utility.

RISK TOLERANCE WORKSHEET

Proj.	Outcome	Value	Prob.	Choice (circle one) Participation Level (%)					
1	Success	35.0	.50	100	75	50	25	12.5	0
	Failure	-15.0	.50						
2	Success	45.0	.15	100	75	50	25	12.5	0
	Failure	-3.0	.85						
3	Success	22.0	.30	100	75	50	25	12.5	0
	Failure	-4.0	.70						
4	Success	14.0	.80	100	75	50	25	12.5	0
	Failure	-9.5	.20						
5	Success	16.0	.20	100	75	50	25	12.5	0
	Failure	-1.4	.80						

Table 2. In the risk tolerance worksheet, the decision maker selects the working interest preferred by the firm for each of the projects. The worksheet can be modified for any firm given its size and the types of exploration projects typically undertaken. Based on the decision maker's responses, the risk tolerance (RT) level can be estimated.

It is possible to estimate the decision maker's implied *RT* value for each of the projects individually. Based on the decision maker's choice of participation level, Equation (1) is used to solve for the implied *RT* value which generates the highest certainty equivalent (C_x) for that choice. Consider, for example, that in Table 2 the decision maker selects the 50% participation level in Project #2. Table 3 shows a summary of the computed certainty equivalent (C_x) values for five participation choices in Project #2 at selected risk tolerance levels. Note that only at the $25 million *RT* level does the C_x value at the 50% working interest dominate all other participation levels, in terms of the certainty equivalent valuation. Since this was the decision maker's preferred alternative for Project #2 and the preferred alternative must have the highest C_x value, we are able to imply a risk tolerance level consistent with that decision.

General findings from a group of 18 independent and integrated oil companies suggest a "rule of thumb" relating the firm's risk tolerance to the firm's current period exploration budget level. Our findings indicate that as a first approximation, the firm's risk tolerance value is equal to one-fourth of the firm's annual exploration budget. For example, a firm with an exploration budget of $40 million would have an approximate risk tolerance level of $10 million. However, it should be noted that this rule represents only a starting point for assessing a firm's risk tolerance value. It would be easy to imagine two firms with identical

	Project #2 - Certainty Equivalent Valuation ($ Millions)				
RT **$Million**	**100% W.I.**	**75% W.I.**	**50% W.I.**	**25% W.I.**	**12.5% W.I.**
$1000	4.05	3.07	2.06	1.04	0.52
$100.0	2.89	2.39	1.75	0.96	0.50
$50.0	1.86	1.76	1.44	0.88	0.48
$33.3	1.05	1.23	1.17	0.80	0.46
$25.0	0.42	0.79	**0.93**	0.72	0.44
$20.0	-0.07	0.43	0.62	0.65	0.42
$13.3	-0.90	-0.24	0.28	0.49	0.37
$10.0	-1.39	-0.67	-0.03	0.36	0.33
$5.0	-2.19	-1.44	-0.69	-0.02	0.18
$2.5	-2.59	-1.84	-1.09	-0.35	-0.01

Table 3. Certainty equivalent (C_x) analysis for Project #2 at selected *RT* values. The selection of the 50% working interest (W.I.) participation level by the decision maker implies a risk tolerance of $25 million since it is at that risk propensity that the 50% interest dominates all other participation levels in terms of the C_x value.

exploration budgets that may have significantly different risk attitudes. These differences are motivated by any number of factors including exploration philosophy, corporate risk policy, exploration business unit contribution to the overall corporate portfolio, *etc*.

Difficulties Associated with the Risk Preference Approach

Most of the reluctance associated with utilizing the preference theory approach in project valuation centers around two issues. First, corporate applications of decision analysis/preference theory models has an esoteric stigma associated with it. It has been my experience that managers often regard these models as so theoretically complex that they are impractical for day to day decision making at the level of the firm. Efforts to represent these decision models as intuitively appealing, as well as theoretically robust, goes a long way towards increasing the level of acceptance. Moreover, developments in generic decision analysis software, as well as petroleum-specific preference-based software, has enabled decision makers to utilize this decision-science approach without a formal background in decision analysis.

Second, management is generally uncomfortable with the notion of measuring the firm's utility function or risk tolerance level. Firms who have undertaken a risk preference assessment to determine the *RT* value often question whether it is the "right" utility function for their competitive and operating environment. It is interesting to note that even though most decision makers would readily admit that their firm is not risk neutral, they are reluctant to quantify their risk tolerance. Development of more intuitive and workable means of measuring corporate risk preferences, such as those discussed earlier, go a long way in reducing the degree of management's reluctance in this area.

CONCLUSIONS AND IMPLICATIONS

The most commonly used methods of project evaluation, NPV and IRR analysis, are inadequate models for making decisions about risky exploration opportunities. The failure to provide guidance on limiting the firm's downside exposure and the theoretical shortcomings associated with risk-adjusted discount rates lead to inappropriate decisions using either or both of these rules. The critical component ignored in these traditional models is the firm's willingness and ability to participate in risky investments.

Preference theory provides a practical and useful approach to alleviating the shortcomings associated with the expected NPV and IRR methodologies. This approach provides a formal means of measuring the firm's risk tolerance, which can then be utilized consistently in the certainty equivalent valuation. Estimating and utilizing a coherent risk policy is of primary significance to all firms. The approach described can increase management's awareness of risk and risk tolerance, provide insight into the relative financial risks associated with its set of investment opportunities, and provide the company a formal decision model for allocating scarce capital. A well-communicated risk policy, viz-a-vis the *RT* measure, makes it easier for key employees to make appropriate decisions within their realm of responsibility. Well-articulated strategies and systematic models of decision making improve the quality of decisions and provide a solid framework for management's review of firm actions and performance.

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The Author

Michael Walls is an assistant professor in the Division of Econonics and Business at the Colorado School of Mines. Dr. Walls' interests are in the areas of strategic decision making, corporate risk management and business strategy. He holds a B.Sc. in geology, an MBA in finance and a Ph.D. in management from the University of Texas at Austin.