AN OPTION BASED MODEL FOR EVALUATING ADR INVESTMENTS IN DESIGN AND CONSTRUCTION PROJECTS

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ABSTRACT

Many architecture, engineering, and construction professionals advocate the use of Alternative Dispute Resolution (ADR) techniques to mitigate and reduce the impact of claims on a construction project's budget, schedule, quality, and environment. However, some of the ADR techniques require additional capital expenditures that need to be justified both economically and politically.

This paper investigates the use of option pricing theory and real option pricing to evaluate cost/benefit tradeoffs associated with ADR investments in design and construction projects. The real options associated with such an investment include options to defer, abandon, expand, and stage investments. These real options enhance the project manager's capability to make well-calculated decisions as uncertainty surrounding the source; the time of occurrence and the cost implications of a particular claim unfold in a design and construction project.

A quantitative model and decision support system to evaluate the real options of an ADR investment in a project is presented. The evaluation in the model is based on the binomial valuation method, which allows simplified valuation of options at discrete times during the project life cycle. Additionally, a hypothetical example is presented to illustrate the application of real option pricing to evaluate an ADR investment strategy in a construction project.

KEY WORDS

Design and Construction Projects, Cost/Benefit Tradeoffs of ADR Investment, Option Pricing Theory, Real Options, Binomial Model

INTRODUCTION

The Design and Construction industry plays a vital role in the "economic health" of the United States as seen from its contribution to the Gross Domestic Product, which totaled $1.03 trillion in 2004, nearly 9 percent of the total GDP (AGC 2005).

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This industry also provides employment opportunities to more than 7.0 million individuals, approximately 5 percent of the non-farm workforce (AGC 2005, BEA 2004). On the other hand, Internal Revenue Service data indicates that only 60 percent of the 624,000 AEC corporations were able to make profits in 2001 with net income as low as 3 percent of the total receipts (Cited by AGC 2005). This "low margin" of profit can be attributed to the fact that presently, AEC corporations are continuously challenged to design/build large and technically complex projects within the framework of various constraints related to budget, schedule, social and environmental laws, and lack of risk sharing between project participants (Peña-Mora et al. 2003, Fenn et al. 1998).

Focusing on risk sharing, considerable evidence indicates that claims related to design/specifications changes, differing site conditions, construction delays/accelerations and ambiguous contract clauses are an inevitable experience to all project participants (Lee et al 2004, Peña-Mora et al. 2003, Rubin et al. 1999, Diekmann et al. 1994 and 1995, Barrie and Paulson 1992, Adrian 1988). These claims occur for a variety of reasons related to key project characteristics such as lack of equitable risk sharing, inappropraite contract type, change orders, differering site conditions, incomplete scope definition and errors in design to name a few. Accordingly, uncertainty surrounding the time of occurence and impact of these claims on a construction project will vary depending on the project environment. A claim due to changes in the design will have a more pronounced impact in a traditional design-bid-build project than in design build project where the contractor is responsible for both the design and construction of the project. Also, at any given time during the project life cycle, any or a combination of claims with different levels of severity may exist. It is estimated that the AEC industry in the US spends $13-26 billion per year on change orders and claims with total costs reaching as high as $50 billion when the additional expenses of legal disputes are added (Ibbs et al 1998-Cited by Hanna and Gunduz 2004). Accordingly, claims have become a key variable in construction project management that needs to be controlled just like cost, schedule, quality, and safety (CII 2005). The construction industry has developed a number of Alternative Dispute Resolution (ADR) techniques (See Figure 1) to manage conflicts and claims as early as possible, and minimize costs (Peña-Mora et al. 2003, Fenn et al. 1998, CII 1995).

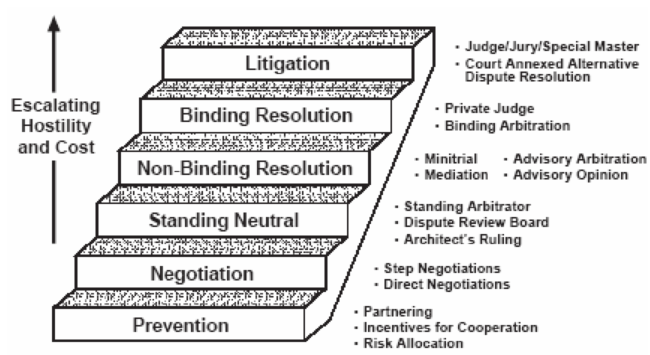


Figure 1: Alternative Dispute Resolution Techniques (CII 1995)

Given all the uncertainties surrounding the occurence of claims in a construction project, it becomes necessary to develop a project specific dispute resolution ladder (DRL) to address the different types of conflicts and claims depending on their severity and time of occurence in the project (Pena Mora et al. 2003, CII 1995). AGC 2000 suggest that the project be divided into three distinct stages for dispute resolution as follows:

1. **Project Planning Phase:** during this phase parties identify issues that may affect the successful completion of the project. ADR techniques that might be considered during this phase include prevention, negotiation and partnering agreements. These techniques require little or no capital expenditures unless training of personnel is envisaged.
2. **On-site Dispute Resolution:** during this phase parties need to address any claims as early as possible to avoid delays, higher costs and reduced productivity. ADR techniques to promptly address these issues need to be selected from the six step ladder. This will allow parties to have a pre-determined plan to address claims at all levels of escalation through the DRL and provide them with incentives to resolve claims as early as possible. At the same time, most of these techniques require capital expenditure especially when it comes to employing external resources like in Dispute Review Boards. The amount and timing of these expenditures need to be carefully considered especially in projects with budget constraints.
3. **Dispute Resolution After Project Completion:** reaching mutually agreeable solutions to resolve claims at this phase of the project becomes extremely difficult. Claims at this phase usually escalate into disputes that can only be resolved through litigation. Costs and time required to resolve these disputes increase tremendously, while parties lose complete control over the outcome of the process (Peña-Mora et al. 2003, Fenn et al. 1998).

The owner of a construction project needs to make early decisions regarding what ADR techniques to incorporate in the project to ensure that claims are addressed as they arise during the project life cycle, and not postponed until issues escalate into legal disputes (CII 2005, AGC 2000). However, a number of uncertainties need to be clarified prior to making the early decision. Such uncertainties include the nature of the claims, their time of occurrence, the effectiveness of the chosen ADR in addressing the situation, and the anticipated cost savings relative to the expenditures required to implement the ADR. From the owner's perspective, these uncertainties need to be taken into consideration when valuing the ADR investments to ensure that additional expenses incurred are justifiable in terms of the perceived savings in the project. This paper presents a framework and a system for valuing the cost/benefit tradeoffs of an ADR implementation using option pricing and real option theory.

OPTION PRICING AND REAL OPTION THEORIES

Options on traded assets like stocks, foreign currencies and commodities give the holder the right to buy (call options) or sell (put options) these assets at a fixed price referred to as the exercise price on or before expiration date (Hull 1999, Cox et al. 1979, Black and Scholes 1973). European options can be exercised on the expiration date only, while American options can be exercised any time before expiration. Options offer the investor the flexibility to postpone investment decisions until information about future market conditions become available. This increases the upside potential of the investment whereby buying/selling occur only if market conditions are favorable and positive payoffs are realized. On the other hand the down side losses are "capped" down to zero (no negative payoffs) if the market conditions are not favorable (Fichman and Tiwana 2005, Trigeorgis 1993).

The application of option pricing theory in capital investment decisions comes in the form of Real Options, which exploits the fact that "investment flexibility" in real (that is, non-financial) projects, e.g. the ability to defer investment or expand, contract, or abandon a project, is analogous to financial options (Boute 2004, Trigeorgis 1993). For example, investments made to acquire a real asset in analogous to Call Options while disposing of a real asset for a salvage value is similar to exercising a Put Option (Fichman and Tiwana 2005, Luehrman 1995). Real options are "active" management tools that provide the decision maker with the flexibility to change the course of an investment, as more information regarding the uncertain future cash flows becomes available (Teach 2003, Trigeorgis 1993). Options to defer, expand, stage, or abandon the investment at any time in response to changes in the future circumstances of the project add more value to a project (Boute 2004, Mbuthia 2001, Trigeorgis 1996, Nichols 1994, Sick 1989). The market value of the real options depends on the value of the underlying asset (e.g., project cash flows), and how this value changes during the life of the project due to inherent uncertainties (Ng 2004, Trigeorgis 1996).

Real options have been used as a financial valuation technique for different types of capital budgeting endeavours where flexibility and active decision making is essential for the success of the project under uncertainty. Examples from literature inlude: oil reserve start up projects (Trigeorgis 1993 and 1996), IT project managment (Fichman et. Al 1995), cable industry (Desai et al. 2001), and pharmaceutical product research and development projects (Copeland and Tufano 2004). The literature review also indicates that the applicability of real options to construction managment has been researched in a variety of situations. For example, Ho and Liu (2003) presented a model to evaluate single and multi investments in A/E/C technologies, Ng and Bjornsson (2004) discussed the use of real options to evaluate alternative investment strategies in A/E/C projects, Boute et al. (2004) evaluated the added value from re-scheduling a project when additional information become available. Finally, Savva and Scholtes (2005) discussed the how embedded options in partnership deals create value to the project and its participants.

ADR AS REAL OPTIONS

As in any investment opportunity, the perceived benefits (e.g., estimated savings in the project due to claim avoidance and mitigation) from any ADR implementation must outweigh its costs for it to be worthwhile. Traditional valuation tools like the Net Present Value can be used to perform this analysis when explicit assumptions regarding the expected future cash flows (cost of ADR implementation and perceived savings in project) can be made with certainty. However, the occurrence of conflicts and claims in the project is directly related to a set of key project characteristics that can only be defined with certainty once the project is under way. This implies that early assumptions regarding the cash flows are difficult if not impossible to make during the project planning and budgeting phase. An owner who does not know whether a given ADR will be needed to resolve claims that might arise in the project due to certain project indicators, will consider a full investment in the ADR at the beginning of the project a risky endeavour. Therefore, having the option to invest a small amount of money or defering the investment until a conflict occurs and more information about the anticipated claim become available would be a more realistic approach to the owner. If favorable project conditions prevail and the ADR is not implemented, then the owner's loss will be limited to a small initial investment. On the other hand, if claims escalate to a level where resolution can only be achieved through a particular ADR implementation, then the option to implement the ADR is still available and can be exercised. In this situation, real option valuation tools will provide the owner with more flexibility to manage ADR investments as the uncertainties surrounding the claim occurrence unfolds during the construction phase of the project. Table 1 shows an analogy of how the most common real options can be used to create value for ADR investments.

Table 1: Applicability of Common Real Options to ADR Investments

Real Option Category	**Definitions (All definitions are adopted from Fichman et al. 2005)**	**Application to Investments in ADR**
Option to Stage	The project is divided into distinct stages. The costs/benefits of a completed stage are assessed to determine if subsequent stages can be pursued.	The DRL can be divided into stages depending on how a claim escalates. First level resolution might involve negotiations followed by a standing neutral advisor if claims are not being resolved at the lower level.
Option to Abandon	Terminate a project anytime prior to completion and deploy resources to other projects.	If the ADR has no significant effect in reducing the impact of the claims in the project, then it can be abandoned.
Option to Defer	A decision on whether to invest in a project can be postponed without imperiling the potential benefits	A decision to employ an ADR to resolve claims during construction can be made during the planning phase of the project, but the required investment can deferred until the construction begins.
Option to Grow	An initial baseline investment allows the project managers to pursue a variety of follow on opportunities.	Expand the work of the advisory arbitration board to include mediation. The board will be responsible to collect information about the claims while the mediator will be responsible to assess the facts and issue non-binding recommendations to the parties.
Option to Reduce	Reduce current scale of the project and save costs.	Reduce the scope of a Standing Arbitrator in case anticipated claims do not occur or are being resolved by another less costly ADR technique like negotiation
Option to Switch	An asset developed for one purpose can be switched or redeployed to serve another purpose	A Dispute Review Board hired to handle claims of a given project can be re-deployed to another more problematic projects.

VALUING ADR INVESTMENTS AS REAL OPTIONS

The modern theory of option pricing dates to 1973 when Black and Scholes presented the first satisfying formula for valuing European call/put options as a function of the price of the underlying common stock and time (Black and Scholes 1973). In 1979, Cox et al. described a simple "risk-neutral" approach to option pricing using binomial trees that simplifies and facilitates analysis and computation (Copeland and Tufano 2004, Cox et. Al 1979). The essence of modern option pricing theory is that the absence of arbitrage opportunities in a financial market (the absence of the ability to get something for nothing) is equivalent to the existence of so-called risk-neutral probabilities that can be used for valuation. "Such risk neutral valuation enables present value discounting, at the risk free interest rate, of expected future payoffs". (Trigeorgis 1993, Cox et al. 1979) A second method to valuing options that yields identical results to the "risk-neutral" approach is the replicating portfolio technique. In this approach, a portfolio that consists of buying/selling a number of shares of the underlying asset, and borrowing/lending against them a certain amount of money at the risk free interest rate is constructed. The number of shares and amount borrowed/deposited shall be such that the portfolio replicates the payoffs from the option in any state (Copeland and Tufano 2004, Boute et al. 2004, Brealey and Myers 2000). The application of the binomial method in valuing ADR investments in a construction project will be illustrated with an example.

HYPOTHETICAL EXAMPLE

Suppose that the owner of a construction project is considering a customized two DRL to prevent and resolve claims during the planning and construction phase of the project. The construction on the project is planned to start one year from now, with an estimated five years to completion. Based on key project characteristics, he estimates that project conflict profile will be as shown in Figure 2 below. The number of claims in the project will reach a maximum ($C2D_M$) during the construction phase with some residual claims ($C2D_R$) at the end of the project in case no ADR technique is implemented. The DRL consists of:

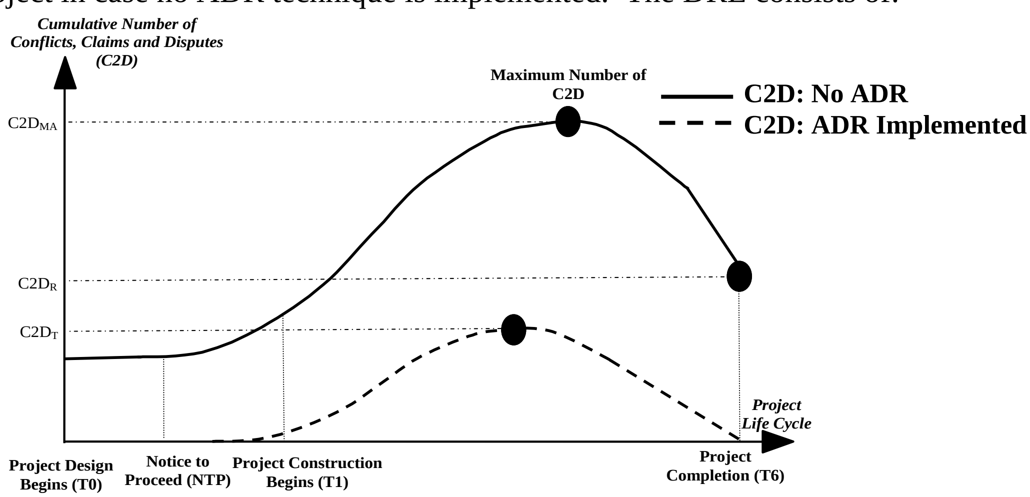


Figure 2: Project Conflict Profile (Adapted from Peña Mora et al. 2003)

Step 1 – Partnering: will involve establishing a long term strategy, training and team building during the planning phase the project (between T0 an T1) followed by implementation during the construction phase and project close-out. The implementation of partnering during the construction phase will encourage parties to resolve any conflicts through negotiation. A single investment of $ 35 K is required at time T0 mainly to setup the basis for partnering and train the necessary resources. The owner anticipates that partnering will facilitate resolution of several claims during the construction phase resulting in the following savings in project budget.

Partnering (ADR1)	Period	T0	T1	T2	T3	T4	T5
	Cash Flows ($)	-35K	+5K	+10K	+20K	+10K	+5K

Step 2 - Dispute Review Board (DRB): which includes three independent construction experts to be selected by the contracting parties. The responsibilities of the DRB include conducting regular site visits to monitor the progress of the work. Thus, the DRB is kept fully aware of the construction process and interfere to resolve claims when parties fail to reach a mutual agreement through the on site implementation of partnering. Although the board's recommendations are non-binding, the partnering process in Step 1 will facilitate the work of the DRB and encourage the contracting parties to abide with these recommendations. Again, a single investment of $450 K in required at the start of construction (T1), and allow the owner to realize the following savings in the project budget.

Dispute Review Board (ADR 2)	Period	T1	T2	T3	T4	T5	T6
	Cash Flows ($)	-450K	+60K	+59K	+195K	+310K	+125K

VALUATION USING TRADITIONAL NET PRESENT VALUE (NPV)

The owner first considers the case with no flexibility whereby the information available today is used to decide whether to invest in the proposed dispute resolution ladder. Given that the opportunity cost of capital (k) is 15 percent and the annual risk free-interest rate (rf) is 10 percent. The resulting net present value is as follows:

ADR 1	Period	T0	T1	T2	T3	T4	T5
	Cash Flows: CF_i ($)	-35K	+5K	+10K	+20K	+10K	+5K
	Discounted Cash Flows: $CF_{i0} = CFi/(1+k)^n$ ($)	-	+4.35K	+7.6K	+13.2K	+5.7K	+2.5K
Capital Investment: I_1 = -$35 K **Current year (T0) anticipated savings in the project: V_1 at 15 % = $33.35 K** **Net Present Value (T0 money): NPV_1 = -$1.65 K**							
ADR 2	Period	T1	T2	T3	T4	T5	T6
	Cash Flows: CF_i ($)	-450K	+60K	+59K	+150K	+250K	+125K
	Current Year Cash Flows: $CF_{i0} = CFi/(1+k)^n$ ($)	-	+52K	+45K	+99K	+143K	+62K
Capital Investment: I_2 = -$450 K **Current year (T1) anticipated savings in the project: V_2 at 15 % = $ 401K** **Net Present Value (T1 money): NPV_2 = - $49 K**							

Given the negative NPV's for both investments, the optimal decision in this case would be not to invest in any of the proposed ADR techniques. However, such a decision implies that the project manager will loose the managerial flexibility that these ADR techniques provide in case claims escalate in the project especially that he is basing his decisions on cash flows that are very difficult to predict with complete certainty at this stage of the project.

VALUATION USING REAL OPTION ANALYSIS

In order to overcome the uncertainty surrounding the anticipated cash flows from the implementation of both ADR techniques, the project manager decides to value the investment using the binomial method for valuing real options in capital investment projects.

This encompasses three major issues: recognition that there is an option, formulation of the problem in the form of a real option and evaluation of the real option (adapted from Samii 2001).

Recognize The Option

The owner realizes that investing in partnering process is necessary although the perceived benefits are not immediately realized. This process will introduce significant improvements to the way that claims are handled during the construction process. In addition, investing in the partnering process will set the grounds for the effective incorporation of the Dispute Review Board during the construction phase. The decision to invest in the Dispute Review Board has to be made three years from now which gives the project manager ample time to evaluate this decision. If partnering were successfully implemented, then the project manager would expect that most of the claims would be resolved through negotiation at no extra cost. However, if parties fail to achieve the partnering objectives then the expected number of unresolved claims will escalate and introduction of a third party neutral becomes necessary to facilitate the resolution. At that time, the net savings in the project anticipated from employing the Dispute Review Board can be estimated more accurately because uncertainty concerning the expected number of claims and their impact on the project budget, schedule, quality, and environment is reduced.

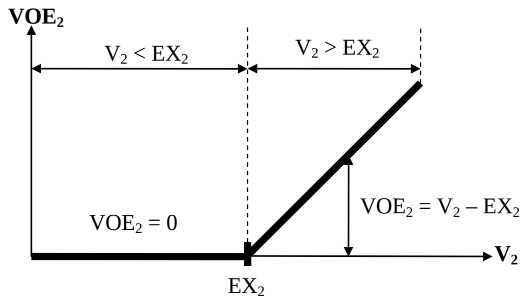
Formulate The Problem In The Form Of An Option

In terms of real options, this is analogous to the option to stage the investment into two distinct phases where investing in the second stage (DRB) is contingent on the results of partnering. This option is similar to having a European Call Option to invest in a DRB with the following terms:
- **Expiration Date:** One year from now or T1
- **Exercise Price (EX_2):** Capital investment required at T1 or I_2 = $450 K
- **Value of the Underlying Asset (V_2):** Expected Savings in the project between T1 and T6
- **Value of the Option (VOE_2):** This value can be zero or positive (See Figure 3)

Evaluate The Option

The first step in evaluating the option using the binomial method involves determining the present time T0 value of the anticipated savings in the project using the opportunity cost of capital (k), $P(V2) = V2/(1+k)^1 = 401/(1+0.15)^1$ = $ 349 K. This value is required to draw the binomial or event tree showing the possible future values of V2 between T0 and T1, the time when the decision to invest in ADR2 needs to be made. Most real option calculations in literature assume that the value of the underlying asset either goes up by an amount $u = \exp(\sigma \times t^{0.5})$ or down by an amount $d=1/u$ (Copeland and Tufano 2004, Luehrman 1995, Teach 2003, Trigeorgis 1996 and 1993). The challenge is to determine the volatility σ of the underlying asset. This can be done is several ways as follows (Copeland & Tufano 2004, Teach 2003, Luehrman 1995):
1. Volatility can be estimated if we have enough historical data from investment returns on similar projects

2. If historical data does not exist it can be created by first identifying the assumptions driving the bottom line of the project, and projecting the future cash flows based on these assumptions. The spreadsheet based projections of a project's future cash flows, together with Monte Carlo simulation techniques can be used to synthesize a probability distribution for project returns and the standard deviation σ of the distribution can be used as the volatility
3. Alternatively, take a guess. Recommended values range between 20 and 30 percent.



If V_2 <= EX_2 thenVOE_2 = 0
If V_2 > EX_2 then $VOE_2 = V_2 - EX_2$
V_2 = Sum of discounted cash flows between T3 and T8

Figure 3: Value of the Option to Stage Investment – Invest in ADR_2 at T_1

In our example, we will assume that the volatility is 30 percent, so that u = 1.35 and d= 0.74. Figure 4 shows the event tree for the anticipated savings in the project due to the investment in ADR2. Finally, the value of keeping the option alive between T0 and T1 is calculated as follows:

- At T1: V2 = $ 472 K or $ 258 K and EX2 = $450 K
- VOE2 = 472 -450 = $ 22 K and zero for the other case.

Subsequent values of the option are calculated using the Replicating Portfolio Technique which allows us to discount cash flows when the appropriate discount rate cannot be determined before hand (it is impossible to set a discount rate to reflect the risk of keeping the option alive) (Copeland and Tufano 2004). The replicate portfolio will have the same payoffs as the option at any given time; therefore, it also has the same present value. This technique is used to discount the two option values at time T1 ($22 K and 0) to the current time T0. For a call option, the replicating portfolio would consist of buying (m) number of shares of the underlying asset (expected savings in the project) and borrowing against it an amount B at the risk free interest rate r_f.

- VOE2 (T1) is $22 K or $0 K
- m x 427 – (1 + rf) x B = 22 and m x 258 – (1 + rf) x B = 0
  Solving the two equations for m and B we get: m = 0.13 and B = $ 30.5 K
- **VOE2 [T0] = m x V_2 [T0] + B / (1+rf) = 0.13 x 427 – 30.5/1.1 = $27.8M**

Expected Savings in Project (V_2)

	$472 K
$349 K	
	$258 K
T0	**T1 (Expiration Date)**

Value of the Option to Stage (VOE_2)

	$22 K
$53.71 K	
	$0 K
T0	**T1 (Expiration Date)**

Figure 4: Binomial Trees for V_2 and VOE_2

The modified net present value at time T0 (now) due to the call option to invest in a DRB when construction begins can be determined using the expanded net present value equation which includes two main components: the "passive" net present value (obtained using the NPV valuation) and the "active" real option value (Trigeorgis 1993):

$$\text{Expanded NPV}_1 = \text{"Passive" NPV}_1 + \text{Value of Real Options from Active Management}$$

$$\text{Expanded NPV}_1 = -\,\$\,1.65\text{ K} + \$\,27.8\text{ K} = \$\,26.15\text{ K}$$

Thus, the net present value of investing in Partnering while keeping the option to invest in a DRB in three years is positive indicating that the option is valuable.

SYSTEM DYNAMICS MODEL

The quantitative model and decision support system to evaluate cost/benefit tradeoff of an ADR investment in construction projects is developed using system dynamics. The field of system dynamics originated in the 1960s with the work of Jay Forrester (Ford 1999). Forrester et al. (1969) developed the initial ideas by applying concepts of feedback control theory to the study of industrial systems. It models the key interrelationships in an organization and focuses on the behavioral trends of projects and their relationship to managerial strategies. Dynamic models describe how the system changes with time, and explain the "physical forces" leading to this change (Ford 1999).

The implementation of system dynamics to evaluate ADR investments will allow us to develop a model that simulates the uncertainties surrounding the implementation of ADR during the life of the construction project. Such a simulation will identify the parameters that will have the most significant impact on the value of the ADR investment. The owner, in this case, will be able to monitor variations in these parameters as the project progresses, and input any significant changes in the base model to determine whether the ADR investment is still worthwhile or can be terminated/abandoned. Also, the effect of holding the option on the ADR for a longer/shorter period on the expanded net present value shall be determined to allow the owner to exercise the option on the ADR at the optimal time during the life of the project.The system dynamics model will build on the previous work done by Peña-Mora and Tamaki (1999). They developed a system for the analysis of ADR implementation based on number of conflicts and claims as specified by the user for three main sources of conflicts: Project Uncertainty, Process Issues, and People Problems. This system allowed the comparison of the number of conflicts based on ADR implementation at different levels of the dispute resolution ladder.

CONCLUSIONS

This paper presented some preliminary results of the research being conducted to determine the applicability of option pricing and real option theories to evaluate cost/benefit tradeoffs of ADR implementation to resolve claims in construction projects. Real options will give the owner the flexibility to postpone ADR expenditures during the project planning phase until more information surrounding the occurrence of claims during the construction of the project become available. At that time a more calculated decision can be made on whether to go ahead and invest in the ADR techniques, expand the scope of an already available ADR technique, or reduce the scale/abandon the application of the ADR Technique.

REFERENCES

Adrian, J. (1988). *Construction Claims: A Quantitative Approach*. Prentice-Hall, New Jersey.

Associated General Contractors of America (2005). *Quick Facts About the Construction Industry*. Downloaded on 09/15/05. (available at http://www.agc.org/galleries/default-file/quick%20facts.pdf)

Associated General Contractors of America (2000). *A Quick Primer on Construction Risks and Contracting Practices*. Downloaded on 01/15/06. (available at http://www.agc.org/)

Associated General Contractors of America (2000). *Enlightened Risk Allocation – The 21st Century Owner's Guide to Cost Effectiveness*. Downloaded on 01/15/06. (available at http://www.agc.org/)

Black, F. and Scholes, M. (1973). "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy*, 81 (3), 637 – 654.

Barrie, P. and Paulson, B. (1992). *Professional Construction Management (3rd Ed.)*. McGraw Hill, Inc., Singapore.

Bureau of Economic Analysis – BEA. (2005). "Table 6.5D. Full Time Equivalent Employees by Industry." Downloaded on 09/09/05. (available at <http://www.bea.doc.gov/bea/dn/nipaweb/TableView.asp?SelectedTable=186&FirstYear=2003&LastYear=2004&Freq=Year)

Boute, R., Demeulemeester, E., and Herroelen, W. (2004). "A Real Options Approach to Project Management." *International Journal of Production Research*, Taylor and Francis Group, 42 (9), 1715-1725.

Copland, T. and Tufano, P. (2004). "A Real World Way to Manage Real Options." *Harvard Business Review*, 82(3), 1-12.

Cox, C., Ross, S., and Rubinstein, M. (1979). "Option Pricing: A Simplified Approach." *Journal of Financial Economics*, North-Holland Publishing Company, 7, 229-263.

Groton, J., Blumenfeld, A., and Ratterman, D. (2005). *How to Keep Your Project Out of Litigation, Arbitration, and Even Mediation*. Construction Industry Institute Annual Conference, Grapevine, Texas.

Diekmann, J., Girard, E., and Abdul-Hadi, P. (1994). *DPI- Dispute Potential Index: A Study into the Predictability of Contract Disputes*. Construction Industry Institute, Dispute Prevention and Resolution Task Force, University of Colorado, Boulder, Colorado.

Diekmann, J. and Girard, M. (1995). "Are Contract Disputes Predictable?" *Journal of Construction Engineering & Management*, ASCE, 121(4), 293-297.

Fichman, R. Keil, M. and Tiwana, A. (2005). "Beyond Valuation: Option Thinking in IT Project Management." *California Management Review*, 47(2), 74-96.

Ford, A. (1990). *Modeling the Environment*. Island Press, Washington, DC.

Forrester, J. (1969). *Principles of Systems*. Wright-Allen Press, Cambridge, Massachusetts.

Hanna, A. and Gunduz, H. (2003). "Impact of Change Orders on Small Labor-Intensive Projects." *Journal of Construction Engineering and Management*, ASCE, 130(5), 726-733.

Lee, M., Hanna, A., and Loh, W. (1987). "Decision Tree Approach to Classify and Quantify Cumulative Impact of Change Orders on Productivity." *Journal of Computing in Civil Engineering*, ASCE, 18(2), 132 - 144.

Luehrman, T. (1998). "Strategy as a Portfolio of Real Options." *Harvard Business Review*, 76(5), 89-99.

Luehrman, T. (1995). *Capital Projects as Real Options: An Introduction*. Harvard Business School, 9-295-074, 1-12.

Mbuthia, G. (2001). "Potential Applications of Real Option Analysis in the Construction Industry in Developing Countries." Downloaded on 10/01/03. (available at http://buildnet.csir.co.za/cdcproc/docs/2nd/mbuthia_g.pdf).

Ng, F. and Björnsson, H. (2004). "Using Real Option and Decision Analysis To Evaluate Investments In The Architecture, Construction and Engineering Industry." *Construction Management and Economics*, Taylor and Francis Group, 22, 471–482

Nichols, N. (1994). "Scientific Management at Merck: An Interview with CFO Judy Lewent." *Harvard Business Review*, January-February, pp. 88-99.

Pena-Mora, F., Sosa, C., and McCone, D. (2003). *Introduction to Construction Dispute Resolution*. Prentice Hall, New Jersey.

Pena-Mora, F. and Tamaki, T. (2001). "Effect of Delivery Systems on Collaborative Negotiations for Large-Scale Infrastructure Projects." *Journal of Management in Engineering*, ASCE, 17 (2), 105 – 121.

Ping Ho, S. and Liu, L. (2002). "An Option Pricing-Based Model For Evaluating The Financial Viability Of Privatized Infrastructure Projects." *Construction Management and Economics*, Taylor and Francis Group, 20(4), 143 – 156.

Risk Glossary. (1996). *Option Pricing Theory*. Downloaded on 09/25/05. (available at http://www.riskglossary.com/link/option_pricing_theory.htm)

Rubin, R., Fairweather, V., and Guy, S. (1999). *Construction Claims: Prevention and Resolution*. (3rd ed.), New York: Wiley.

Savva, N. and Scholtes, S. (2005). *Real Options in Partnerships*. Discussion paper presented at the 9th Annual Conference on Real Options, Paris

Sick, G. (1989). *Capital Budgeting with Real Options. Monograph Series in Finance and Economics*. Salomon Brothers Center for the Study of Financial Institutions, 3rd quarterly, Leonard N. Stern School of Business, New York University.

Teach, E. (2003). "Will Real Options Take Root?" *CFO Magazine*, 19(9), 73 – 75.

Trigeorgis, L. (1993). "Real Options and Interactions with Financial Flexibility." *Financial Management*, Financial Management Association, University of South Florida, 22(3), 202-224.

Trigeorgis, L. (1995). *Real Options in Capital Investment Models Strategies & Applications*. Westport, CT: Praeger Publishers.

Trigeorgis, L. (1996). *Real Options Managerial Flexibility & Strategy in Resource Allocation*. Cambridge, Mass: MIT Press.