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A real options approach to valuing strategic flexibility in uncertain construction projects

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To maximize project value, managers of construction projects must recognize, plan for and strategically manage uncertainty. Current construction planning, estimating, and management practices regarding uncertainty can undervalue projects by failing to exploit opportunities to increase project value, as well as minimize risks. Dynamic uncertainties are described as project conditions that cannot be resolved adequately through improved description or planning for pre-project strategy selection. A real options approach is proposed for proactively using strategic flexibility to recognize and capture project values hidden in dynamic uncertainties. An example of a proposal for a toll road project demonstrates a method of valuing managerial flexibility to evaluate and select strategies. Impacts of real options in other domains, along with this example, are the basis for concluding that using a structured real options approach in construction management can increase returns through improved project planning and management. Potential impacts of the use of real options are discussed, and challenges in valuing real options in construction projects are identified as the basis for future research.

Keywords: Project planning, strategy, risk management, real options, project management

Introduction

To be competitive, construction companies must recognize and capture as much project value as possible. Some project value is easy to recognize and relatively predictable, such as increased productivity from training or the potential of reduced costs with shorter project durations. Such value can be recognized and realized using traditional construction management methods and tools. However, significant project value may remain hidden, and therefore unexploited, in the more uncertain portions of projects. Many potentially critical aspects of construction projects are uncertain, including prices, weather, and the durations of activities such as design, fabrication, and installation. Also, individual construction projects may include project-specific sources of uncertainty that affect project value. For example, delaying procurement, such as postponing equipment purchases, can add value to the purchaser if future prices are uncertain and happen to fall. Latent project values such as in this example can remain unrecognized and unexploited by any or all of the project's participants.

Pre-project planning includes the assessment and selection of alternative strategies. These strategies can utilize many project features to manage uncertainty, including contract terms, procurement methods, and construction technologies. The uncertainty in some project conditions is small enough to allow the design, analysis, and choice of rigid strategies during pre-project planning. In these rigid strategies, managerial policies do not respond to changes in uncertain conditions during the project. However, many construction project conditions evolve over time, and the conditions, times, and managerial choices for effective decision-making cannot be determined completely and accurately during pre-project planning. Additional data collection can sometimes improve descriptions of

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apparently large uncertainties sufficiently to allow the design, assessment, and selection of alternative rigid strategies. However, often uncertainties are, or appear, too vague for effective design, assessment and selection among strategy alternatives before a project must proceed.

As used here, 'dynamic uncertainties' are conditions in which the costs of selecting suboptimal alternatives during pre-project planning are high but the uncertainties cannot be resolved adequately for strategy selection during pre-project planning.[1]

Dynamic refers to the evolution over time of the uncertain conditions, or the perception of those conditions, that determine the optimal strategy for the party receiving the benefits and absorbing the costs of that uncertainty. Consider a consulting firm that is evaluating a proposed wharf project for an owner. Traditional sensitivity analysis could reveal that to remain competitive throughout its proposed life the facility must be able to service the primary mode of transport (e.g. bulk, containerized, roll-on/roll-off) to satisfy uncertain future markets. The future market needs are an example of a dynamic uncertainty. Building a bulk materials handling wharf could be financially disastrous if the market were to move strongly towards containerized goods. However, if the direction of the market clarifies within a few years, waiting to commit to an operational mode could increase the project's value by increasing the wharf's ability to meet future market needs.

How can planners develop effective project strategies when specific uncertainties cannot be resolved before proceeding with the project? How can those strategies be valued for pre-project estimating and planning? Dynamic uncertainties are particularly difficult to incorporate into pre-project planning because the knowledge about future conditions that is needed to make effective decisions is unavailable or inadequate. However, the effective management of these high impact dynamic project uncertainties can increase project value. The ubiquity and potency of dynamic uncertainties require that they be managed effectively if all the value in a given project is to be developed and captured. Project planners and managers who do not use strategic flexibility to recognize, develop, and exploit the latent project value available in dynamic uncertainties may significantly undervalue those projects.

A review of the literature reveals that the current management of construction uncertainty focuses on limiting project losses. This perspective has produced standard risk management processes that typically include identification, measurement, and mitigation. The prevalent perception of uncertainty only as something negative, that can only generate losses, is reflected in the four general methods of mitigating risk: avoidance, reduction, shifting or transfer, and assumption (CII, 1989). Although these processes provide some forms of flexibility to manage uncertainty and can effectively help reduce the negative effects of uncertainty, they presume loss (e.g., see Mak and Picken, 2000). They therefore limit managers' ability to recognize and exploit opportunities to increase project value. For example, managing uncertainty with contingencies presumes that undesirable conditions will develop, and prepares a project to absorb the potential costs. A perspective of uncertainty that focuses on potential losses constrains managers to mitigate negative consequences of uncertainty and draws attention away from increasing project value by managing all aspects of uncertainty.

To develop and realize more project value construction firms must, in addition to decreasing losses, exploit opportunities to increase project value by increasing income (if acting as an owner), decreasing costs, or both. Construction managers are aware of the potential benefits of uncertainty in projects. For example, experienced contractors with lump sum fixed project incomes understand that uncertainty in future prices may increase profits if prices fall or generate losses if prices rise. Many experienced construction project planners use flexible strategies to manage large projects, including processes similar to the one described here (Miller and Lessard, 2000). However, based on a study of 60 large engineering projects, Miller and Lessard concluded that the management of uncertainty for gain remains buried in intuitive management practices. Therefore it is unavailable for description, evaluation, improvement, and more widespread use. Miller and Lessard (2000) recommended the development of a real options framework to improve the planning of large engineering projects, but provided only a general description. Although uncertainty has been used in project portfolio management to manage construction firms, project planners and managers rarely, if ever, use a structured approach to proactively address dynamic uncertainty during the pre-project planning or management of individual projects. This is partially because it is difficult to assess the values of flexible strategies when relatively large uncertainties exist.

The purpose of this paper is to demonstrate the potential benefits of applying a real options approach to the strategic planning of construction projects and identify challenges in its implementation. To do this the next section specifies the problem of managing dynamic uncertainty and the role of strategic flexibility. A real options approach that can increase captured project value is then described, and an example based on a proposal for the construction and operation of a toll road is used to illustrate the potential of a real options approach for valuing strategic flexibility. This provides the basis for describing the potential effects of adopting a real options approach in construction planning and management, and for a discussion of valuation issues related to applying a real options approach to managing construction project uncertainty. Conclusions suggest fertile future research topics.

The challenges of managing uncertainty with strategic flexibility

Successfully managing dynamic, uncertain project conditions requires a proactive approach that perceives and models multiple possible future conditions, forecasts the outcomes of potential actions, and guides managers as projects develop. Such a proactive approach includes plans for specific actions that will be taken based on specific future conditions, and does not merely react to conditions after uncertainty has been resolved. This approach contrasts sharply with the paradigm 'The future is to be predicted, not chosen or created', that Meadows (1991, p. 4) suggests is endemic and a serious impediment to improving the design and management of complex systems. As an example, after identifying future prices of excavation work from subcontractors as an important project uncertainty, a general contractor might consider two strategies. The contractor could hire the excavation subcontractor with the lowest current price and negotiate with this subcontractor later if subsequent prices are too high. This is a reactive and rigid strategy. In contrast, the general contractor could initially pay an additional fee to the excavation subcontractor for the right to extend the contract for future work at a specified price. The general contractor would extend the contract if market prices rose above the specified price and not extend the contract and take market prices if prices fell below the specified price. This is a more proactive and flexible strategy. The general contractor's expected value is greater with the proactive strategy because it will pay only prices at or below the specified price, not the higher prices possible with the reactive strategy. The proactive strategy in this example may cost the general contractor the additional fee if future prices are low, but can significantly lower total costs by providing an option to purchase at the specified price if future market prices are high. Proactive flexible planning for uncertain prices and waiting to decide can increase the value of the project to the general contractor.

How valuable is this flexibility? How much additional fee should the general contractor be willing to pay the subcontractor for this option? How can planners and managers use flexibility to exploit the opportunities and mitigate the risks of uncertainties to capture latent construction project value? Few tools are currently available to construction managers for analysing the financial effects of uncertainties on project value (Ranasinghe, 1999) and none is known that address dynamic uncertainty. Traditional approaches to analysing alternatives (e.g. net present value analyses) take static perspectives of projects and alternatives by describing project strategies as fixed combinations of conditions and decisions that occur with fixed probabilities. However, strategic flexibility for managing dynamic uncertainty has been recognized as an important value-adding part of project management in several other domains. For example, Toyota's planned delays in selecting automobile systems has demonstrated the potential benefits of waiting for uncertainty to (partially) resolve before making important development decisions (Ward *et al.*, 1995). But the strategic approach used by Toyota has not been structured, nor have the costs and benefits been quantified, nor has the process been specified adequately for application to construction projects.

The roles of project participants relative to specific uncertainties are important in the management of uncertainty. Typically, construction project participants determine which organizations will receive the benefits and absorb the costs of dynamic uncertainties through risk allocation using traditional risk management processes. For example, the impacts of dynamic construction cost uncertainty would be borne by the owner if a cost-plus contract were used but by the general contractor if a lump sum contract were used. The general contractor could also shift a portion of that risk to subcontractors through the use of lump sum contracts with subcontractors. Risk allocation and the risk management processes that precede it determine who must manage specific dynamic uncertainties, but not how they should be managed. The proposed approach adopts the perspective of the project organization receiving the benefits and absorbing the costs of the uncertainties, regardless of risk allocation or which organization performs the strategic planning for the uncertainties. In the preceding example the general contractor with excavation work may gain or lose from planning for price changes and also performs the strategic planning. In the wharf example, however, the consulting firm takes the owner's perspective in planning for market demand uncertainty, even though the owner will probably benefit from or pay for the impacts of those uncertainties.

In the construction industry, design engineers, architects, owners, and contractors could apply a structured flexible approach to manage the uncertainties for which they are responsible. In addition, organizations that provide project planning services for others can apply the approach as a part of providing those services. More specifically, the target audience for this work is strategic project planners attempting to manage the dynamic uncertainties that benefit or are absorbed by the organization they represent. These persons use information such as revenue streams, cost estimates and forecasts, and schedules that are developed by experts using established tools and methods. Those established tools and methods are beyond the scope of this work. Therefore the information products generated by them are assumed to be provided to the project's strategic planners for use in developing strategies.

A real options approach to construction project strategy development

A real option is a right without an obligation to take specific future actions depending on how uncertain conditions evolve (Amram and Kulatilaka, 1999a). The central premise of real options theory is that, if future conditions are uncertain and changing the strategy later incurs substantial costs, then having flexible strategies and delaying decisions can have value when compared with making all strategic decisions during pre-project planning. Real options theory attempts to answer the questions: what are the future alternative actions; when should we choose between these actions to maximize value based on the evolution of conditions; and how much is the right to choose an alternative worth at any given time?

Real options theory is based on the approach developed to value and analyse options on financial assets (Black and Scholes, 1973; Cox *et al.*, 1979; Bookstaber, 1982). Methods for valuing options specifically on real assets have since been developed and analysed (Kemna and Vorst, 1990; Trigeorgis, 1993, 1995; Dixit and Pindyck, 1994; Brealey and Meyers, 2000), applied to engineering (Baldwin and Clark, 2000; Park and Herath, 2000; Benaroch, 2001), and promoted as a strategic planning aid by both academics (Kensinger, 1988; Bierman and Smidt, 1992; Amram and Kulatilaka, 1999b; Miller and Lessard, 2000) and practitioners (Leslie and Michaels, 1997). The options approach has been adapted to financial strategy (Myers, 1984; Trigeorgis, 1993). Real options have been used to capture latent value in many domains, including natural resources, research and development, technology, real estate, and product development (Kemna, 1993; Dixit and Pindyck, 1994; Trigeorgis, 1995; Amram and Kulatilaka, 1999a; Brennan and Trigeorgis, 2000; Benaroch, 2001). This work focuses on the application of a real options approach to individual construction projects.

Real options can be described along several dimensions, including ownership, the source of value, the complexity, and the degree to which the option is available. A common topology separates real options according to the type of managerial action applied (Dixit and Pindyck, 1994; Brealey and Meyers, 2000; Benaroch, 2001). One set of managerial action categories can include options that postpone (hold and phasing options), change the amount of investment (growth, scaling, and abandonment options), or alter the form of involvement (switching options). Many construction project plans can be described as real options. Designing and building foundations and columns to support more floors of an office building than are currently constructed creates and purchases an option to expand in the future by adding more floors. If the future availability of concrete is uncertain, building a concrete plant 'buys' an option to augment purchased concrete with internal production. Miller and Lessard (2000) provide additional examples of flexible strategies in large engineering projects that can be described as real options.

A real options approach to project valuation can be applied to the strategic planning and management of construction projects. The use of the approach potentially improves several aspects of project planning. A real options approach improves strategic thinking by helping planners recognize, design, and use flexible alternatives to manage dynamic uncertainty. By modelling the value-adding decisions that managers can make after uncertainty has been partially or wholly resolved, real options can reveal and quantify latent project value. In addition, specifying the managerial signals, decision rules and actions of project plans operationalizes flexible strategies for implementation. By improving project valuation and strategic plans, a real options approach can add precision and rigour to decision-making that engineers commonly apply to design but rarely to project planning. This work posits that construction managers currently do not exploit real options fully to capture the value of strategic flexibility, largely because they do not use a decision-making framework to recognize or quantify estimates of the value of options. The example in the next section illustrates one way to capture the value of design strategy alternatives, and an option to change strategies during the project.

A toll road project example

A simplified application is used next to illustrate the potential of real options to increase project value. Based on the application of a real options approach to strategy design at Shell International Petroleum Company, Kemna (1993) recommended focusing on one or a few simple options. Therefore, to facilitate illustrating the central focus of the current work, the example is simpler than an application that would be used in practice. In practice such an application would also include analyses of the feasibility of exercising the option and interactions of the option with other strategies and performance measures, the contract structure, contract terms and other project agreements.

Consider the challenges faced by the strategic project planners of a hypothetical large construction firm who are preparing a proposal to the government of a developing country to design, procure construction materials and services, build, and operate a toll road for 20 years. At the end of the 20 years the toll road will be turned over to the government at no additional cost. The estimated value of the project to the firm is the basis of the proposal. Because of the build-operate-transfer (BOT) structure of the project, the firm effectively owns and operates the toll road for 20 years and therefore absorbs the dynamic uncertainties associated with revenues as well as planning, design, and construction. If awarded the project, the government will require the firm to contractually obligate itself to open the toll road to traffic in eight years. Toll rates have been set by the host agency. Traffic projections have been estimated by the firm and used to forecast gross operating revenues. These are combined with the debt service, operating, maintenance, and other costs to estimate net operating revenues. Using an appropriate risk adjusted discount rate for net operating revenues based on existing similar toll roads (estimated to be 8%), the year eight value of the project net operating revenues is forecast to be $55 million.

Having addressed the net operating revenues, the planners turn their attention to project costs. Analysis reveals two critical issues in the strategic planning of the project: the timing of design and procurement, and the uncertainty of construction prices. The selection of a design strategy frames the planning decision, and initially two alternatives are identified. The first strategy is referred to as the basic design strategy (BD, Table 1), in which post-award project planning is expected to take a year. Design and contract document preparation could then be completed in an additional two years, at the earliest. The procurement of construction services could then begin. The design cannot be value engineered or include any productivity improvement modifications if it is to meet the BD schedule. Therefore a second strategy was developed, referred to as the engineered design strategy (ED), in which project planning is still expected to take a year and design and basic contract document preparation are still expected to take an additional two years. Here, however, the design will be value and productivity engineered. Since both value and productivity engineering require the majority of the design to be completed before they can begin, the six months required for value and productivity engineering would delay the completion of contract documents and the start of procurement by six months.

Table 1 Two toll road project design strategies

Time (years)	Design strategy	
	Basic design	Engineered design
0.0–1.0	planning	planning
1.0–3.0	basic design	basic design
3.0–3.5	procurement	value and productivity engineering
3.5–4.0	construction	procurement
4.0–8.0	construction	construction
8.0–20.0	operation	operation

The first question the planners struggle with is: how would delaying procurement to engineer the design affect project value? That is, should the design be stopped and procurement started three years into the project (the basic design strategy) or should procurement be delayed six months to value and productivity engineer the design (the engineered design strategy)?

The other critical issue faced by the planners concerns the uncertainty of construction costs. To promote the local economy the government requires that local firms perform most of the construction. The local construction market is volatile, resulting in the problem of fluctuating construction prices during the project. An analysis reveals that effectively managing construction price uncertainty could make the difference between profit and loss for the firm. The planners received estimates of several factors influencing construction costs from departments within the firm:

- Cost estimate of $4 million in current dollars for planning and basic design
- Cost estimate of $25 million in current dollars for construction costs
- A 10% design and construction costs risk adjusted discount rate, which is based on several similar projects[2]
- A standard deviation of approximately 15% per year for construction costs
- An 80% likelihood that prices increase over the 3 year period of planning and basic design and a 20% likelihood that prices decrease[3]

The selection of the basic or the engineered design strategy and the management of project cost uncertainty are interdependent because the project's value using each strategy depends on construction costs, and therefore on the uncertainty of those costs. Therefore another important question facing the planners is: how does construction cost uncertainty affect project value using each design strategy, and therefore the design strategy decision?

Valuing design strategy alternatives

Using the information provided, the planners forecast the expected net present value of the basic design strategy $E[BD_0]$ to be \$0.71 million.

$$E[BD_0] = (55.00/1.08^8) - 4.00 - 25.00 = 29.71 - 29.00 = 0.71 \quad (1)$$

Note that committing to the basic design strategy during pre-project planning does not include any options, and precludes the firm from influencing what costs it incurs after the project begins. The firm therefore has no opportunity to increase project value by waiting for construction cost uncertainty to resolve before making the final design strategy decision.

The engineered design strategy would have several effects on the project when compared with the basic design strategy. Design costs would increase because of the additional effort required for value and productivity engineering. Procurement and construction would have to be completed in six months less time. If productivity gains do not reduce construction duration by at least six months, acceleration costs will be incurred to meet the deadline for the start of operations. On the other hand, construction costs would be expected to significantly decrease because of value and productivity engineering. The planners received the following information about the engineered design strategy from departments within the firm.

- Cost estimate in year 3 dollars of \$7 million for additional project costs
- Estimated 25% reduction in construction costs
- Total construction cost estimates in year 3 dollars of \$37.71 million if costs rise and \$15.53 million if costs fall, not including savings due to engineering the design

If construction costs have risen from year 0 to year 3, the expected net construction costs using the engineered design strategy $E[CC_{\text{up year3}}]$ is \$35.28 million.

$$E[CC_{\text{up year3}}] = (0.75 \times 37.71) + 7.00 = 35.28 \quad (2)$$

Similarly if construction costs have decreased, the year 3 expected net construction cost using the engineered design strategy $E[CC_{\text{down year3}}]$ is \$18.65 million.

If the design is engineered regardless of how costs evolve, the planners forecast the expected net present value of the engineered design strategy $E[ED_0]$ to be \$1.71 million.

$$E[ED_0] = (55.00/1.08^8) - 4.00 - [\{(80\% \times 35.28) + (20\% \times 18.65)\}/(1.10)^3] = 1.71 \quad (3)$$

Although the engineered design strategy is more valuable than the basic design strategy, committing to the engineered design strategy during proposal preparation also includes no options. It provides no flexibility to capture more project value as cost uncertainty is resolved. As will be shown next, the engineered design strategy is the optimal strategy if costs increase, but not if costs decrease.

What is needed more than the basic or engineered design strategy is a flexible strategy. Such a flexible design strategy (FD) would postpone the decision on choice of design strategy to use until year 3, when construction cost uncertainty is partially resolved. To develop an intuitive understanding of how the flexible design strategy can add project value, consider the effect of the engineered design strategy under two scenarios: if costs increase or decrease. If costs increase from year 0 to year 3, it makes sense to do value and productivity engineering because the savings (0.25×37.71 = \$9.43 million) exceed the \$7 million additional cost. On the other hand, the firm would prefer the basic design strategy if costs fall from year 0 to year 3 because the savings (0.25×15.53 = \$3.88 million) are less than the additional cost of \$7 million.

A strategy that can use the basic or engineered design strategy, depending on the evolution of construction costs, is preferred over either design strategy applied rigidly.

What is the value of such a flexible strategy? The flexible design strategy can be valued by using engineered design strategy construction costs if costs rise and basic design strategy construction costs if costs fall. Although the following approach to valuation is not precise, for reasons discussed next, it illustrates the potential of improving construction project planning using a real option approach. Project planners forecast the expected present value of the project using the flexible design strategy value $E[FD_0]$ to be \$2.18 million.

$$E[FD_0] = (55.00/1.08^8) - 4.00 - [\{(80\% \times 35.28) + (20\% \times 15.53)\}/(1.10)^3] = 2.18 \quad (4)$$

The above value of the project using the flexible design strategy was determined using a decision tree analysis, combined with a traditional discounted cash flow analysis that assumes symmetrical net profits or losses. However, the flexible design strategy results in an asymmetric distribution of payoffs and, therefore the 10% discount rate used for the flexibility is technically not correct. The value of this flexibility can be modelled with a binomial option pricing models (Cox *et al.*, 1979) to account properly for the asymmetry. If the flexibility is modelled as a call option, the value of the basic design strategy (\$0.71 million) is added to the value of the option to switch to the engineered design strategy if construction costs increase (\$1.01 million, assuming 5% annual risk-free rate) to estimate the value of the flexible design strategy as \$1.72 million. Alternatively, if modelled as a put option, the value of the engineered design strategy (\$1.71 million) is added to the option to switch to the basic design strategy if construction costs fall (\$1.39 million, assuming 5% annual risk-free rate) and the value of the flexible design strategy is \$3.10 million. Although the valuations from the different pricing models differ, the strategy recommendation does not change. The planners should select the flexible design strategy, engineer the design only if prices rise, and (based on equation 4) use a project value of \$2.18 million in its proposal. This consistency in recommendations despite value differences occurs throughout the application of real options pricing models, and is not a coincidence or unique feature of this example.

The flexibility provided by the flexible design strategy adds both monetary value (Table 2) and strategic value to the toll road project. The flexible design strategy adds \$1.47 million (6% of the expected construction costs) to the basic design strategy and \$0.47 million to the engineered design strategy. In addition, by identifying and designing multiple possible paths through the project, the firm moves from planning and managing in a narrow and constrained way to a broader spectrum of scenarios and actions from which the firm may choose. Of particular note is that the value of the flexibility is captured only by recognizing and modelling this latent project value, and that doing so requires minimal additional resources.

Real option valuation challenges

Important valuation issues must be addressed to apply real options to strategic construction management. Lander and Pinches (1998) described the challenges of practically modelling and implementing a real options approach. With regard to construction planning and management the key challenge relates to the appropriateness of the assumptions used to model financial assets with options pricing models for modelling construction project benefits and costs over time. Traditional options pricing models assume that values follow a well defined diffusion process (typically geometric Brownian motion), and that returns are normally distributed. Typically, only one, possibly two, sources of uncertainty are modelled. These approaches are adequate for assets that are widely and openly traded, but accurately modelling the evolution of construction project benefits and costs requires a model that reflects the dynamic interactions among the drivers of project performance and multiple interacting sources of uncertainty. An approach to designing and valuing options is needed that predicts project values over time explicitly for specific strategies, projects, and uncertainties, based on the drivers of construction project performance.

Valuation issues also arise concerning the discounting of benefits and costs. Correct and exact discount rates are difficult to determine because of the need to reflect market risks and potentially unique project risks, as well as asymmetric payoffs. Although real options can be valued with approximate discount rates, improved estimates are needed for cases in which the discount rate can change recommendations.

Table 2 Estimated project values using three design strategies (× \$1 m): toll road project example

Design strategy	Estimated project value	Improvement over basic design strategy	Improvement over engineered design strategy
Basic	0.71	0.00	N.A.
Engineered	1.71	1.00	0.00
Flexible	2.18	1.47	0.47

Conclusions

Frequently managers do not capture project value that is hidden in dynamic uncertainty but is available through the use of flexible strategies. This may lead them to undervalue projects, forego available returns, limit their influence over project outcomes, and thereby lose competitiveness. As currently practiced, the use of flexibility in project management is not structured adequately to provide useful strategy design and valuation tools. Valuing real options in projects has been demonstrated to potentially increase project value by explicitly designing specific uses of managerial flexibility during projects and valuing that flexibility in pre-project planning. However, several important challenges must be overcome to gain the full benefits of real options in construction planning.

Based on previous applications of real options theory, the literature, and the example above, the explicit incorporation and valuation of options in construction project planning can help correct project undervaluation and expand the control of project planners and managers by increasing the number of available scenarios. Specific dynamic uncertainties can be managed and their value captured by designing, valuing, and implementing flexible strategies. The regular use of real options could have several effects on construction project planning and management practice, as follows.

- Increased description, measurement, and management of project uncertainties
- More planning and management flexibility and thereby improved control through increased

numbers of project scenarios which firms design and select from to capture project value

- More purposeful and planned project strategies, managerial decisions, and actions as real options strategies are implemented
- Increased firm competitiveness from the ability to manage uncertainty and capture latent project value
- Expanded perceptions of uncertainty that include opportunities as well as risks

These impacts suggest that potentially large improvements to construction management could result from the development and adoption of a structured real options approach. The last effect listed above may eventually be the largest. Because option values increase with uncertainty, firms that develop expertise in using real options may seek out high uncertainty projects or assume avoidable risks to obtain opportunities to capture latent project value. The ability to manage uncertainty could be developed as a strategic advantage (Collis and Montgomery, 1995), and highly uncertain projects could become a profitable market niche.

This work identifies the recognition, modelling, and capture of latent project value generated by dynamic uncertainty as an important but under-investigated aspect of construction project management. It describes the use of options in strategic project planning as a means of improving project management. Although the application of a real options approach to strategic construction project management can potentially improve construction management, additional research is required into several aspects of its implementation. These include the development of a structured and implementable strategy design process that explicitly includes options, the causal modelling of the impacts of uncertainty on project cash flows and values, and the relationship between flexibility in project strategies, flexible corporate strategies, and meeting corporate objectives. Some initial work in these areas has begun (Benaroch, 2001; Ford *et al.*, 2002). Such research will improve our understanding of project uncertainty and flexibility, and will lead to improved construction project performance.

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Endnotes

1. Lessard and Miller (2001) include the concept of dynamic uncertainty in their term 'dynamic complexity' which, they claim, must be managed with flexibility in the form of options.
2. Discount rates and the standard deviations were developed iteratively to find consistent values, i.e. to maintain consistency between cost projections forecast with standard deviations, the expected values forecast with the discount rate, and options pricing models (Black and Scholes, 1973; Cox *et al.*, 1979). An initial assumption of a standard deviation of 15% was used. Iteration resulted in the use of a standard deviation of 14.68% per year for the construction costs.
3. Increasing costs are considered more likely because the local builders expect an increase in demand for construction due to the toll road project itself, and they are aware of the requirement to use local construction firms.