Evaluating Options to Choose Among the Most Profitable of Several States in the Physical Realm and the Information Realm

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Abstract

Option models have provided insight into the value of flexibility to switch from one state to another (such as switching a mine or refinery from operating to closed status). More complex flexible processes offer multiple possibilities for switching states. A fabrication facility, for example, may offer options to shift from the current status to any of several alternatives (reflecting reconfiguration of basic facilities to accommodate different operating processes with different outputs). New algorithms enable practical application of complex option pricing models to flexible facilities, improving analysts' ability to draw sound conclusions about the effects of flexibility and innovativeness on share value. Careful attention to estimating the matrix of correlations among the values of potential alternative states allows explicit integration of financial analysis and strategic analysis—especially the influence of substitutes and the anticipated reactions of competitors, suppliers, and potential new entrants. [JEL: G31, G13]

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1. Introduction

One of the problems challenging decision makers today is deciding how much to spend for fabrication facilities that offer flexibility to switch among several operational states.[1] In this paper we apply option-pricing methods to evaluating investments in facilities that readily can be reconfigured to support the most valuable choice among several processes that produce different outputs (or utilize different inputs to produce a given output).

Previous work has addressed the classic problem of flexible manufacturing facilities that operate in batch mode and can switch on very short notice among many different output goods, even offering choices to use the least expensive among several different inputs (for example, classic flexible fabrication cells such as computer-controlled machine tools can convert a generic input, such as a cube of steel, into any of a variety of different machined parts).[2] The problem addressed in this paper is substantially different. Here we are dealing with facilities that operate in process mode. Thus they do not offer the extreme flexibility of batch mode, yet still provide significantly greater value than simple facilities that are specialized for a single process. Option pricing models offer a tractable application that can greatly illuminate the analysis of investments in process-oriented flexible facilities.

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[1]See Triantis and Hodder (1990), Avishai (1989) and Kaplan (1986).

[2] See Chen, Conover, and Kensinger (1998).

Kaplan (1986) addresses the problems of analyzing investments in flexible facilities using discounted cash flow (DCF) analysis, noting the difficulty in estimating how much the inherent flexibility of such a system adds to its value. The multiple exchange option approach, however, could significantly reduce the degree to which the analysis of such investments must be left to qualitative considerations.

Triantis and Hodder (1990) define flexible production systems broadly enough to include refineries, chemical plants, and a range of flexible manufacturing system (FMS) installations. Inputs may be varied, too, as in the case of beverage-can-making equipment that can work with either steel or aluminum, whichever is cheaper. Over its economic life such a system normally operates in several different configurations, and its worth in each state is the value it adds to the economy by accomplishing resource conversion. In no rational case, however, would the operation be sustained if negative value would result.

The value of the facility at a given time includes its value over its remaining economic life in the current configuration, plus the value of the option to switch into any of *m* different configurations. The option to switch would be exercised when the value in a different configuration (plus the associated switching option in that state) exceeds the current value plus the cost of switching. The array of possible choices includes, but is definitely not restricted to, shutting down temporarily. Thus the valuation problem covers the following points:

- There are options to choose the most profitable from an array of choices available at the moment.

- There are options to shut down temporarily when no profitable activity is available. This issue has been examined by McDonald and Siegel (1985) oil refineries and other facilities that can switch back and forth between two states (operating or closed). Here we extend the problem to multiple states.
- There are options to add new products to the repertoire by developing or purchasing additional capabilities that can be supported by existing facilities. This is analogous to the growth options analyzed by Majd and Pindyck (1987).

The standard discounted cash flow (DCF) investment analysis tools ignore the value of flexibility. Instead, one who uses the standard tools treats the project as a "black box" that will somehow produce a stream of future cash flows without human guidance in response to future changes in the environment.[3] It is simply assumed that the project will be launched and then left on its own.

The first applications of option pricing theory to the valuation of real options were aimed at valuing the option to abandon a project entirely and liquidate its assets.[4] Then, applications were developed for valuing natural resource investments such as mines and oil leases. Such projects can be viewed as options to buy basic commodities.[5] Next, options to exchange one product for another have been applied to gain insight into the value of flexible production systems.[6]

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[3]Richard Brealey and Stewart Myers discuss this shortcoming extensively in Chapter 10 of their book, *Principles of Corporate Finance* (5th Edition), McGraw-Hill, 1996.

[4]See Kensinger (1980) and Myers & Majd (1983).

[5]See Brennan & Schwarz (1985) and Siegel, Smith, & Paddock (1987).

[6]See Kensinger (1987), Triantis & Hodder (1990), and Chen, Conover, and Kensinger (1998).

In Section 2 we extend the existing techniques to a discussion of options to switch from the current configuration to the most valuable of several alternative states. We discuss this in terms of Margrabe's (1982) generic model, which is broad enough to include a variety of probability distributions for generating prices. Then we discuss implementation using the Boyle-Tse (1990) algorithm for solving the Johnson (1987) multiple exchange option model. This extends beyond the previous work to gain insights into the value of flexibility in process-oriented facilities.Developing methodologies for valuing real options is important in making progress toward integrating finance theory with the concepts of business strategy. In Section 3, we address issues of corporate strategy that arise in the analysis of flexible fabrication facilities. Also, some potential applications of option pricing models are anticipated in other areas besides flexible manufacturing:[7]

- Valuing options for future growth that might arise from current activities.
- Valuing the act of contingency planning, in the sense that the object of such planning is to create and manage a portfolio of strategic "real options."
- Valuing options to redeploy assets to new uses as the business environment changes.

2. The Option to Switch Among Multiple States

2.1. The Generic Model

In order to analyze flexible facilities that can support any of several processes, let us specify the case of multiple alternatives ($ALT_1, \dots, ALT_n$) that could be substituted for the current state (*CURRENT*). Then the value of the facility equals the value over its

[7]See, for example, Myers (1984) and Trigeorgis & Mason (1985).

economic life in the current state, plus the value of the options to switch. We will consider two different scenarios.

In the simplest scenario the costs of switching are different for each of the alternative states. Then there is a portfolio of options to switch between the current state and a single alternative (with *n* alternatives, there are *n* options with different exercise costs). This is a special case of the more general scenario that follows.

In the second scenario the cost of switching at any given time is the same for multiple alternatives. Then the switching option has multiple underlying assets. In the least complex case there may be just one such option covering all possible alternative configurations. In more complex situations there may be two or more switching options representing alternatives that incur different switching costs for different groupings of alternative configurations. The payoff from exercising an option to switch from the current state to the most valuable of *m* alternatives can be represented by the following expression:

$$Payoff = Max\,\{Max\,[ALT_1, \ldots, ALT_m] - Switching\ Cost,\ 0\} \tag{1}$$

That is, when the decision is made about how to configure the facility the alterative with maximum value will be chosen; and the payoff will be the difference between the value of that alternative and the cost of switching. Switching would occur only if the payoff from exercising a switching option exceeds the value of remaining in the current state.

The value of a switching option at any time prior to the expiration date can be solved numerically, using techniques developed by Margrabe (1982). This scenario can be represented more compactly by supposing that the current values at time *t* for the various alternatives form a vector, $x = [x_1,\ldots, x_n]$, the prices at future time T form a vector $X = [X_1,\ldots, X_N]$, and $q(\ldots)$ is a multivariate p.d.f. for the vector X, given the initial set of current prices at time zero (the vector x.). The payoff for switching to an alternative configuration can be represented by some function $f(X)$..[8] This function could be simple or quite complex. The interest rate is r for US Treasury securities maturing at time T. Then, the value of an option to accomplish the optimal transformation is given by the following:

$$Option\ Value = e^{-r(T-t)} \int \cdots \int f(X)\, q(X,T|x)\, dx \tag{2}$$

where integration is over the n- dimensional array of future values for all of the alternative configurations. Margrabe proved this solution for the case of a log-Gaussian p.d.f.—showing that the richer the array of choices, the higher the NPV of the project.

By including divestiture as one of the alternatives in the portfolio of options representing a project, it is possible to incorporate project abandonment into the analysis. In earlier work on project abandonment, the abandonment option was treated as a put, and its value was added to the present value of expected cash flows. By incorporating the abandonment option as one of n alternatives, all options, a clearer picture of the project's value can be developed.

2.2. Implementing the Model Using the Boyle and Tse Algorithm

Johnson's (1987) model calculates the exact value of a call option with exercise price X and time to maturity T, on the maximum of N assets with current values $S_1, S_2,\ldots, S_n$. Computing the exact solution requires numerically evaluating $N+1$ N-dimensional

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[8]For example, $f(X) = Max(0, X_2 - X_1)$.

standard normal distribution functions. This is practical for N <6 on personal computers using the Schervish (1985) algorithm. Solving with N =6 is practical only on minicomputers and mainframes, while N >6 is practical only on super computers.

We have implemented the multiple exchange option framework using the Boyle-Tse (1990) algorithm for evaluating an option on the maximum or minimum of several assets. This algorithm has overcome earlier criticism that realistic problems could not be solved without consuming large amounts of computer time (the program is available from the authors upon request). We are able to solve problems with up to 1,000 different output goods at high speed on a personal computer, and have solved problems with up to 9,000 output goods in about 30 seconds on a desktop workstation.

The Boyle/Tse (1990) formulation can be applied to a wide range of problems that once were too costly (or impossible) to evaluate. Detailed description of the steps is too lengthy for this paper, but the authors will mail a copy of the computer code to readers upon request. What follows is a description of the principle steps of the algorithm. First, the N assets are assumed to be jointly multivariate normal. Direct evaluation of the multivariate normal distribution function is very costly for N >6, but the maximum of two bivariate normally-distributed assets is well defined. The algorithm uses a recursive technique that successively compares N assets, taken two at a time. Let us begin by assuming that $MAX(x_1, x_2)$ is normally distributed. Given this assumption, the expected value, variance, and covariance of $MAX(x_1, x_2, x_3)$ can be approximated using the recursive relationship:

$$MAX(x_1, x_2, x_3) = MAX\left(MAX(x_1, x_2), x_3\right) \tag{3}$$

Then, the first four moments of the maximum of the first three assets with the fourth are calculated using:

$$MAX(x_1, x_2, x_3, x_4) = MAX(MAX(x_1, x_2, x_3), x_4) \tag{4}$$

Repeatedly applying this procedure to the remainder of *N* variables (using the current cumulative maximum value at each step) allows approximation of the distribution of the maximum of *N* jointly random normal variables.

Zero strike options on lognormally-distributed assets are examined by discounting (under risk neutrality) the expected value of the log of the maximum of *N* asset prices. For non-zero strike prices the procedure estimates the probability that the maximum of *N* assets will exceed the strike price of the option. First, the recursive algorithm described above is used to calculate the first four central moments of $MAX[x_1, x_2, \ldots, x_N]$. The second step is to form a Taylor series expansion of the option pricing problem using the standardization transform in terms of the first four central moments of the maximum of *N* jointly multivariate normals from the first step. A Gram-Charlier expansion of the Taylor-series is solved to calcualte the probability that $MAX[x_1, x_2, \ldots, x_N]$ will be greater than the exercise price.

The algorithm described in Boyle/Tse (1990) is an accurate approximation that is fast enough to run on a personal computer. For *N* up to 50 assets, the approximation error is as low as 0.06 percent. The algorithm has four appealing characteristics:

- It requires only the evaluation of univariate normal distributions that are simple and inexpensive to perform.
- The algorithm runs very quickly compared to its only competitor, which is repeated simulation sampling.

- The algorithm is very accurate over a wide range of the parameters.

- The model predictions can be checked against independent estimates of the model prices from Monte Carlo sampling of multivariate distribution functions or direct evaluation of the distribution functions.

In simulation trials to evaluate how value responds to increasing flexibility, we found results similar to those observed in diversified portfolios of securities. At first, additional alternatives add substantially to value, but after twelve to fifteen alternatives are already available, more new alternatives add very little additional value.

2.3 Estimating the Covariance Matrix

In the Johnson model, and the Boyle and Tse implementation, each of the *n* asset prices, *n* standard deviations and the *nxn* correlation matrix of each asset with the other assets must be specified. The model is very sensitive to any errors that might occur in estimating the covariance matrix.

Option models that capture the value of a simple option on a single asset, such as Black-Scholes (1973), specify the underlying stochastic process generating returns on the asset simply in terms of the asset's total variability (including both systematic and unsystematic risk combined into one measure). Options to exchange one asset for another, such as Margrabe (1978), specify the underlying stochastic process in terms of the ratio of the prices of the two assets (thus the covariance of the two assets enters the calculation). Multiple exchange options are much more complex and demand careful estimation of the parameters input into the model. In well-functioning financial markets, asset prices move together when the assets are close substitutes (otherwise there would be arbitrage opportunities). This characteristic is captured in a carefully-estimated covariance matrix, or in a diagonal-model approximation such as the capital asset pricing model in which variability is partitioned into systematic and unsystematic components.

In order to successfully apply the financial markets model to the real options involved in flexible production facilities, it is necessary to insure that the variance-covariance matrix adequately captures the webwork of interrelationships among the values for the alternative configurations. We discovered during simulation trials of the Boyle/Tse algorithm that the result is very sensitive to any lapses in this regard, rapidly converging toward undefined high values if the systematic linkage is inadequately captured. The intuition behind this problem is fairly clear. Without explicit linkage, as the number of alternatives increases, there is an increasing probability that at least one of them will rise to a high price.

In reality, economic forces of supply and demand would prevent the value of any one of the alternatives from rising well beyond the others. One of the possible output goods might rise substantially over a short time, but producers would increase their output of it, while reducing output of the others. Price adjustments would follow, so that the whole group of related goods would remain clustered (although relative prices would be free to fluctuate substantially within the bounds of the cluster). We have resolved this problem by defining the underlying stochastic processes using a linear model similar to the Capital Asset Pricing Model, in which the are two components defining variability: one component affects all the goods in the matrix, while the other component represents the unique shocks specific to the individual assets. Besides facilitating the analysis of flexible manufacturing facilities, solving this problem significantly extends the work of Triantis and Hodder (1990).

The values the analyst must estimate, then, are the annualized standard deviations of the values of the alternatives, current values of the alternatives, and the correlation matrix of values. No forecasting of future prices is necessary (such forecasts, in contrast, are the essence of discounted cash flow analysis).

Maintaining consistency in the estimates that become inputs into the model, and insuring appropriate structure of the correlation matrix, can to a significant extent be made a function of the software used to incorporate the exchange option models into a decision-support system. Programmers will find interesting opportunities to provide expert assistants that will quiz users, prompting them to think clearly through the underlying strategic issues.

3. Ways in Which the Exchange Option Approach Integrates Finance and Strategy

The care necessary in estimating the covariance matrix actually offers a significant advantage over discounted cash flow techniques, that may not be immediately evident. When done carefully, the estimation process described above involves explicit consideration of several strategic issues, including the following:

- While considering the movement of the values of the various alternatives, the analyst must evaluate potential reactions of competitors, and the influence of substitutes.
- While considering the movement of the values of the various alternatives, the analyst must evaluate potential reactions of suppliers.
- While considering the potential for sustained profitability, the analyst must consider the reactions of potential new entrants that could impact the value of one or more of the alternatives.

In addition to the strategic considerations captured in the process of estimating the covariance matrix, there are several other ways in which the exchange option approach integrates financial analysis with strategic analysis. Let's begin with the end-of-period payoff given above in Equation 1 and reproduced below as Equation 5.

$$Payoff = Max\ \{Max\ [ALT_1, \ldots, ALT_m] - Switching\ Cost,\ 0\} \tag{5}$$

It can be shown that this dominates an option that includes a smaller set of alternatives, such as one with the following payoff:

$$Payoff = Max\ \{Max\ [ALT_1, \ldots, ALT_{m-1}] - Switching\ Cost,\ 0\} \tag{5}$$

To demonstrate this point, we compare an option which includes two alternatives with another that includes those same alternatives plus one more, and find that the three-alternative option is worth more because its payoff would be greater in those states of the world in which $ALT_3 > Switching\ Cost - CURRENT$, $ALT_3 > ALT_2$, and $ALT_3 > ALT_1$. Therefore, we can state the following:

> *A company that has the same potential uses for a system as another company, plus one or more additional possible use unique to that company, will gain a higher NPV by purchasing the system. Thus, the NPV of a project may differ from one company to another, and companies with more flexibility have an advantage in generating positive net present value.*

A well-known property of such options, whether or not the p.d.f. is log-Gaussian, is that prior to expiration they are worth more than the present value of the spread expected at expiration (expected value of alternative minus expected cost of switching). Therefore, the option approach supports the following point:

The discounted cash flow NPV, using expected cash flows from the most likely state of operation, represents only the lower bound of the project's true NPV. The true NPV may be significantly higher.

That is, some projects which appear to have a negative NPV when analyzed by traditional DCF methods may actually have a positive NPV.[9] This point is illustrated in the next numerical example. There is sound intuition behind it. With active management throughout the system's life, the choice can be made to shut down in any period when there would be an operating loss and switching is not attractive. With the values of the alternative states fluctuating at random, the spread between them is free to widen as well as shrink. The existence of discretion allows management to take whatever profit opportunities arise when the spread is wide, but cut off losses that would occur when the spread becomes negative. The more volatile the spread, the greater are the possible profits. Since losses are limited, however, the increased upside potential is not offset on the downside. The model therefore supports another point:

The more volatile the relationship between the values of alternative states, the greater the difference between the true project NPV and the discounted cash flow NPV.

The more volatile each state's value, and the lower the correlation between their values, the more volatile the spread. Therefore, the highest NPVs are to be found in the case of systems which can switch from one volatile state into another volatile one, for alternatives whose values have low correlation. If there were a great many companies operating such systems, competition among them would tend to keep the spread from

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[9]Stulz (1982) makes the same point for his scenario, also.

fluctuating widely, and values of alternative states would be highly correlated. A low correlation would be associated with a situation in which competition is not intense. As the capability diffused throughout the economy, however, the advantage dissipated. Therefore, the model supports another point:

> *The difference between the true project NPV and the discounted cash flow NPV is greater the more innovative the project, and the stronger the barriers to entry for potential competitors.*

This statement is very similar to the lessons derived from a qualitative analysis of anecdotal evidence by Shapiro (1986) and Porter (1985). The process of estimating the matrix of correlations, therefore, entails a quantification of the industry structure. This dimension is not made explicit in the DCF approach.

The exchange option approach requires two types of data: (1) current values for the alternative states involved, and (2) the descriptions of the probability distributions that generate future values. The current values themselves often can be observed via commodity prices for inputs and outputs. In those cases when futures contracts or commodity options are traded on the underlying commodities, the parameters of the probability function could be imputed from observable data.[10] Only when this is not possible would the parameters have to be estimated subjectively, or on the basis of historical data. Thus, in doing project evaluations, the dependence upon management-

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[10]One might at first wonder why, if futures contracts and options are available on the commodities and the company hedges with them, the project NPV is not based simply on the discounted value of the locked-in spreads. Even with such hedges, the company would still have the option .us not to physically convert commodities when a loss would result. The company would simply take its profits from the futures contracts, and shut down the conversion system for a time. Therefore, even with futures hedges or commodity options contracts in place, there are still real options to be considered.

generated subjective forecasts could be substantially reduced, and the job of forecasting could in large part be turned over to the marketplace.

4. Concluding Remarks

The basic research on exchange options has been done by Margrabe (1978 & 1983), Stulz (1982), Stulz & Johnson (1985), and Johnson (1987). In this paper we have applied their work to the problem of evaluating investments in production facilities that possess the capability to support multiple alternative processes. The benefit of doing so is not only a more robust set of quantitative tools for measuring the economic value added by a project, but also refined insight into the qualitative aspects of a positive net present value project. By analyzing a project in the exchange option pricing framework, it is possible to draw well-founded conclusions about the effects on project value of such attributes as flexibility and innovativeness. A project which uses machines that have many alternative uses is revealed by such analysis to be more valuable than an otherwise identical project which uses very specialized machines, because the former provides a greater array of choices. Likewise, a company which thinks of a new use for some kind of machinery will be able to generate a project which has a higher value than any other company could generate from the same machinery. The reason is that the innovative company can create a project with a broader array of choices.

By including divestiture as one of the alternatives in the portfolio of options representing a project, it is possible to incorporate project abandonment into the analysis. In earlier work on project abandonment, the abandonment option was treated as a put, and its value was added to the present value of expected cash flows. By incorporating the abandonment option as one of n alternatives, rather than one of only two alternatives, a clearer picture of the project's value can be developed.

A capital investment project is not a "black box" and should not be evaluated as such. Adding the value of active management into the capital budgeting equation is therefore a worthwhile problem for financial economists. The benefits of doing so—which include not only a more robust set of quantitative tools for measuring the economic value added by a project, but also refined insight into the qualitative aspects of a positive net present value project—have spurred many to make the effort over the years. This paper describes new procedures for analyzing investments in flexible production facilities within the exchange option pricing framework, making it possible to draw well-founded conclusions about the effects on project value of such attributes as flexibility and innovativeness. For example, a project which uses machines that have many alternative uses is more valuable than an otherwise identical project which uses very specialized machines. Because the first project provides a greater array of choices (that is, has more options), the exchange option analysis can capture the difference in value. Likewise, a company that thinks of a new use for some kind of machinery will be able to generate a project which has a higher value than any other company could generate from the same machinery. Because the innovative company can create a project with a broader array of choices (that is, more options), the exchange option analysis can once again capture the difference in value.

The proposed techniques surpass the power of complex simulations. To be sure, contingency tables and dynamic programming might be used instead, but the exchange option approach can be more efficient as well as more powerful. The more complex models require solution by numerical integration, which of course can't be done with a simple hand-held calculator (as can the standard DCF procedures). The powerful computers that are now widely available to decision-makers, however, make it possible to offer such complex project evaluation techniques to practitioners in versatile packages with "smart" interactive interfaces.

Appendix: Multiple Switching Costs

The cost of switching from state A to state B may be different, compared with cost of switching from state A to state C. The appendix addresses this extension. The general model for multiple alternative states, with different costs for switching between states, has the following payoff:

$$\text{Payoff} = \text{Max}\ \{\text{Max}\ [(\text{ALT}_1 - \text{Switch}_1), \ldots, (\text{ALT}_n - \text{Switch}_n)], 0\}$$

Example with Two Alternative States

At the initial opportunity to build the new facility, the following payoff holds:

$$\text{Payoff} = \text{Max}\ \{\text{Max}\ [\text{State}_A, \text{State}_B], 0\}$$

Where the state values consist of the following:

$$\text{State}_A = \text{Ongoing}_A + \text{Option}_A$$

$$\text{State}_B = \text{Ongoing}_B + \text{Option}_B$$

Thus the value of being in State_A includes the value of the facility as an ongoing enterprise in the current mode of operation, plus the value of the option to switch from State_A to State_B .

The option payoffs, if exercised, are as follows:

$$\text{Payoff}_A = \text{Max}\ \{(\text{State}_B - \text{Switch}_{AB}), 0\}$$

$$\text{Payoff}_B = \text{Max}\ \{(\text{State}_A - \text{Switch}_{BA}), 0\}$$

Management would want to change states if the improvement in value from switching is greater than the cost of doing so. If the current status is State_A the condition for changing states is the following:

Change if: $\text{State}_A < \text{State}_B - \text{Switch}_{AB}$

Further clarification about changing states, with the focus on options

Suppose the current status is $State_A$ then change if

$$State_B - State_A > Switch_{AB}$$

Expanding this yields the following:

$$Ongoing_B + Option_B - Ongoing_A - Option_A > Switch_{AB}$$

Which rearranges to:

$$Ongoing_B - Ongoing_A - Switch_{AB} > Option_A - Option_B$$

So the condition for switching is that the gain in ongoing value exceeds the difference in value of options (the act of switching extinguishes $Option_A$ and replaces it with $Option_B$). An interesting special case exists if $Option_B$ is more valuable than $Option_A$. Then switching may be attractive even if the gain in ongoing value is negative. (The situation might occur because of different exercise prices; for example, if the cost of switching from state B to state A were sufficiently different from the cost of switching from state A to state B.)

Example with Three Alternative States

Initial evaluation of opportunity to build:

The value of obtaining the facility is expressed by the following payoff function:

$$\text{Payoff} = \text{Max}\ \{\text{Max}\ [State_A, State_B, State_C], 0\}$$

Where the values of the various states are as follows:

$$State_A = Ongoing_A + Option_A$$

$$State_B = Ongoing_B + Option_B$$

$$State_C = Ongoing_C + Option_C$$

Thus the value of being in $State_A$ includes the value of the facility as an ongoing enterprise in the current mode of operation, plus the values of the options to switch from $State_A$ to $State_B$ or from $State_A$ to $State_C$.

The option payoffs, if exercised, are as follows:

$$Payoff_A = Max\ \{Max\ [(State_B - Switch_{AB}), (State_C - Switch_{AC})], 0\}$$

$$Payoff_B = Max\ \{Max\ [(State_A - Switch_{BA}), (State_C - Switch_{BC})], 0\}$$

$$Payoff_C = Max\ \{Max\ [(State_A - Switch_{CA}), (State_B - Switch_{CB})], 0\}$$

Management would want to change states if the improvement in value from switching is greater than the cost of doing so. Supposing that the current status is $State_A$ the condition for changing states is the following:

$$State_A < Max\ [(State_B - Switch_{AB}), (State_C - Switch_{AC})]$$

Again, the condition for switching is that the gain in ongoing value exceeds the difference in value of the options. Thus it may perhaps be necessary to deal with an intricate array of compound options. Also, as the number of potential states increases, so does the likelihood of the special case in which the existing option might be replaced with others of higher value.

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