7 Barriers to Real Options Adoption and Use in Architecture, Engineering, and Construction Project Management Practice

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The limited adoption and use of real options by practicing managers in the architecture/engineering/construction (AEC) industry remain an important challenge. This chapter describes a risk-rich managerial practice in which real options can add value but are not fully exploited. This setting is used as a basis for identifying and describing specific barriers to widespread real options adoption and use by practicing project managers. These barriers are used to suggest tools, methods, and approaches that may reduce those barriers.

## 7.1 ARCHITECTURE, ENGINEERING, AND CONSTRUCTION (AEC) ENVIRONMENT

Investments in real assets such as manufacturing facilities or power plants often create future growth opportunities (e.g., follow-on development if demand is favorable) or have contingency possibilities (e.g., delaying or abandoning the project). Similarly, the designers of real assets can improve the ability of systems to respond to future changes through strategies such as modularization. Indeed, these sorts of opportunities or options are prevalent in the built environment. Architecture, engineering, and construction (AEC) projects are rife with uncertainty and ripe with flexibility, which is often incorporated as an intuitive managerial approach for dealing effectively with uncertainty. Examples include preliminary planning and feasibility studies such as environmental impact studies, geotechnical surveys, and traffic volume analyses, which can reveal information that may alter further investment and development decisions. Flexible designs such as oversized foundations and columns permit AEC projects to more readily adapt to changing conditions, such as an increase in expected demand for the project’s output. Construction activities often proceed in a series of stages that seek to better define project scope and discover unknown information. Indeed, staged construction, particularly in large projects, can afford decision makers the opportunity to gain more information as market and project conditions become more certain (Miller and Lessard 2000). In short, flexibility can effectively reduce life cycle costs by allowing a timelier and less costly response to a dynamic environment. Undoubtedly, flexibility can add value, but it also comes with costs measured in terms of money, time, and complexity.

Some researchers have identified the potential of real options to improve the management of project uncertainty. Both the amount and nature of project uncertainty make it difficult to plan for and to manage. Miller and Lessard’s (2000) study of sixty large ($985 million average cost and 10.7 years average duration) engineering projects concluded that project success depended largely on the amount of uncertainty and how these uncertainties were managed. Ford and Ceylan (2002) investigated the complex nature of uncertainty in a single, large ($2.4 billion) U.S. Department of Energy acquisition project and concluded, in part, that the complexity of managing
uncertainty in practice currently exceeds the ability of available tools and methods. Other researchers have extended existing real options pricing models to civil infrastructure contexts (Zhao and Tseng 2003; Zhao et al. 2004; Ng et al. 2002; Ng and Bjornsson 2001; Ho and Liu 2003; Chareonpornpattana et al. 2004; Cui et al. 2004; Moel and Tufano 1999; Ford et al. 2002).

Despite the widespread attention and the general consensus regarding the value of option “thinking,” the transfer of real options modeling into AEC project management practice has been slow. Several explanations (described later) have been offered. The writers posit that the attributes of AEC project managers and the character of the AEC industry may have more to do with the lack of transfer of real options analysis than these plausible explanations. Given these circumstances, the identification and assessment of the barriers to real options adoption in AEC project management practice seem to be a prerequisite to devising strategies for the transfer of real options analysis. The subsequent discussion will further characterize AEC project management practice and AEC projects to highlight common characteristics and how they reveal barriers to the wider adoption and use of real options. This will lead to the identification and assessment of potential strategies for overcoming these barriers.

7.2 CHALLENGES OF REAL OPTIONS ADOPTION AND USE

As previously mentioned, the transfer of more formal real option modeling into AEC project management practice, as with other fields, has not been rapid. In 2002, a survey of 205 Fortune 1,000 chief finance officers (CFOs) revealed that only 11.4 percent use real options, while 96 percent use net present value (NPV; Teach 2003). Several explanations for the slow adoption have been offered. Martha Amram, a well-known authority in real options, has stated, “We’ve missed something important. To communicate, [real options analysis] has to be transparent and clear” (quoted in Teach 2003). Alexander Triantis, another leading real options researcher, directly addressed this issue in his five challenges that must be met to take real options from an appealing theoretical concept to a useful practitioner's tool: (1) improve real options models to better reflect reality, (2) understand “split” real options that are owned by multiple agents, (3) model managerial behavior, (4) develop heuristics, and (5) link real option values to the value of the whole firm (Triantis 2005). Each of Triantis's challenges suggests an explanation for the slow adoption of real options by practitioners. Others (Schmidt 2003; Landen and Pinches 1998; Teach 2003) believe that the cause of slow adoption is a lack of knowledge and understanding of real options by managers and that the education of current and future managers about real options (e.g., in MBA programs) will address this barrier, resulting in more widespread adoption and use. Another rationale for the lack of transfer is the notion that the quantitative models rely upon too many assumptions that may be sensible for pricing financial options but are not reasonable for many real options and therefore cannot or do not price real options accurately. If practicing project managers suspect

* See Johnson et al. (2006) for a discussion of how Triantis's five challenges relate to real options in the oil and gas industry.
that this is true, then they are likely to avoid these quantitative models. Yet another rationale concerns the mathematical complexity of some of the models. Many have suggested that the use of sophisticated mathematics such as stochastic calculus limits the accessibility of such models to average decision makers. Without rejecting these potential causes, the current work takes a primarily behavioral perspective of engineering project management practice to identify barriers to real options use. We hypothesize that the attributes of AEC projects, project managers, and the AEC industry may have more to do with the lack of transfer of real options analysis than education or math-based explanations.

Several factors contribute to the challenge of more formal real options use by AEC project managers. First, AEC project managers work in a “risk-rich” environment in which many risks must be managed for project success, many of these risks can cause large decreases in project performance, and risks are interdependent. This situation proliferates practices that focus project management on limiting negative exposure to uncertainty rather than capturing upside potential, and thereby limits the potential benefits of real options use to risk reduction. Second, the management of large-scale AEC projects is quite complex, requiring the management of multiple production activities that routinely employ a wide variety of resources, methods, and technologies; the coordination of labor, materials, and equipment within an environment that is temporary and time constrained; the management of business, environmental, and safety risks before, during, and after projects; and the leadership of a diverse set of stakeholders who often have uncommon interests toward a common goal. A historic example of large-scale project complexity is elegantly documented in McCullough’s (1973) account of the development of the Brooklyn Bridge; a more contemporary example is presented by Sabbagh (1991) describing the construction of a modern skyscraper. A structured practice of recognizing, designing, and implementing real options adds significant complexity to project management, so the additional intricacy of real options analysis is not necessarily welcome. Finally, AEC projects are typically unique, and their aforementioned scale often makes them high-cost, long-duration endeavors. Indeed, many projects are multimillion dollar, multyear enterprises where the opportunity to “get it right” is limited, and little or big mistakes may not necessarily be absorbable for either the AEC manager or organization. In other words, one would be pressed to find an average AEC project. These features and characteristics of the AEC industry make it fertile ground for the use of real options. They also contrast sharply with the financial options and many real options that have been the basis for most real options models. Given these circumstances, the identification and assessment of behavioral barriers to real options adoption in AEC project management practice seem necessary before crafting strategies for the improvement and transfer of real options analysis.

Most of AEC project management of uncertainty focuses on risk. But risk management models (including real options models) include assumptions that do not fully reflect actual project conditions. In the case of real options, these include assumptions of well-behaved future asset values, complete markets for assets, arbitrage opportunities, few and independent options, and the independence of option holders from the future performance of the underlying asset. See Lander and Pinches (1998), Garvin and Cheah (2004), Alessandri et al. (2004), and Ford
and Sobek (2005) for descriptions and discussion of real options model inconsistencies with practice. Engineering managers compensate for these gaps by using intuition, judgment, and heuristics to evaluate and select alternatives. Recognizing and understanding the model adaptations used in practice can reveal barriers to the adoption and use of real options. The subsequent discussion will further characterize AEC project management practice and AEC projects to highlight common characteristics and how they reveal barriers to the wider adoption and use of real options. Some of these barriers are challenges that suggest improvements that can increase real options adoption and use. But others appear more like explanations of reasonable, if not perfectly rational in the economic sense, project management practice. The latter are not necessarily problems to be fixed, but conditions to be understood in customizing real options to engineering project management and especially AEC projects.

7.3 PROBLEM CHARACTERISTICS IN AEC PROJECT MANAGEMENT

The structure and culture of the AEC industry create several problems for project management related to the use of real options. We describe three characteristics that generate problems and then address the barriers to adoption that they create.

Characteristic 1: Many AEC project managers have a relatively short-term and local perspective, which tends to promote the conceptualization of risk as exposure to independent events, as opposed to average outcomes across a diverse risk portfolio.

The typical project manager in an AEC organization is overseeing one or a few projects of finite durations at any one time. As used here, an exposure perspective of risk assumes the worst-case scenario will occur and makes decisions to minimize the resulting losses or increase the minimum gains. An exposure perspective of risk contrasts with a probabilistic perspective of risk where decisions are made based upon average (expected) outcomes and managers seek to improve the average. An exposure perspective is (locally) rational because a modest to significant failure in any one project may have very substantial consequences for the project manager’s career or professional status (e.g., demotion, dismissal, or loss of professional license). Given this, the natural tendency is to seek to reduce exposure. A bias toward an exposure perspective is exacerbated in situations where the project manager works in an organization that does not have a diversified project and risk portfolio. In such a case, the local perspective is rather appropriate since a significant mistake by a project manager could put the organization in severe financial distress.

Often AEC project managers are rewarded or penalized for performance on individual projects, which reinforces their short-term and local perspective. This is not to say that project managers are not rewarded or penalized based upon cumulative performance but rather both explicit and implicit performance incentives are always present on each and every project. For instance, every time a professional engineer “stamps” a design drawing, that engineer assumes professional liability. A design error can result in additional cost to the engineer (or to his or her firm),
a loss of reputation, and/or a loss of professional status, if the error warrants revocation of the engineer's license. Conversely, a superior design can increase the engineer's professional stature, increase professional recognition via industry awards, and/or generate additional income for the engineer (or his or her firm) via new contracts.

**Characteristic 2**: The centrality and dependence of real options pricing models on uncertainty are inconsistent with the lack of familiarity, understanding, and use of uncertainty by most project managers.

Real options are modeled conceptually and priced formally on the uncertainty of the future behavior, performance, and value of the underlying asset (the project). But project managers do not generally understand uncertainty well or how it can or should impact decision making. Current models cannot turn uncertainty into an effective tool for managing projects instead of a threat to project success. But project management may evolve to make uncertainty an effective management tool. For example, a contractor with an exceptional ability to capture more value of uncertain projects as well as manage construction risks effectively would have a significant competitive advantage. Consider the analogous critical path method for scheduling. For a while after its development in the 1960s, the method's complicated calculations and recalculations of schedule networks and the difficulty of explaining results constrained understanding, acceptance, and use to those with the ability and interest in understanding and performing, checking, and interpreting those calculations. But the development and dispersion of the more intuitive concepts of critical path, total float, and free float and method-based heuristics such as "Feed the critical path" made the method accessible to most project management practitioners, regardless of their interest, understanding, or facility with the calculations. Real options modeling has not yet developed adequately to bridge from the complexity inherent in managing uncertainty with structured flexibility to managerial forms that are useful to a majority of project managers. We later describe how such real options development might occur.

**Characteristic 3**: The objectives of an AEC project's manager may not necessarily align with the objectives of its owner.

AEC projects usually involve three principal parties: an owner, a designer (architect or engineer), and a builder (general contractor or construction manager). A classic case of conflict is where an architect develops a program for a project that does not quite conform with an owner's intent. This mismatch may be caused by the architect's desire to achieve an artistic effect (which may generate subsequent professional praise and business) that is not shared by the owner or an architect's inability to translate the requirements of an owner into an optimal program. Similarly, a project's builder may prolong construction duration unnecessarily to keep crews busy while awaiting the start of subsequent projects, or the builder may substitute inferior materials to those specified to reduce his or her costs and thereby increase profits. Differences in objectives can cause project managers to not select real options that maximize project value.

AEC projects are inherently unique and complex—combining technical, logistical, financial, organizational, political, and social issues in a temporary engagement among a project's stakeholders. Not surprisingly, this often puts the managers of
these projects in very challenging situations. For instance, a routine day during the
construction period of a bridge renovation project might involve lane closure and traf-
fic management operations; just-in-time delivery of materials or equipment; multiple
concurrent production activities such as decking demolition and removal, replace-
ment of supporting steel members, and installation of new decking; procurement of
materials needed in the future; inspection of completed work by a third party; and
responding to the project’s owner about complaints received from motorists who use
the bridge. For a project manager, the challenges of managing complex projects may
make simplifying the management effort a priority or at least of equal importance to
adding project value. These different objectives can create the challenges of multiple
option ownership described in Triantis’s second challenge (2005).

7.4 BARRIERS TO REAL OPTIONS ADOPTION AND USE

7.4.1 BARRIER 1: REAL OPTIONS MODELS ASSUME MANY REPEATED
BETS, BUT PROJECT MANAGERS MAKE ONE-SHOT CHOICES

Not all options that are modeled, priced accurately and whose price recommends
its purchase and use increase. Whether an option actually increases project value
or not depends on uncertainty resolution and managerial decisions (the applica-
tion of the exercise decision rule). If the uncertainty resolves such that the option
should not be exercised, then the option purchase and maintenance costs are paid
without capturing benefits. (Cases in which there is no possibility of uncertainty
resolving such that the option should not be exercised are not options since the
decision to exercise should be taken immediately.) These options decrease project
value. These options are recommended because they are priced based on the aver-
age payoff of many repeated bets, that is, on the assumption that the same circum-
stances and option will occur many times and the option holder will capture the
average of all the benefits and losses. Engineering project management practice
often differs markedly from this assumption. Project managers face many one-
shot choices where they will likely experience the circumstances and option only
once. This encourages an exposure-based perspective of risk and can create prob-
lems for managers of single options.

Consider the simplified example of a construction project that has fallen behind
schedule. The expected completion date is 100 days after the original deadline, with
a range of possible delays from 50 to 150 days. An option to improve productivity
has been obtained that will change the expected completion delay to an aver-
age of 75 days with a range of 40 to 125 days. Alternatively, overtime can be used
to change the expected completion delay to an average of 85 days with a range of
50 to 100 days. A project manager with an exposure-based perspective of risk (e.g.,
who fears being dismissed if the project is over 100 days late) may apply a one-shot
perspective and use the single worst possible conditions to select a strategy instead
of a probabilistic perspective that uses average values. In this example, this would
result in the manager using overtime instead of improved productivity because over-
time reduces project exposure more than improved productivity, from 150 days to
100 days instead of from 150 days to 125 days, even though improved productivity
would improve the average project schedule performance more than overtime, from 100 days to 75 days instead of from 100 days to 85 days. Ceteris paribus (all other things held equal), the productivity option is priced higher than the overtime strategy. But the manager rationally chooses overtime based on his or her one-shot, exposure-based perspective that precludes waiting for the average payoff.

Research supports the existence and common use of an exposure-based perspective of risk. The results of controlled experiments by Li (2003) support our distinction between exposure-based and probabilistic perspectives in decision making under uncertainty. In these experiments, subjects preferred a chance with a lower expected payoff and a higher minimum payoff (i.e., less exposure) to a chance with a higher expected payoff and a larger chance of no payoff. The subjects took an exposure-based perspective by preferring to improve their worst-case scenario (minimize their loss) instead of maximizing their expected value even though they were provided and understood the reward structure. Li (2003, p. 122) concludes, in part, “These results therefore raise doubts about whether people behave . . . as if they were always trying to apply a long-run [probabilistic] perspective of maximization to short-run [one-shot] probabilistic events.”

What might cause a project manager to take either an exposure-based or probabilistic perspective and make the very different decisions that each suggests? First, project managers may intuitively foresee circumstances in which they might be forced to explain an expense they authorized (to obtain or maintain an option) that, in hindsight, clearly did not add project value because the option was not needed. Using expected values allows valuation with uncertain futures but also makes the value added by any one specific option uncertain. Project managers may avoid strategies that are difficult to defend, even if they can, but may not, add value. Second, assuming that the manager accurately prices the options, the choice of an exposure or probabilistic perspective may depend upon whether they can survive the potential losses that may occur if either the option is not exercised or wrongly exercised, or if losses exceed benefits before the law of averages even out and the long term net value of options is realized. This choice depends largely upon the manager’s risk tolerance and the incentive structures used by an enterprise for its project managers. If the common short-term or project-specific incentives are dominant, the project manager is likely to act conservatively and only execute low-risk, low-payoff options since overall performance and job security are strongly linked with performance on independent and mutually exclusive projects. In contrast, if longer-term and cumulative project incentives are dominant, then project managers can probably rely more on the law of averages in decision making. Hence, in this circumstance more high-risk, high-payoff options are likely to be implemented.

One argument against an exposure perspective being a rational barrier to real options adoption is that the option should be considered similar to insurance, in that the cost (premium) is justified for the protection (coverage) whether or not the option is exercised (claim made) or not. This is essentially an argument for a probabilistic perspective. However, to remain competitive in competitive bidding circumstances, firms often cannot afford to include the cost of loss-limiting (i.e., put) options and remain competitive because often a competitor will assume the uncertainty will resolve in the desired way such that the high expenses will not occur or that they can
be recovered, such as through a deadline extension. Such a “hope-for-the-best” practice of not including adequate protection for uncertain conditions is fatal to overly optimistic firms in the long run (over many projects). But the potential to shift costs to others (e.g., through change orders due to unexpected conditions) and low barriers to entry for some parts of the industry maintain a population of such competitors, preventing more cautious firms from including reasonable put options.

7.4.2 BARRIER 2: PROJECT MANAGERS ARE RISK AVERSE IN VALUING REAL OPTIONS

Like almost all managers, engineering project managers tend to be risk averse, meaning that they are willing to forgo some benefits to reduce uncertainty. Given two otherwise equal strategies, they prefer the one that depends less on the resolution of an uncertainty to determine whether, or how much, it adds value to their project. Many managerial actions in which uncertainty is perceived to make little or no difference in whether value is added or not (e.g., budget increases, or scope decreases) can and do increase project value. In sharp contrast, all real options are, and if perceived accurately are understood to be, very dependent on how uncertain conditions resolve. Practicing managers demonstrate their risk aversion regularly when choosing among value-adding alternatives with different amounts of uncertainty and reward. As an example of managerial risk aversion in practice, a risk-averse manager might prefer to extend a project’s deadline to reduce a project’s forecasted completion delay instead of adopting a new, untested technology to accelerate production even if the resulting expected delay with the deadline strategy is larger. This could be because the duration reductions of the new technology are considered more uncertain and more likely to fail than the deadline change.

Managers may tacitly implement risk aversion by adding a cost in their valuation of real options that reflects their level of risk aversion. This would decrease the attractiveness of real options relative to more certain alternatives and thereby decreases the use of real options. The lower value that a manager is willing to accept to get certainty is the certain equivalent value of the uncertain strategy (Howard and Matheson 1972). In real options assessment and selection, this difference effectively adds a risk aversion cost to real options that can be as large as the difference between the price of the option and the manager’s certain equivalent of that alternative. Current real options pricing models do not include the risk aversion costs due to manager’s perspectives. These managerial risk aversion costs increase the perceived cost of real options, reduce their values to managers and therefore real options are used less than their price implies. Discounting real options due to aversion to uncertainty may reflect a manager’s perspective of risk as exposure and attempts to reduce exposure.

Risk aversion and the resulting reduced use of real options may be very rational from the manager’s perspective. Why would a manager take the risk of being wrong (not needing to exercise the option to add value and thereby reducing project value by the purchase and maintenance costs of the option) when less risk is taken with a more certain alternative? If an exposure-based perspective is appropriate, managerial inclusion of risk aversion costs in real options valuation can be also appropriate. However, the size of those costs is probably determined intuitively and tacitly, may
be larger than needed to reflect the value of reduced uncertainty, and may reduce real options values more than they should, thereby reducing real options use.

7.4.3 Barrier 3: Managerial Project Real Options Are Worth Less than Traditional Pricing Suggests

Project management practice varies greatly from two fundamental assumptions of most real options pricing models. These differences cause real options to be valued less than estimated prices. First, there are many possible managerial actions that increase project value. Examples abound, including overtime or special equipment to control schedule performance, subcontracting work to access additional resources, and shifting targets. Many of these can be structured as options. Trigeorgis (1993) shows with closed form valuations and Bhargav and Ford (2006) demonstrate with simulation that the values of individual options decrease with the number of additional options that are available. One intuitive interpretation of this result is that each additional alternative strategy that improves performance without the option being considered reduces the amount of benefit the option can add. Therefore, the many alternatives for managing uncertainty that are available to project managers may reduce the value of each real option to significantly less than if it was the only alternative. If project managers intuitively understand this relationship and include it in their tacit valuations of real options, they may estimate real options values closer to their actual values than traditional, single-option pricing models. Both the lower estimated values and the discrepancy between formal valuations and perceived values could reduce the acceptance and use of real options by project managers.

A second reason that some project management real options are worth less than traditional pricing suggests is that most option models assume that the option holder does not influence the value of the underlying asset. This assumption is usually unstated in the literature. Its foundation is in option pricing models for financial assets (e.g., stocks in a market that can reasonably be assumed to be perfect) in which the option holder is independent of the asset except through the market. For some real options, this assumption is reasonable. For example, the holder of an option to accelerate exploitation of a fossil fuel reservoir by drilling additional wells cannot influence the characteristics of the reservoir (e.g., size, or porosity) or the market price of the refined products. In sharp contrast, when project managers use real options to control their own projects, they purposefully and strongly contradict the assumption of option holder/uncertainty independence by working to manipulate the uncertainties in their projects through traditional means. Examples of these uncertainty manipulations in project management are numerous, including using overtime or special equipment to control schedule performance, taking subcontracted work in-house, and using construction manager at-risk contracts that include options to change builders. Miller and Lessard (2000) describe these dependencies in major project decisions, and Alessandri et al. (2004) describe this type of linkage in a specific set of project management decisions. In these cases, real options decisions and project management decisions are tightly linked. Therefore, real options pricing models that assume independence of option holders and underlying assets and
uncertainties may not price strategies accurately enough to guide AEC project managers. Since project managers tend to manipulate project uncertainties to increase project values, this reduces the potential benefits of options. Therefore, violating this pricing assumption may cause real options to be overvalued using traditional models. If we assume that managers intuitively value options and include these two features of project management practice, this would reduce the value of options, requiring that they add more value to be justified and reducing the use of real options by project managers.

7.4.4 **Barrier 4: Project Managers Have Limited Resources**

Real options theory says that when an option adds value, the potential holder of the option should purchase, maintain, and use the option. But practicing managers often require that options add lots of value before they are purchased. We have heard managers describe the circumstances that justified the purchase of an option as "no brainers" (i.e., the option would probably add so much value that the manager considered the choice to purchase the option to be obvious). Why do practicing managers require very large expected payoffs and regularly forgo obtaining and using options that potentially add value? Reduced actual and perceived option values for the reasons described above can provide a partial explanation. Resource limitations may also play a part.

As described, engineering project managers often have a plethora of alternatives for adding project value. Most of them require resources to identify, design, analyze, and implement. Limitations on several types of resources restrict the use of real options, including (1) funds for purchasing and retaining flexibility; (2) labor, equipment, and materials to implement management decisions; (3) combinations of cognitive ability, tools, and methods to understand, design, evaluate, and implement options and other value-adding alternatives; and (4) time and attention to recognize and use options and other value-adding alternatives. Engineering project managers are forced to choose from among their many alternatives for increasing project value when faced with these constraints. Choices are often based on a benefit-cost ratio analysis to maximize total project value derived from any given set of limited resources. Alternatives with the largest perceived ratio are chosen first. If conditions such as holding many project improvement alternatives (Barrier 3), attitudes such as uncertainty aversion (Barrier 2), and managerial perceptions such as not understanding and therefore avoiding options drive managers' evaluations, then real options will have relatively low benefit-cost ratios and will therefore be selected rarely.

7.4.5 **Barrier 5: As Option Holders, Project Managers Do Not Necessarily Seek to Maximize Project Value**

Option holders not seeking to increase asset values contrast directly with real options theory and are related to the classic agency problem discussed by organizational behavior theorists. Managerial real options are often valued and assessed
in dimensions that cannot be measured with money, or at least with project money. For example, Ford and Ceylan (2002) found that managers at the U.S. Department of Energy's National Ignition Facility explicitly used options to increase the likelihood of successful technology development and to increase vendor competition, as well as to reduce costs. The previously described circumstance where failure seriously harms the manager's career is another good example. Providing protection against project failure and therefore career damage increases the value of the option to the manager, if not the project. Hence, the manager assesses the option differently than the project owner (or its investors) would. Again, the U.S. Department of Energy's National Ignition Facility project provides an example. Here, the project manager linked an unfortunate resolution of uncertainty without a specific option (unsuccessful technology development) with project failure (Ford and Ceylan 2002). The high-profile nature of the project and failures of previous managers made the potential of project failure and its impacts on his career unacceptable to the manager. Therefore, the manager might have valued the option more highly than the project owner (U.S. Congress, in this case), who might have been willing to accept project failure, although there is no direct evidence that this assessment actually took place. This pushes real options adoption and use away from traditional "optimal" and "project-maximizing" choices.

The presence of factors other than economic product value changes the environment for real options analysis substantially. As opposed to the presumed economic or project-centric view, evaluations regarding options are made based upon dimensions other than project money. This can lead to an increase in the perceived value of certain options to the project manager that may not necessarily enhance the value of the project. This also suggests that project managers have various motivations as well as means to manipulate or influence asset values. This may reduce the perceived value.

7.4.6 Barrier 6: Exercising Options Can Have Dramatic Secondary Impacts on Project Management That Increase the Difficulty of Project Management

A special but particularly widespread case of limited resources that all project managers and project management teams experience is bounded rationality (a well-known notion first characterized by Nobel Prize winning economist Herbert Simon), their maximum cognitive capacity. Project management tools can expand the capacity, but there remains an upper limit. The complexity inherent in AEC projects often approaches or exceeds the bounded rationality of project managers and project management teams. Therefore (ceteris paribus) project managers prefer simpler alternatives to more complex ones. An alternative with many or complex side effects is less attractive. This can decrease the attractiveness of options that add management complexity from the perspective of the project manager.

Consider the example of an actual situation disguised as the Project Isolated case and described by Johnson et al. (2006). Project Isolated is a new fossil fuel development
project in a remote location requiring a specialized piece of equipment that is available from only one manufacturer. Once equipment manufacturing is complete, it will be transported by sealift from the manufacturer to the project location. However, the Project Isolated site is accessible by sea only during a short time window due to weather. The Project Isolated team is concerned that the manufacturer will not complete the equipment in time for delivery to the site by sealift within the available time window. If this window is missed, the next available window is several months later. This would significantly delay the development of Project Isolated and the delivery of product, and therefore severely degrade project performance. The project team is considering purchasing an option to transport the equipment by a more expensive airlift to avoid missing the weather window.

Johnson et al. (2006) developed a relatively simple project simulation model. The model was used to estimate option value. But the option's monetary value reflects only part of the impact the airlift option has on the project and its management. Johnson et al. (2006) also used the model to simulate delivery dates with and without the air-transit option (Figure 7.1).

![Figure 7.1](image-url)

**FIGURE 7.1** Distribution of transportation completion dates.

The airlift option has at least two significant impacts on project management. First, the option transforms the transportation completion date distribution from a bimodal distribution into a single modal distribution. This requires that the project be prepared for delivery in one, not two, discrete time periods. Second, without the airlift option the project manager must design and prepare for only one mode of delivery (sealift). But with the airlift option, the project manager must design and prepare for two possible delivery modes (sealift and airlift). Preparing for both sealift and airlift delivery is clearly a more difficult project management task than planning for either one. The combined impacts of the option may increase project management complexity. Faced with potentially exceeding the project management’s
bounded rationality if an option is used, some managers may find options less attractive and tacitly discount some option values to account for the anticipated additional managerial complexity.

7.5 OVERCOMING BARRIERS TO REAL OPTIONS ADOPTION AND USE

Significant improvement can be made to the adoption and use of real options by AEC project managers by developing and providing tools and methods that expand the capabilities of project managers to understand and use options. Useful tools and methods can be developed from both sides of the understanding and application gap by (1) improving existing real options models to better reflect AEC projects and project management practice, and (2) using existing project management concepts, tools, and methods to model real options. We describe and discuss each of these approaches.

7.5.1 IMPROVE EXISTING REAL OPTIONS PRICING MODELS TO BETTER REFLECT AEC PROJECTS AND PROJECT MANAGEMENT PRACTICE

This approach seeks to improve the accuracy and applicability of real options models for AEC projects (Triantis’s third challenge, 2005). The many methods for modeling real options and their applications across different settings have created a confusing situation for project managers, and the confusion is heightened by different assumptions that underlie the modeling techniques. Assumptions are often taken for granted, misunderstood, or unrealistic. Critics are quick to jump to the conclusion that the entire real options field is mathematically elegant, but hardly useful in practice. We disagree, but believe the current state of the art of most real options models remains distant from most AEC project management practice. Several common features of existing real options models differ from current practice to such an extent that improving the models might lead to greater acceptance of real options by practitioners.

One issue is the prevalence of single-factor models—models that use one variable to represent the underlying value of the asset or project over time. Copeland and Tufano (2004) have suggested that very often the underlying value of a real asset is driven by one key variable. Their assertion is probably correct for some relatively simple types of assets such as commodities or natural resources. In these cases, a single-factor model is sufficient to price project options. Pricing techniques for single-factor models are generally familiar (to ROA analysts at least) and relatively simple, such as the binomial tree method. Conversely, many financial analysts of complex infrastructure projects are likely to suggest that it is difficult to describe the drivers of an infrastructure project’s value with a single variable. Valuing these complex assets and options to increase their efficacy typically requires multiple interdependent variables. Multifactor models generally require Monte Carlo simulation techniques or more sophisticated lattice models. Until recently, the use of Monte Carlo simulation was possible on only the simplest forms of options (e.g., European); however, recent advances have made its use more practical for other forms of options (Broadie and Glasserman 1997; Longstaff and Schwartz 2001).
For example, Chiara and Garvin (2007) recently introduced a novel approach that models revenue risk mitigation contracts in privately financed infrastructure projects as multiple-exercise real options. The approach structured revenue guarantees (put options) into risk mitigation contracts and valued them by two methods, the multi-least squares Monte Carlo method and the multi-exercise boundary method. Effectively, the two methods combine Monte Carlo simulation and dynamic programming techniques to price the multi-exercise options. While this approach may be more palatable with regard to the evolution of a project's value, the method is clearly more mathematically sophisticated than most traditional real options pricing models. Moreover, it is currently applicable to a very specific type of project option. Thus, it may be more realistic, but this potential improvement comes at a cost in terms of modeling complexity and specificity.

### 7.5.2 Use Existing Project Management Concepts, Tools, and Methods to Model Real Options

The objective of this approach is different from the first. This approach seeks to improve the options thinking skills of practitioners by (1) improving their understanding of and intuition about real options, and (2) providing practical heuristics that reflect both real options theory and practice (Triantis's fourth challenge, 2005). Optimally these models begin with practitioner understanding as it exists and include aspects of projects and project management that interact with real options use. Many options thinking skills can be improved by building upon basic project management concepts, tools, and methods. Examples include (1) recognizing management challenges as uncertainty management situations, (2) explicitly considering flexible project management alternatives that can be structured as options in decision making, (3) assessing when flexibility can and cannot add value, (4) recognizing options in common and innovative project management alternatives and structuring those alternatives as options, (5) developing order-of-magnitude estimating techniques of option values, and (6) creating guidelines for implementing adopted options to capture their value.

A process model of designing real options is a simple example of a tool that can improve options thinking skills. Options development and use can be modeled as a series of steps that include describing the uncertainty to manage, developing management alternatives, structuring alternatives as options, building alternative designs, strategy selection, and option implementation (Mun 2005). A more detailed process model could provide additional guidance and a framework for other tools that improve options thinking skills. One such tool developed by Johnson et al. (2006) for structuring some project management alternatives as options can help project managers to more fully grasp the potential utility of a flexible strategy when compared with an inflexible one. Figure 7.2 depicts the tool, and the subsequent example illustrates its use.

For a given project challenge or situation, to structure a flexible project management alternative as a real option:

1. Write a one- or two-paragraph description of the situation that accurately describes the challenge facing the project team and the available solutions, including the solution that includes flexibility. This description should
include a statement of the challenge, identification of what influences the challenge, a way to measure this influence, and solution strategies for addressing the challenge.

2. Based on the description, complete the following paragraph.

The challenge facing this project is (1)_______. The uncertainty that is causing this challenge is (2)_______. The traditional approach to this challenge is (3)_______. A possible alternate solution to this problem is (4)_______. The performance measurement that can be used to evaluate these alternative strategies is (5)_______. The value of this measurement that justifies switching from the traditional strategy to the alternative strategy is (6)_______. In order to have the ability to change strategies, we must (7)_______. To change strategies, we would (8)_______.

3. Is the paragraph consistent with the description of the situation? Does the paragraph accurately describe the situation? If not, adjust the paragraph to describe the situation.

4. Fill in the structured description in Figure 7.2 by placing the answers from the paragraph above in the appropriate box. Complete the decision rule as shown.

<table>
<thead>
<tr>
<th>Uncertain performance measure</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver of performance uncertainty</td>
<td>2</td>
</tr>
<tr>
<td>Reference strategy</td>
<td>3</td>
</tr>
<tr>
<td>Alternative strategy</td>
<td>4</td>
</tr>
<tr>
<td>Signal for changing strategy</td>
<td>5</td>
</tr>
<tr>
<td>Conditions for strategy change</td>
<td>6</td>
</tr>
<tr>
<td>Actions required to obtain or retain flexibility</td>
<td>7</td>
</tr>
<tr>
<td>Action required to change strategy</td>
<td>8</td>
</tr>
<tr>
<td>Decision rule for changing strategy</td>
<td>IF (box 5) MEETS (box 6)</td>
</tr>
<tr>
<td></td>
<td>THEN (box 4)</td>
</tr>
<tr>
<td></td>
<td>ELSE (box 3)</td>
</tr>
</tbody>
</table>

**FIGURE 7.2** A tool for structuring flexible project management strategies as options.

The tool transforms a poorly structured management problem into a real options description. Specifically, (1) is a measure of asset value, (2) is the driving uncertainty, (3) is the strategy without the option, (4) is the strategy if the option is exercised, (5) is the condition that is monitored for making the exercise decision, (6) is the strike or exercise conditions or price, (7) are the actions that generate option purchase and holding costs, (8) are the actions that generate option exercise costs, and the decision rule defines if and when the option should be implemented. The Project Isolated example described in Section 7.4.6 can be structured using the tool described below and shown in Figure 7.3.
The challenge that this project is facing is a possible delay in the start of production. The uncertainty that is causing this challenge is the delivery of equipment to the Project Isolated site. The traditional approach to this challenge is to use a sealift to deliver the equipment. A possible alternate solution to this problem is to airlift the equipment to the Project Isolated site. The performance measurement that can be used to evaluate the strategies is the forecasted delivery date of the equipment by sealift. The value of this measurement that justifies switching from the traditional strategy to the alternative strategy is the required equipment delivery date (close of the weather window). In order to have the ability to change strategies, the Project Isolated team must reserve airlift capacity and design the equipment so that it can be airlifted. To change strategies, the Project Isolated team would cancel the sealift and notify the airlift company.

<table>
<thead>
<tr>
<th>Uncertain performance measure</th>
<th>Start of production.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver of performance uncertainty</td>
<td>Equipment delivery date.</td>
</tr>
<tr>
<td>Reference strategy</td>
<td>Sealift equipment.</td>
</tr>
<tr>
<td>Alternative strategy</td>
<td>Airlift equipment.</td>
</tr>
<tr>
<td>Signal for changing strategy</td>
<td>Forecasted delivery date of the equipment by sealift.</td>
</tr>
<tr>
<td>Conditions for strategy change</td>
<td>End of weather window.</td>
</tr>
<tr>
<td>Actions required to obtain or retain flexibility</td>
<td>Reserve airlift capacity in advance, design equipment for airlift.</td>
</tr>
<tr>
<td>Action required to change strategy</td>
<td>Cancel sealift, notify airlift company.</td>
</tr>
<tr>
<td>Decision rule for changing strategy</td>
<td>IF (forecasted delivery date) &gt; (end of weather window), THEN (airlift equipment), ELSE (sealift equipment).</td>
</tr>
</tbody>
</table>

**FIGURE 7.3** The structure of an option to airlift equipment.

A second example of a tool that can improve options thinking skills addresses valuation. Practicing managers often use simple valuation tools such as net benefit, benefit-cost ratios, and payback periods. A potentially common error in options thinking is the failure to recognize and include all the relevant benefits and costs of the option. The following "algebra of options" compares option benefits and costs to estimate the net economic value of the option:

\[ V = B - C \]  

(7.1)

where

- V: option value or the value added by flexibility
- B: benefits provided by the real option
- C: costs of the real option
Expanding the benefits and costs into their respective components gives the following:

\[ V = (B_p + B_c + B_z) - (B_l + C_l + C_m + C_e + C_s) \]  \hspace{1cm} (7.2)

where

- \(B_p\): net performance benefits, the value of improved performance if the decision is delayed. This value can be estimated as the difference between the project benefits with and without the option.
- \(B_c\): cost benefits, the value of reduced costs if the decision is delayed. This value can be estimated as the difference between the project costs with and without the option.
- \(B_z\): strategic benefits, the value of delaying decisions that are external to the project.
- \(B_l\): lost benefits, benefits that are unavailable due to delaying the decision. This value can be estimated as the sum of the lost performance benefits and the lost cost benefits.
- \(C_l\): initial option costs, the costs of initially obtaining the flexibility.
- \(C_m\): option maintenance costs, costs of keeping the flexibility available until the delayed decision is made.
- \(C_e\): exercise costs, costs to implement a change in the project strategy.
- \(C_s\): strategic costs, costs incurred by delaying the decision that are external to the project.

For rigorous analysis, all valuations must be consistent for aggregation, such as having the same time basis (e.g., annual or over the entire project) and being discounted or projected to the same point in time with discount rates that reflect the uncertainty in the discounted or projected values. Other tools such as Feinstein and Lander's weighted average discount rate (Feinstein and Lander 2002) can facilitate this modeling. However, even without completely rigorous analysis, Equation (7.2) helps identify, describe, and evaluate the potential of options to increase project value by providing a disaggregation of option value into components that are relatively easily recognized, described, and discussed by practicing managers. Some costs or benefits may be zero. But missing one could cause a manager to make a worse decision about purchasing an option than if all the benefits and costs were incorporated into the decision. The algebra of options provides a checklist of potential sources of impacts on real options value as well as a specification of the directions of impacts. Likewise, some components may be easier to quantify than others. In some cases, such as when one or two components of the option value far exceed all others, rough estimates may be adequate to make accurate decisions about project management options.

The algebra of options can also help managers decide when to consider an option. Using maximum estimated benefits and minimum costs and vice versa in Equation (7.2) can be useful in "triaging" risk management strategies into three categories: (I) those for which the minimum benefits and maximum costs provide positive net
value and therefore should be committed to immediately, (2) those for which the polarity of the net value depends on the benefits and costs and therefore consideration of an option is advised, and (3) those for which the maximum benefits and minimum costs provide negative net value and therefore should not be considered further. The further development of tools such as the algebra of options will facilitate the development of heuristics that managers can use to identify and assess options.

7.6 DISCUSSION

The barriers to the widespread adoption and use of real options by practicing AEC project managers are rooted in the complexity of AEC projects, the limitations and characteristics of managers, and the current state of the art of real options models. These root causes interact to create the barriers, such as the cognitive limitations of managers interacting with the complexity of projects, to create a preference for simpler project management alternatives. The multiplicity and interdependence of the causes of the barriers prevent any one single approach from successfully bridging those barriers. Advancements in multiple areas that borrow from and link different perspectives are needed. We have suggested two perspectives that may prove useful: the improvement of existing real options pricing models toward practice and the use of existing project management concepts, tools, and methods to improve options thinking skills. Each approach can help address at least one barrier, but each approach has limitations.

The improvement of existing real options pricing models to better reflect AEC project management practice (the first suggested approach) can help address the gap between real options models and practice. More specifically, we suspect that the valuation of combinations of different types of real options that have a variety of characteristics (Barrier 3, Section 7.4.3) can be significantly improved through additional real options model development. These models could provide insights and potentially valuable project management heuristics about the use of real options. However, more elaborate valuation models worsen other barriers by adding model complexity and thereby making it harder for practicing managers to understand the model and accept model results. This approach to bridging the barriers sets up a trade-off between model accuracy/applicability and simplicity that facilitates understanding and acceptance. The choice should typically depend upon the purpose of the valuation; if a tactical or reasonably precise analysis is necessary the former approach is probably required, but if a strategic or order of magnitude analysis is needed the latter may be adequate. More than likely, the field of ROA will produce additional and more specialized approaches in the future. Regrettably, the fundamental trade-off between complexity and precision versus simplicity and inaccuracy will probably remain. Although we believe that real options pricing model developments should be pursued, improving those models cannot resolve the real options adoption and use challenge alone.

The second suggested approach to bridging the barriers builds on existing project management concepts, tools, and methods to improve options thinking skills. This approach more directly addresses the primarily behavioral barriers (Barriers 1, 2, 4,
5, and 6). Generally, these barriers result from human motivations and limitations, the industry's project environment, and common organizational policies and norms. To be effective, tools that improve utilization of managerial options may need to be "thinking" tools, not "solution" tools. As used here, thinking tools initiate, facilitate, or guide a manager's cognitive processes and add insight without necessarily providing exact or always correct solutions. The two tools described previously are examples of thinking tools. Consultants already may have developed and provided such tools for improving real options thinking to their clients. But, to our knowledge, few, if any, have been rigorously tested and they are not publicly or widely available, thereby severely limiting their usefulness for bridging the barriers on a large scale. More sharing of existing tools and the development and testing of additional tools and methods for improving options thinking skills are needed.

Fundamental features and characteristics of AEC projects, their managers, and existing real options models have created large barriers to the widespread adoption and use of real options by practicing managers. These barriers prevent or severely limit AEC project managers from capturing the potential benefits of real options. The barriers can be overcome only by broadening the development of real options tools and methods to include, and therefore balance pricing, valuation, project characteristics, and managerial practice. Doing so may be difficult but can transform real options into a standard part of every project manager's toolkit.

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