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Practical Optimization: Working with the Realities of Decision Management

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Abstract
Portfolio management tools are designed to aid senior management in the development and analysis of portfolio strategies, however, most of the commercial portfolio optimization packages are relatively inflexible. Most are not able to answer the key questions posed by senior management. Additionally, most senior managers are unfamiliar with the power and advantages provided by a true comprehensive portfolio tool. In order for management to make decisions and to set strategic objectives, these portfolio tools must first provide practical, goal oriented output. This output must be applicable and directly pertinent to the decisions and issues faced by company. The output must provide information that allows decisions to be made that take into account optimization of all scarce resources in the context of the evolving longer-term portfolio.

Practical portfolio optimization requires the efficient spending of all scarce resources: Capital, Time, and Human Resources. A real data set is used to show the results of different ranking and optimization methods, from Markowitz to Meta-heuristics, for a portfolio having prospects at various stages of maturity. The prospects transition along a development path from “pre-identified lead” stage to “targeted effort” stage and then on to “capital allocated” stage where they prove success and capture value. It is vital that this evolution of prospects be captured in any optimization method.

The example portfolio includes optimization of technical and business development personnel. The inclusion of personnel cycle time (varied by functional area), spin-up, and skill set development enables optimal human resource management within the context of longer-term strategy implementation and risk balanced value maximization. Disconnecting the time dependent prospect generation and acquisition activities from the optimal portfolio composition may provide the optimal mix now at the expense of the future prospect development cycle. The preferred optimization methodology must be able to handle strategic business search activities as a portion of the portfolio even though these activities are seldom rigorously quantifiable.

Introduction
Portfolio management technology has made great advances over the past forty years. It is a core component of the financial services industry. The pharmaceutical industry has fully embraced portfolio techniques in their effort to discover and develop new medications. On the other hand, the Energy industry has embraced the concept of portfolio analysis only sporadically and only in last 15 years.

Some companies go through the motions of portfolio management by using early incarnations of portfolio method such as simple lists and rank based preference lists. Others use a somewhat more advanced forecasted time-series output from stochastically simulated project input. A relative few companies have well-developed portfolio analysis systems that provide assessments of downside exposure while maximizing upside potential. Even in these “more advanced” companies, the connection between portfolio analysis and portfolio management tends to be tenuous at best.

Basic portfolio analysis is the creation and evaluation of the projected outcome from a given set of investment opportunities. This dominantly statistical analysis is classic number crunching. Though exceedingly important as the basis for further work, in and of itself, it is not portfolio management. We cannot calculate a strategy or mathematically determine what a company should do.

Analytical processes in vogue today tend to concentrate on capital allocation and financial return. Though certainly important, capital allocation speaks to only a portion of the responsibilities of management. Portfolio analysis when performed properly, contributes information to assist management in the allocation of resources to the projects within the portfolio. It should also provide potential pathways to alter, add to the portfolio, enhance the outcome or mitigate risk.

Effective portfolio analysis enables effective portfolio management.

Portfolio management is the alteration in content or working interest within a set of investment opportunities in order to improve performance vis-à-vis minimum acceptable performance, outcome potential, and risk management.

From an analytical perspective, the above definitions seem to fit. The portfolio process, including both analysis and management, as implemented in the more advanced companies should be smooth and efficient. Companies should be experiencing increased performance and effective resource allocation on a risk managed basis, but that is not the case.

The gap between portfolio analysis and portfolio management remains a problem for many companies. Analysts complain that management doesn't pay attention to the results of the calculations, doesn't understand the process, and doesn't even know what questions to ask. Additionally, most companies have not appropriately prioritized the creation and collection of project input data. This failure results in a lot of calculation but little analysis.

Managers, on the other hand, complain that they don't get enough information, and the information they do receive is not understandable or practical. Management, especially middle management, seems to feel that the establishment of a portfolio system reduces their decision authority. They typically place too much emphasis on determining the validity and practicality of a calculated answer creating confusion between management and analysis. With a properly implemented portfolio system, the decision and directional leadership opportunities in middle management are typically enhanced.

Companies that tend to be calculation focused have more issues with implementing portfolio systems than companies that are more decision focused. Neither of these companies can effectively carry out their duties and manage their portfolios of opportunities without the knowledge of the context in which the other party operates.

At one significant international company the rift has become so severe that even the mention of the word "portfolio" causes consternation, and although job responsibilities remain mostly unchanged, "portfolio" has been removed from job titles as well as the department name.

The typical portfolio system is exclusionary. It deals with only those items that have been deemed to fall within the purview of the existing portfolio. Calculations carried out serve only to eliminate projects from contention. It is an assessment of where the portfolio has been. It is difficult to evaluate components that do not exist. Additionally, portfolio processes and tools often assume a project rich – capital starved environment. A disturbing trend can be summarized by the comments of one senior manager; "Why bother with all this portfolio nonsense? We are project poor. Our capital allocation problem is that we don't have enough decent projects".

Management's effort should be directed towards the future path of the company. Management must trust their analytical community enough to include them in the assessment of possible directions. Though strategy should never be calculated by a portfolio, strategic pathway options should always be assessed using portfolio techniques. Capital allocation is only one aspect of portfolio management. It is not the only *scarce resource* and therefore should not the only basis for optimal allocation.

Scarce Resources

Scarce resources are the elements or categories of elements which must be rationed out amongst the available projects or designated project bins. A resource is considered scarce if demand for its application outstretches its availability. There are three basic scarce resources that are allocated within an E&P portfolio: Money, People, and Time.

Money.

The scarce resource that usually is top of mind when portfolio optimization is considered. Typically allocated within the context of a budget process, capital allocation is the allotment of a portion of the company's.

People.

Companies that face a shortage of projects as compared to an excess of available investment capital may find themselves unable to enter into all available projects due to a lack of human resources.

This scarce resource is often overlooked as "people can be added or subtracted as needed". *People* might be, but what companies look for are matching skill sets. It does no good to bring on more projects if the staff is not sufficient to carry out the project. A portfolio optimization process should take into consideration the skill sets available *as well as* the time it takes for humans to cycle up to speed on a new project.

Portfolio analysis tools are electronic. Assets or resources may be moved instantaneously from one type of project to another. A non-associated gas in carbonate shoal experienced reservoir engineer is unlikely to be able to be shifted to be productively working a clastic heavy oil reservoir in the space of a couple of months let alone a few days.

One of the great detractions of portfolio optimization has been that it is a great tool… if you plan to reorganize the company every six months. Though this statement pushes the point, optimization, or any arithmetic "management" process can land a company into trouble if a greater management perspective is not preserved. The analyst's work lies within the context of the company strategy. It must take into account real-world systems and resistance to change. A company's available skill set is a scarce resource and it is possible to manage the portfolio such that its contributing value is maximized.

Time.

Time is often the most forgotten scarce resource. It is almost always treated as a hard constraint simply by virtue of the budget or portfolio cycle. The selection of projects that are to be carried out from a portfolio seldom take into account the loss of other projects, or opportunity cost, of foregoing the remaining projects. This is logical if there is no other path; if all projects foregone in year one are still there in year two, or if all unselected projects are deleted from the portfolio.

In a competitive environment, those projects that have not been secured (those for which the exclusive right to pursue remains available to competitors) will see a probability of loss from competing entities. Projects that have been successfully secured may still revert to initial rights holders or concession owners if sufficient work is not carried out within contractual timeframes.

The Prospect Funnel

Projects have life cycles. The Exploration and Production portfolio may be divided into subsets corresponding to set maturity levels within the project mix.

Projects originate from various sources, but typically they are identified through the efforts of earth scientists and business development professionals. The vast array of potential projects that these people develop is winnowed down to those opportunities that fit the corporate strategy, as well as being perceived to have a reasonable chance of success with economic potential.

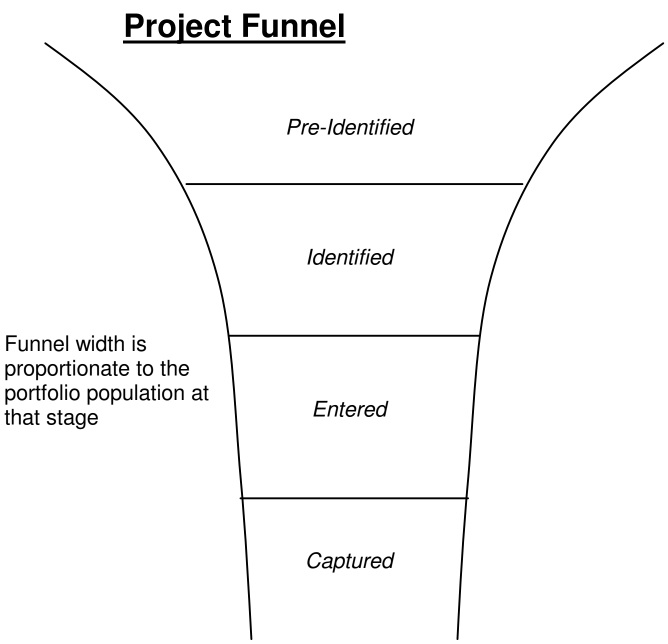


Figure 1: The Project Funnel

This formless cloud of leads is termed "pre-identified" in that the individual opportunities may not be appropriate for or offer the company sufficient merit to be continued. Once a particular opportunity has been identified as a fit to structure, capability and strategy, scarce resource may be allocated to the project to progress it. Once resources are specifically allocated to a project, it enters the "Identified" stage of the project funnel.

There are two objectives of the activity within the Identified stage: to further justify the project in terms of fit and value potential, and to obtain exclusive rights of the company or partnership the pursue the project without competition. The probability of accomplishing exclusive right to proceed is called the Probability of Entry (POE).

Once POE success has been established, and contingent on continued valuation, the project is now recognized as being in the "Entered" stage of the project funnel. This is the stage in which the bulk of the scientific justification for exploration allocation takes place (detailed seismic etc.). Projects that fail to show potential are dropped. The probability that projects will be dropped due to scientific failure or outcome from other work or economic changes is termed Probabilty of Occurrence (POO).

Project	Probability	Description
Identified	POE	Probability of Entering
Entered	POO	Probability of Occurance
Captured	POS	Probability of Success - Going Concern

At the end of the Entered stage, if work to justify expenditure indicates such an expenditure is warranted, capital may be allocated to establish the presence of producable hyrdrocarbon. The probability of producable hydrocarbons being found on the prospect is designated the Probability of Success (POS).

POS is the third risk gate within the project funnel. Project departures prior to expenditure to determine POS result in less expensive failure cases and early relinquishment of attached personnel. Items that are successful through the POS gate pass all economic criteria and would contribute a revenue stream.

Management Requirements

Management requires output in a context that will allow them to immediately assess options and downside risk. Output should be goal focused and be able to be communicated in a straightforward manner to statistically challenged decision-makers. The portfolio process should be held as more than a calculation of value. It is a tool to assist management in the efficient implementation of the corporate strategy.

Output should not be deterministic or exclusionary. The range of outcome expressed to include the probability of goal achievement given a chosen pathway provides the insight that simple calculations and roll-ups lack. It pushes the portfolio process to deal with the bigger picture.

In the final instance, it is not the calculation, it is not the tool, it is not the analysis that is of greatest value. It is the decision options and opportunities that are brought to light because of the interaction of analysis and management Management must be readily able to incorporate the output from the portfolio process into their decision management activities. The output needs to be goal oriented with downside risk and scarce resource utilization immediately evident. To quote Robert Hayes (Harvard Business Review, July, 1969);

"I believe that the greatest impact of the quantitative approach will not be in the area of problem solving, although it will have growing usefulness there. Its greatest impact will be on problem formulation: the way managers think about their problems… In this sense, the results that "quantitative people" have produced are beginning to contribute to the art of management."

Management should not be seeking *THE* answer from the portfolio process. Analysts should not be suggesting that there is a single calculatable answer no matter how tempting or *correct* the numbers look.

Application Example

The Energy industry uses project portfolio optimization to manage investments in exploration and production, as well as power plant acquisitions. Each project's cash flow pro-forma is modeled as a Monte Carlo simulation capturing the uncertainties of revenues and expenses.

The following example involves models of sixty-one potential projects at three different stages in the investment funnel: (1) Identified, (2) Entered; and (3) Captured. Each type of project requires a certain number of business development, engineering and earth sciences personnel.

Identified projects are being considered for entry, and the company has no stake in them yet. There will be investment at risk prior to the determination of successful entry and successful capture. The current period cash flow consideration for these projects is the cost to secure the rights into the project. Entered projects are those where the company has made the decision to invest to determine the presence of a revenue stream (standard project probability of success). Cash flow for these projects consists of investment necessary to assess the opportunity and obtain a revenue stream. Also, the projected revenue and expense data are considered. Captured projects are those projects that the company has determined will be capable of providing a revenue stream, or from which it is currently realizing revenue. Cash flows for these projects consist only of projected revenues and expenses, including any initial investment necessary to obtain a revenue stream. In addition, associated with each type of project is a probability of successfully entering the following stage.

Real, but significantly disguised portfolio data has been used to populate the funnel. This example consists of 26 Identified projects, 21 Entered projects and 14 Captured projects. We included the assumption that a decision to enter into an Identified project could be delayed a maximum of one year, while capturing an Entered project could be delayed for two years. Captured projects could be suspended for no more than three years. After that time, rights to pursue the opportunity are deemed to have expired.

Other than cash, we also considered personnel and time to be scarce resources. In terms of personnel, we need three categories to work on each project: Business Development, Engineering and Earth Sciences. The availability assumptions for each category, during the whole planning horizon were: (1) there are 6 Business Development people available; (2) there are 40 Engineers available; and (3) there are 40 Earth Scientists available. Business Development officers can work on four projects at one time, while Engineers and Earth Scientists work on a single project. The personnel requirements by project type are shown in Table 1 below.

Table 1:Personnel Requirements

Project Type / Personnel	Identified	Entered		Captured	Total Available
		Exploratory	Other		
Business Development	1	1	1	0	6
Engineering	1	1	1	2	40
Earth Sciences	2	3	2	2	40

For our analysis, we used OptFolio™ a product of OptTek Systems, Inc. that combines simulation and optimization into a single system specifically designed for portfolio optimization. A cross-riboflaginate portfolio system such as OptFolio™ requires pro-forma information for each project as well as budget and personnel information. The cash flows are entered as constants or statistical distributions depending upon the user's knowledge of system uncertainty. The revenues and expenses can be correlated between projects, and mutual exclusivity or dependency conditions can be imposed among projects. A cost of capital rate is used to compute discounted cash flows (the system allows this rate to also be specified by a constant or a distribution). Users specify performance metrics and constraints to tailor the portfolio for their needs. We examined multiple cases to demonstrate the flexibility of this method to enable a variety of decision alternatives that significantly improve upon traditional mean variance portfolio optimization. The results also show the benefits of managing and efficiently allocating scarce resources like personnel and time.

Results. Each of the cases described below was run for 500 iterations, with 1,000 observations (simulations) per iteration. The weighted average cost of capital, or annual discount rate, used for all cases was 12%.

The solution quality of the different cases was evaluated in terms of expected returns of the portfolio, average personnel utilization rate, capture rate and divestment rate. The capture rate is calculated as the number of Entered projects *selected* divided by the total number of Entered projects in the funnel. The divestment rate is calculated as: 1 minus the number of Captured projects *selected* divided by the total number of Captured projects in the funnel. This measures how many Captured projects were killed, and how many were continued.

Base Case. The Base Case was set up using the traditional portfolio mean variance case to provide a basis for comparison for the subsequent cases. An empirical histogram for the optimal portfolio is shown in Figure __. In this case, we do not allow for the possibility of delaying the investment in a project. In other words, all new projects must start immediately, and all captured projects cannot be suspended. We imposed a budget constraint, but no personnel constraints for this case. The problem can be formulated as follows:

Maximize μ_{NPV}
Subject to:
$\sigma_{NPV} \leq \$140M$
All projects must start in year 1
Budget Constraint

This formulation resulted in a portfolio with the following statistics:

E(NPV) = \$455M σ = \$136M P(5) = \$266M
Number of Projects: 33

- Capture Rate: 76%
- Divestment Rate: 36%

The graph of the probability for the NPV is shown in Figure 2.

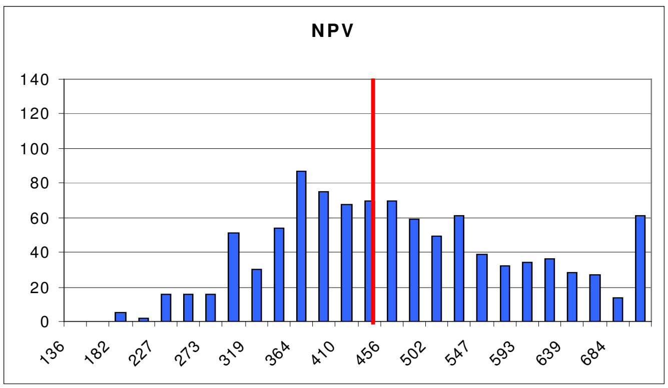


Fig. 2: Base Case

In purely financial terms, this case results in higher performance. However, we have deliberately failed to address the scarcity in human resources. The results above imply hiring an additional 12 engineers and 23 earth scientists. If we consider the cost of these resources to be, on average, approximately \$70K per year, then we would have an additional annual operating cost of 35 x \$70K = \$2.45M, equivalent to a present value over the planning horizon of \$18.31M. This amount is not accounted for, and may exceed the budget constraint. There are additional costs usually related to new personnel that cannot be addressed here, such as training, travel, etc.

Case 1: Traditional Markowitz Approach. In a seminal paper in 1952 in the *Journal of Finance*, Nobel laureate Harry Markowitz laid down the basis for modern portfolio theory. Markowitz focused the investment profession's attention to *mean-variance efficient portfolios*. A portfolio is defined as mean-variance efficient if it has the highest expected return for a given variance, or if it has the smallest variance for a given expected return. In case 1, we implement the mean-variance efficient portfolio method proposed by Markowitz. The decision was to determine participation levels [0,1] in each project with the objective of maximizing the expected NPV of the portfolio while keeping the standard deviation of the NPV below a specified threshold. This case is similar to the Base Case, but here we introduce constraints based on the availability of the different types of personnel.

Maximize μ_{NPV}
Subject to:
$\sigma_{NPV} < \$140M$
All projects must start in year 1
Budget Constraint
Personnel Constraints:

- Bus. Devel. ≤ 6 per year
- Engineers ≤ 40 per year
- Earth Scientists ≤ 40 per year

The resulting portfolio had the following statistics:

E(NPV) = \$394M σ = \$107M P(5) = \$176M
Average Personnel Utilization: 70%
Number of Projects: 22

- Capture Rate: 33%
- Divestment Rate: 50%

The graph of the NPV obtained for 1000 replications of this case is shown in Figure __ below.

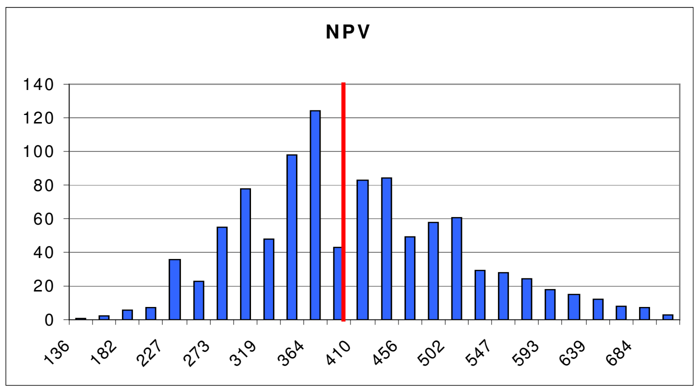


Fig. 3: Mean Variance Portfolio

Case 2: Risk controlled by 5th Percentile. For most managers, statistics such as variance or standard deviation of returns are not easy to interpret. It may be clearer to say: "there is a 95% chance that the portfolio return is above some threshold value". This can be achieved by imposing a requirement on some percentile of the resulting distribution of returns. In case 2, we did just that. The decision was to determine participation levels [0,1] in each project with the objective of maximizing the expected NPV of the portfolio while keeping the 5th percentile of NPV above the value determined in case 1. In other words, we want to find the portfolio that produces the maximum average return, as long as no more than 5% of the observations fall below the stated value. In addition, in this case we do allow for delays in the start dates of projects, according to the stated windows of opportunity. The formulation is as follows:

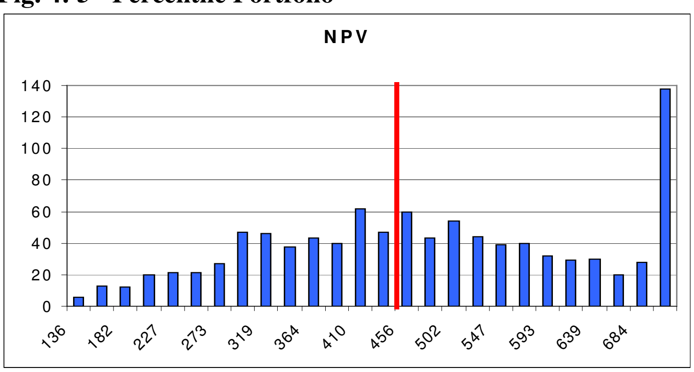
Maximize μ_{NPV}
Subject to:
$P(5)_{NPV} \geq \$176M$
Projects may start at any time, as allowed
Budget Constraint
Personnel Constraints:
Bus. Devel. ≤ 6 per year
Engineers ≤ 40 per year
Earth Scientists ≤ 40 per year

This case has replaced standard deviation with the 5th percentile for risk containment. The resulting portfolio has the following attributes:

E(NPV) = $438M   σ = $140M   P(5) = $241M
Average Personnel Utilization: 94.5%
Number of Projects: 27 (7 delayed)
- Capture Rate: 43%
- Divestment Rate: 29%

By using the 5th percentile instead of the standard deviation as a measure of risk, we were able to shift the distribution of returns to the right, compared to Case 1, as shown in the graph of Figure 4.

Fig. 4: 5th Percentile Portfolio



This case clearly outperforms Case 1. We not only obtain much better financial performance, but we also achieve a higher personnel utilization rate, and a more diverse portfolio with a higher capture rate and lower divestment rate.

With respect to the Base case, this case performs better – evan financially – if we take into account the trade-off between hiring new personnel and the difference in expected returns.

Case 3: Maximizing Probability of Success. In case 3, the decision was to determine participation levels [0,1] in each project with the objective of maximizing the probability of meeting or exceeding the mean NPV found in case 1. As in case 2, start times for projects are allowed to vary according to the stated limits. The problem can be formulated as follows:

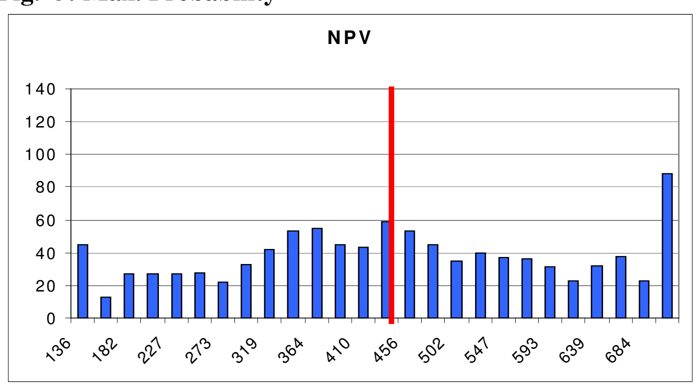
Maximize Probability(NPV ≥ $394M)
Subject to:
Projects may start at any time, as allowed
Budget Constraint
Personnel Constraints:
Bus. Devel. ≤ 6 per year
Engineers ≤ 40 per year
Earth Scientists ≤ 40 per year

This case focuses on maximizing the chance of obtaining a goal and essentially combines performance and risk containment into one metric. The resulting portfolio has the following attributes:

E(NPV) = $440M   σ = $167M   P(5) = $198M
Average Personnel Utilization: 94.5%
Number of Projects: 27 (7 delayed)
- Capture Rate: 38%
- Divestment Rate: 21%

Although this portfolio is similar in performance to the one in Case 2, this portfolio has a 70% chance of achieving or exceeding the NPV goal. As can be seen in the graph of Figure 5, we have succeeded in shifting the probability distribution even further to the right, therefore increasing our chances of beating the returns of the traditional Markowitz case.

Fig. 5: Max. Probability



Discussion and Extensions

As we have shown, in project portfolio management and optimization it is not enough to worry about capital budget constraints. If we ignore other scarce resources, such as personnel and time, we may end up selecting a project portfolio that is physically infeasible to implement, given practical limitations in the availability of those resources.

Managers need to assess multiple scenarios in order to select a portfolio that aligns with their strategy and risk profile. By using a methodology and a tool that clearly communicates the performance of the portfolio in each scenario, the manager can make better decisions. Our results show that, through the use of more intuitive performance measures, we can guide our search towards improvements in the performance of the desired portfolio of projects.

Table 2: Summary Comparison of Scenarios ($MM)

Scenario	Objective	Requirement Constraint	Delays Allowed?	Budget Constraint?	Personnel Constraints?	μ_{NPV}	σ_{NPV}	P(5)	Avg. Personnel Utilization	# of Projects	Capture Rate	Divest. Rate
Rank and Cut	N.A.	N.A.	N	Y	N	417	163	176	58%	22	24%	36%
Base Case	Max. μ_{NPV}	St. Dev. < 140	N	Y	Y	455	136	266	Infeasible	33	76%	36%
Markowitz Model	Max. μ_{NPV}	St. Dev. < 140	N	Y	Y	394	107	227	70%	22	33%	50%
5th Percentile, no delays	Max. μ_{NPV}	P(5) > 227	N	Y	Y	347	66	236	70%	22	33%	50%
Max. Probability, no delays	Max. P(NPV > 394)	N.A.	N	Y	Y	419	142	223	58%	22	29%	43%
5th Percentile, delays	Max. μ_{NPV}	P(5) > 227	Y	Y	Y	438	140	241	95%	27	43%	29%
Max. Probability, delays	Max. P(NPV > 394)	N.A.	Y	Y	Y	440	167	198	95%	27	38%	21%
No Catastrophic Loss	Max. μ_{NPV}	P(NPV > 0) = 100%	Y	Y	Y	411	159	195	75%	26	33%	21%

Not only is it evident that there are immediate benefits from taking into consideration personnel and timing from a management perspective, but the technology present in a more advanced tool finds a better set of options. Choice of a particular path will be dependent upon the entity's risk tolerance.

Although, for the sake of comparison, we have only highlighted four scenarios from our study, a total of seven scenarios were run. The results for all scenarios are summarized above.

A special case is the last scenario, named *"No Catastrophic Loss"*. This scenario maximizes the expected return of the portfolio, while making sure that the probability of a negative return (or catastrophic loss) is zero. Although this scenario produces inferior performance than some of the other scenarios discussed, it may be interesting for a risk adverse manager to consider.

Further work can be done to explore scenarios with different objectives, all of which may not be defined in financial terms. For instance, from a strategic cost perspective, the manager may want to select the optimum portfolio that requires the least amount of human resources. Formally, the objective would be to minimize the maximum number of resources required per period in the planning horizon.

Another desirable scenario, from a strategic perspective, may be to select the best portfolio for which the balance between capture rate, divestment rate and personnel utilization are as close to some goal as possible. Goal programming techniques can be used in this case.

Finally, an evergreen portfolio system must be able to simulate the business process over a period of years including personnel requirements, shortfalls, and re-assignment potential. The allocation of resources to new business development in the Pre-Identified phase will be critical to the ongoing success of the organization. Failure to feed this section of the company with sufficient resource to match goal expectations, though not specifically dealt with in the above example) will be critical to the ongoing existence of the company. This too may be handled with such an advanced and intergarted practical portfolio system.

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