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REAL OPTIONS AND SYSTEM DYNAMICS APPROACH TO MODEL VALUE OF IMPLEMENTING A PROJECT SPECIFIC DISPUTE RESOLUTION PROCESS IN CONSTRUCTION PROJECTS

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ABSTRACT

This paper presents a methodology to study the effect of different resolution strategies on the value of the investment in a project-specific dispute resolution ladder (DRL) using option/real option theories from financial engineering, process centric modeling, and system dynamics methodology. Of particular interest in this paper is the integration of these research methodologies into a computer model to support the evaluation of the DRL investment in a particular construction project by taking into account the characteristics of: (1) the project, and (2) the different alternative dispute resolution (ADR) techniques chosen for the DRL implementation. Finally, an example is presented to illustrate the application of the computer model in a real construction project.

1 INTRODUCTION

Project-specific dispute resolution ladders (DRL) are typically implemented in construction projects to resolve issues arising between the project participants. The DRL typically consists of single or multiple alternative dispute resolution (ADR) techniques to address construction issues at each of the three levels of escalation: conflicts, disputes, and claims (Caltrans 2006, Peña Mora et al. 2003). Most of the existing studies in construction claim resolution focus on the improvement and prediction of the outcome of the ADR methodology with particular emphasis on the most time and resource consuming ADR techniques. Peña Mora and Wang (1998) developed CONVINCER, a computer-supported collaborative negotiation methodology based on negotiation and game theories to facilitate the negotiation of conflicts during the development phase of large-scale construction projects. Ren, Anumba, and Ugwu (2003a and 2003b) developed MASCOT, a multi-agent system for construction claims negotiation, to tackle inefficiencies in the construction claim negotiation process using the ZEUS agent building toolkit. Arditi and Thaveeporn (2005) used boosted decision trees to predict the outcome of construction litigation. Finally, Kassab et al. (2007) developed a framework for resolving construction conflicts using the graph model and the information-gap theory. The framework assists the project participants to identify the most robust resolution in the presence of uncertainty associated with the decision makers' preferences. All these studies have focused on the outcomes of the ADR process itself without considering the time and costs associated with the DRL implementation in a given construction project.

Therefore, the study presented in this paper seeks to explore the intrinsic costs carried by the project participants to achieve the ADR outcomes within a certain period of time. This is important because project participants spend a great amount of resources including time and money on the DRL process. Any interruptions in the process result in loss of efficiency, delays, opportunity cost of diverting the owner/contractor employees' attention, and more importantly an extensive amount of money in an already strained project budget (NRC 2007). On the other hand, if the project participants can tackle the sources of these inefficiencies during the dispute resolution process, then claims and change orders (CCO) can be resolved more efficiently and economically. Thus, it is important to develop a framework to monitor the dispute resolution process in terms of time and money expenditure, and eliminate the inefficiencies that might reduce the value of the investment in the DRL. The value of the investment in the DRL was defined by Menassa, Peña Mora, and Pearson (2009a) as the difference between the expected benefit of the investment in the DRL, and the total cost of the investment in the DRL. There are three main expected benefits of investing in the DRL that include the prevention of CCO's from occurring, timely and effective resolution of CCO's when they occur, and difference between the total amount claimed for all CCO's and the total amount of settlement for these (Menassa, Peña Mora, and Pearson 2009b). The greater the difference between the cumulative amount claimed and the total amount of settlement, the higher the value of the investment in the DRL because this difference represents an amount could be saved by the owner of the project due to the DRL implementation. In this paper, this quantitative benefit of DRL implementation in construction projects is considered when determining the value of the investment in the DRL.

This paper presents a methodology to study the effect of different resolution strategies on the value of the investment in a DRL based on: (1) option/real option theories from financial engineering (Menassa et al. 2009b); (2) process centric modeling to represent the DRL process as a sequence of operations being performed on the different CCO's occurring during the construction phase of the project (Anylogic 2008); and (3) system dynamics methodology to study complex feedbacks affecting the total value of the investment in the DRL (Sterman 2000). Of particular interest is the integration of these research methodologies into a computer model to support the evaluation of the DRL investment in a particular construction project by taking into account the project's characteristics, as well as the characteristics of the different ADR techniques chosen for the DRL. Finally, an example is presented to illustrate the application of the computer model in a real construction project.

2 PROJECT-SPECIFIC DRL

Cox (1997) emphasizes the importance of establishing a proper methodology to manage claims prior to the start of construction. To achieve this objective, the project participants can choose from the wide spectrum of ADR techniques which include: prevention (e.g., partnering), negotiation, standing neutral (e.g., dispute review boards-DRB), non-binding resolution (e.g., mediation), binding resolution (e.g., arbitration), and litigation (Peña Mora et al. 2003, AGC 2000, CII 1995). For example, a typical DRL will include negotiation at first level, followed by a DRB and finally arbitration/litigation if resolution at the previous two levels could not be achieved.

Once the decision regarding the different ADR techniques to be included in the DRL is made, the DRL can be implemented each time a claim occurs during the construction phase of the project. Thus, if n claims are expected to occur during the construction phase of the project from notice to proceed (t = 0) to project completion (t = T), then each claim i (i = 1, 2,…, n) can be defined by the amount of claim c_i per claim and the time of occurrence of the claim t_{ci}. In order to effectively resolve these n claims as they occur during the project construction phase, a conceptual representation of a DRL consisting of k different ADR techniques that can be implemented in the project as shown in Figure 1.

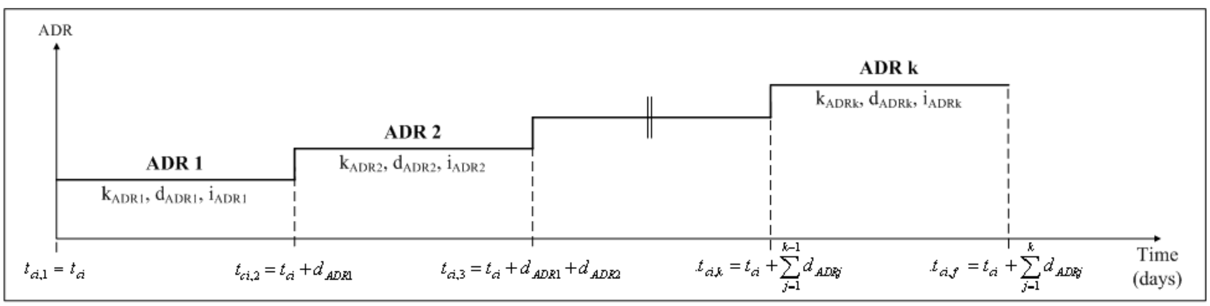

Figure 1: Project-specific Dispute Resolution Ladder (DRL)

Once a claim i is initiated at time t_{ci}, it immediately goes through ADR 1 as a first attempt to resolve that claim. If resolution is not achieved at this level of the DRL, then the claim i escalates to subsequent levels of the DRL until resolution is achieved at a given ADR j, where j = 1, 2, …, k. Each of the ADR techniques in the DRL has the following three parameters that need to be input into the model to calculate the cost-benefit tradeoffs associated with its implementation in the project:

(1) Effectiveness of ADR (k_{ADRj}): This parameter represents the usefulness of the given ADR in helping the disputing parties to achieve an equitable settlement of the claim at or below the original amount claimed c_i. In this sense, it is defined as the ratio between the amount settled per claim s_{ci} and the amount claimed per claim c_i. Thus, this parameter can assume values between 0 (i.e., highly effective ADR) and 1 (i.e., least effective ADR).

(2) Maximum Allowable Time for ADR Implementation (d_{ADRj}): Most project contracts specify a maximum allowable time limit for each level of ADR implementation for resolving a given claim (Zucherman 2007, Caltrans 2003). If this time limit is reached prior to claim resolution with the ADR under consideration, this claim escalates to the next level of ADR in the DRL.

(3) Cost of ADR Implementation (i_{ADRj}): This parameter represents the cost associated with each of the ADR techniques chosen for the DRL. These cost cover the expenses of the resources (e.g., site engineers, claim analysts, construction experts and lawyers) allocated all the parties involved in the project (DRBF 2006, Caltrans 2003). When a claim escalates from an ADR j to ADR (j+1) in the DRL, the costs incurred at the lower level of resolution become sunk costs.

(4) Probability of Resolution: This parameter represents the randomness associated with the resolution of a given CCO at a given level of ADR in the DRL. In this model, the probability of resolution is randomly generated using a uniform distribution. If the probability of resolution for the given CCO exceeds 0.5, then the CCO is resolved through the given ADR. On the other hand, if the probability of resolution is less than 0.5, then the CCO is assumed to spend the maximum allowable time for ADR implementation d_{ADRj} before it escalates to the next level of ADR in the DRL.

3 EFFECT OF CLAIM OCCURRENCE / RESOLUTION

In an earlier study conducted by the authors to estimate the value of the investment in a DRL, an analogy was established between this type of investment and investments in financial and real market options (Menassa et al. 2009b). Based on this study, an initial estimate of the expected amount of savings in the project (C_T) is determined by taking into account the specific project characteristics. However, this initial value of C_T will change due to the effect of the claim occurrence and resolution through the DRL implementation during the project construction phase. If a claim occurs in the project and is found to have merit, then it will reduce the value of the initial estimate of C_T similar to the reduction in the gross value of a capital investment project due to exogenous competitive entry in real market options.

3.1 Competition and Strategy in Real Options

The real option approach to value investments in capital projects provides the capital project investor with the dynamism to postpone investment until future uncertainty about expected cash flows is resolved (Smit and Trigeorgis 2006, Trigeorgis 1996). According to Trigeorgis (1996 and 1993), the ability to defer a certain amount of investment in a capital project is similar to an American call option on the gross project as depicted in the upper part of Figure 2. If there are no dividend-like returns to a timely and prompt investment by the firm, then the firm will wait until the end of the period to invest in the given project. Further, competition entry has a direct effect on the gross value of the project similar to the effect of dividends on call options, where the expected return from investing in the project is reduced by an amount determined by the level of competition, same as the value of the stock in financial markets is reduced by the amount of the dividend paid to investors after the stock goes ex-dividend (McDonald 2005). Thus, if n competitors share the investment opportunity with the company, then the gross project value V is expected to drop to $V' = k_jV$ ($k_j < 1$) at the time when competitor j enters the market.

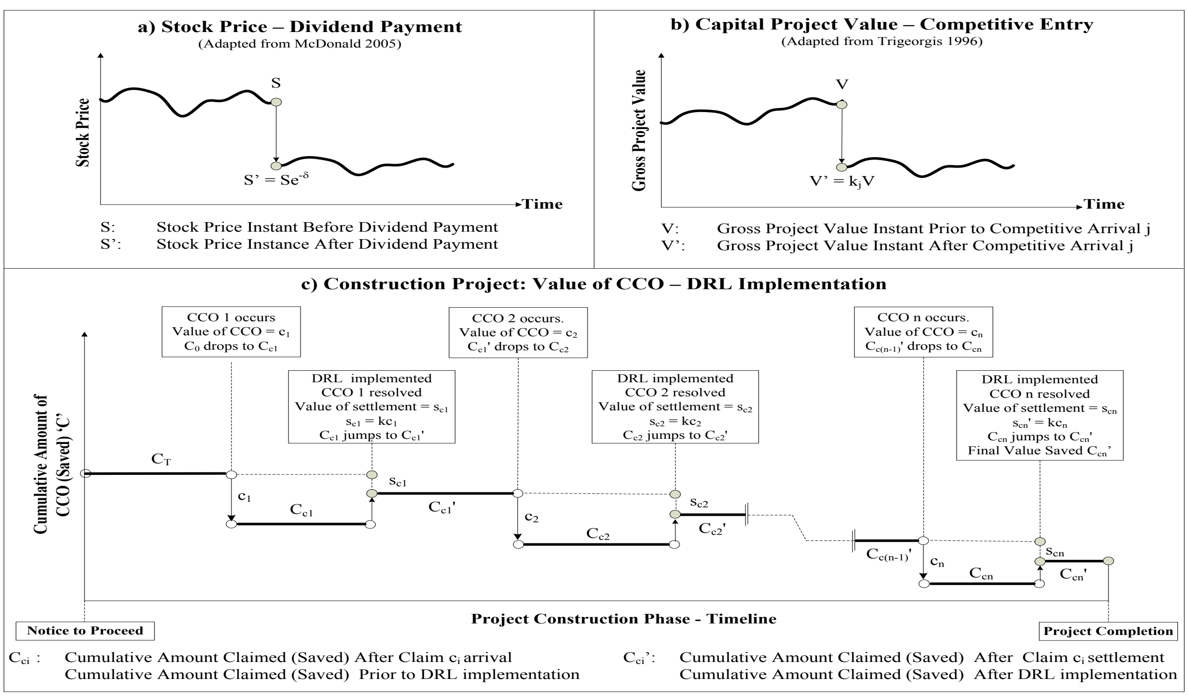

Figure 2: Analogy between: a) financial market (stocks with dividends); b) real market (capital investment project with exogenous competitive entry); and c) DRL model (CCO occurrence and resolution during the construction phase of the project)

3.2 DRL Investment Model – Competitive Arrival of Claims

If the initial estimate of the cost savings in the project due to the DRL implementation is C_T, then the occurrence of the first claim during the construction phase of the project reduces C_T by the amount of the claim c_1 to C_{c1} as shown in Figure 1. On the other hand, the processing of this claim through the DRL is expected to help the owner and the contractor agree to a settlement of the claim s_{c1} at or below the original value of the claim. This implies that part of the reduction in C_T might be recovered due to the implementation of the DRL. The value of this recovery is the difference between the amount claimed c_1 and the amount settled s_{c1}, and the expected savings in the project increase from C_{c1} to C_{c1}'.

Thus, the occurrence of the claim during the construction phase of the project and the effectiveness of the DRL in helping the owner to settle the claim at or below the actual value of the claim are seen as analogous to exogenous competitive entry in capital project investments. A competitive entry causes a drop in the gross project value from V to V' while the occurrence of the claim causes a drop in the expected value of the cumulative amount of savings due to DRL implementation from C_{ci}' to $C_{c(i+1)}$. If the DRL is instantiated each time a claim occurs, it is expected to help the project participants to settle the claim at a value s_{ci} which is less than or equal to the actual value of the claim c_i ($i = 1,2, \ldots, n$). This will cause the expected value of the cumulative amount of savings in the project to jump from C_{ci} to C_{ci}' after the claim is resolved.

4 CASH FLOW CALCULATIONS OF DRL INVESTMENT MODEL

The DRL investment problem can be conceptualized using three main cash flow calculations These include: 1) the change in C_T during the construction phase due to the occurrence of claims and their subsequent resolution through the DRL as shown Figure 1; 2) the change in DRL investment cost to reflect the cost associated with the resolution of all the claims at any given time during the construction phase. Finally, given the above two cash flows, the value of the DRL investment can be determined as the difference between the expected savings in the project and the cost of the DRL. These three cash flows are plotted for the case of a single ADR in Figure 3. Therefore, the following mathematical equations can be derived, respectively:

(1) The value of the cumulative amount claimed (i.e., saved) at any given time during project construction is given in (1) and (2) and at project completion is given in (3):

$$C_{ci} = C_0 - \sum_{m=1}^{i} c_m + \sum_{m=1}^{i-1} \left(c_m - s_{cm}\right) \tag{1}$$

$$C_{ci}' = C_0 - \sum_{m=1}^{i} c_m + \sum_{m=1}^{i} \left(c_m - s_{cm}\right) \tag{2}$$

$$C_{cn}' = C_0 - \sum_{i=1}^{n} c_i + \sum_{i=1}^{n} \left(c_i - s_{ci}\right) \tag{3}$$

(2) The total cost of the investment in case of a single ADR (4) and multiple ADR DRL (5):

$$I_n = I_0 + \sum_{i=1}^{n} i_{ADR} \times d_{ci} \tag{4}$$

$$I_n = I_0 + \sum_{i=1}^{n} I_{ci} \tag{5}$$

$$I_{ci} = \sum_{m=1}^{j-1} \left(d_{ADRm} \times i_{ADRm}\right) + d_{ci,j} \times i_{ADRj} \tag{6}$$

(3) The value of the investment in the chosen DRL prior to (7) and at project completion (8):

$$VO_i = C_{ci}' - I_0 - \sum_{m=1}^{i} I_{ci} \tag{7}$$

$$VO_n = C_{cn}' - I_n \tag{8}$$

5 SYSTEM DYNAMICS – FEEDBACK CAUSED BY CCO OCCURRENCE AND RESOLUTION

In this paper, system dynamics is used to study the change in value of DRL investment (VO) due to the synergetic effect of CCO occurrence, DRL implementation and CCO resolution during the project construction phase. Given that the maximization of the DRL investment value is a fundamental objective for any construction project owner, the application of system dynamics will allow the project participants to track the sources of inefficiencies in the DRL process that might lead to a reduction in the value of the investment in the DRL. Figure 4 shows a process model of the CCO occurrence and resolution during the construction phase of the project.

The four stocks variables in the model (i.e. possibleCCoStock, beingResolvedCCO, returnedCCO, and resolvedCCO) track the accumulations of different types of CCO types during the DRL process. For example, CCO's that are initiated but waiting to be submitted by the contractor are included in the possibleCCoStock. When one of these CCO's (e.g., unforeseen site conditions) occurs, the project participants will instantiate the DRL implementation in an effort to promptly resolve this CCO. Thus, the CCO flows through the system to the beingResolvedCCO stock. This stock variable includes all the CCO's that are currently being resolved through the DRL. If the resolution of any of these CCO's is successful, then it flows to the resolvedCCO stock where the DRL process ends. However, in some cases a CCO goes through all the available ADR of the DRL and does not get resolved. It is typical that the owner and contractor either decide to re-negotiate this CCO, or are forced to do so by the arbitrator or judge. In this case, the CCO flows to the returned CCO stock variable where it remains there until it can be send through the DRL process again. The effect of this process on the value of the investment in the project specific DRL will vary depending on the state that a given CCO is in. More specifically, CCO's that occur and are send to the DRL for possible resolution will reduce the value of the investment in the DRL by the amount of the CCO (i.e., c_i) as explained in the previous section. When this CCO is resolved satisfactorily (i.e., $s_{ci} <= c_i$), then some of the DRL lost value is recovered after taking into account the actual cost of implementing the DRL to achieve resolution (i.e., i_{ci}). On the other hand, when CCO's are returned and have to go through a new DRL iteration, then all the initial DRL cost of implementing the DRL will permanently reduce the value of the investment in the DRL as they will not be recoverable.

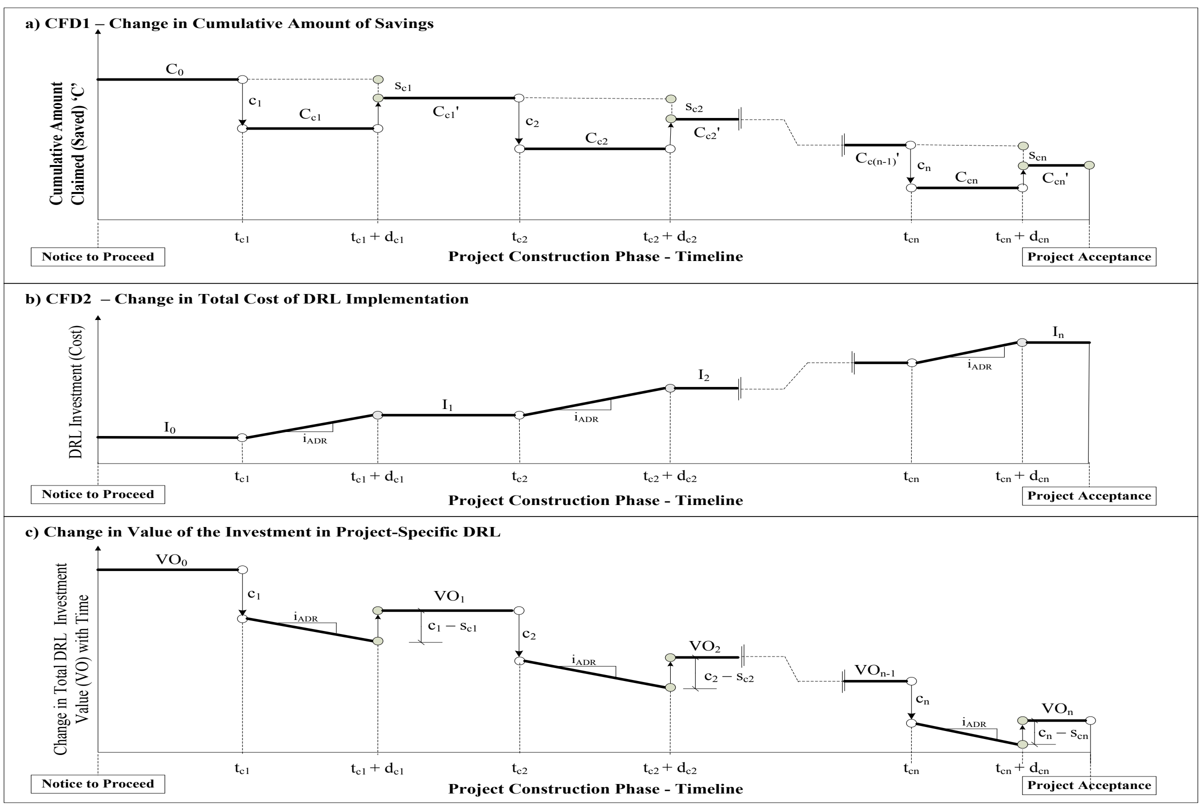

Figure 3: Cash Flow Diagrams and Value of Investment due to Project-Specific DRL Implementation during the Construction Phase of the Project

The main effect of the CCO iteration process described above is to reduce the value of the investment in the DRL. Another important underlying process that has a major effect of limiting the detrimental effect of the re-resolution process is the learning effect. This effect occurs when the project participants and external neutral consultants become familiar with the project and the underlying difficulties. This familiarity allows them to approach the resolution process more efficiently where they will need less time whether to understand the background of the issues, or to try to reach an amicable resolution. In the process model shown in Figure 6, the increase in the number of resolvedCCO affects the learning effect variable in the model represented as learnigEffect. An improvement in this variable will result in reduction in the amount of time required to resolve the CCO represented by the variable timeToResolution, and an increase in the probability of resolution through a given ADR in the DRL represented by the variable probOfResolution.

In this model, the anticipated reduction in conflict, dispute and claim resolution time is expressed mathematically using the method proposed by (Oglesby et al. 1998). Assuming an improvement of α percent each time the number of conflicts, disputes and claims resolved through a given ADR doubles (i.e. timeToResolution = α * max Allowable Time Resolution In ADR when number of resolved conflicts, disputes and claims in a given ADR increases from 1 to 2), the reduction in time to resolution is due to the learningeffect is incorporated in the model using (9), (10) and (11):

$$learningEffect = \text{-slope} * \log(\text{resolvedCDc}) + \log(\text{maxAllowableTimeResolutionInADR}) \quad (9)$$

where:

$$slope = -\frac{\log(\alpha)}{\log 2} \quad (10)$$

and,

$$d_{ADR,j}' = timeToResolution = \exp(learningEffect) \quad (11)$$

The processes described above (i.e. re-resolution and learning effect) can be modeled as feedback loops using a system dynamics approach to assess their effect on the value of the investment in the DRL. These feedbacks can be divided into two main categories reinforcing (i.e. positive) that amplify the effect of a given process in the system, and balancing (i.e. negative) that counteract the reinforcing change in the system (Sterman 2000). For the proposed model, the two main causal loop categories are described below:

Category 1-Reinforcing/Positive Feedback: This category includes strategies and behaviors that reinforce the loss in value of the investment in the DRL. In this case the iterative cycles caused by CCO reaching arbitration or litigation and then send back for negotiation at the project level will reduce the value of the investment in the DRL. The main reason for this is that all resolution incurred costs prior to reaching litigation become sunk costs that the owner and the contractor have to deal with in addition to the costs of re-negotiating the CCO either at the project level, or at the standing neutral level through mediation for example.

Category 2-Balancing/Negative Feedback: This category includes strategies that reinforce the value of the investment in the DRL. The most important of these behaviors is the learning curve associated with the resolution of the CCO's. For example, consider the case of a differing site condition involving the presence of an old water pipe that was not revealed by the preliminary site investigation. If the site engineers have the experience or access to information on how to resolve such an issue without delaying the foundation activity, then the time required to negotiate this issue with the contractor can be tremendously reduced. This creates a positive impact on the value of the investment in the DRL. First, the time required for negotiation is reduced resulting in lower cost of negotiation associated with this particular issue. Second, the resolution of the CCO at the negotiation level, reduces the risk of escalating this issue to other ADR levels in the DRL that are more time consuming and costly.

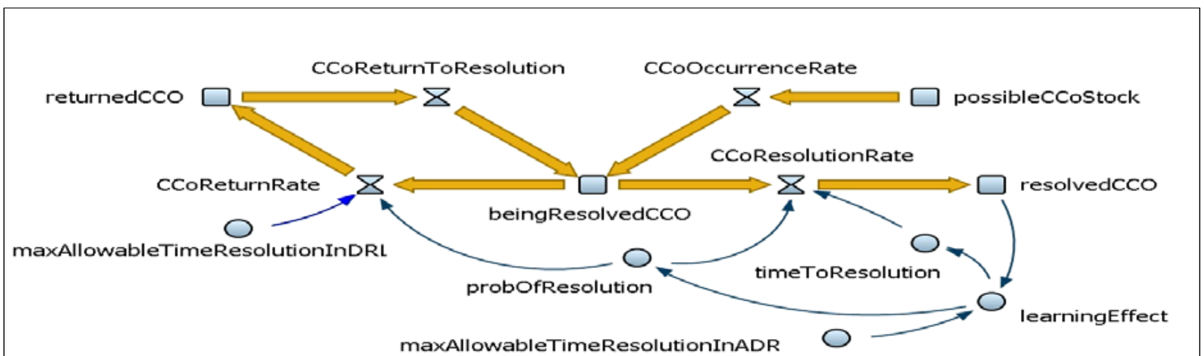

Figure 4: Process Model for Conflicts, Disputes and Claims (CDC) Occurrence and Resolution

6 DYNAMIC DRL INVESTMENT MODEL

The proposed computer model is implemented in a software system using Anylogic (V.6), a dynamic simulation tool that allows for hybrid modeling using process centric and system dynamics (Anylogc 2008). The general model architecture is depicted in Figure 5. As mentioned earlier each time a CCO occurs in the project, it goes through the DRL process. The CCO resolution process is driven by the daily work force working on ADR (resource quantity) and the work force's productivity (i.e. effectiveness in achieving resolution). Process centric modeling is used to represent the DRL process as a sequence of operations being performed on the different CCO's occurring during the construction phase of the project (Anylogic 2008) as illustrated in Figure 5. The simulation starts with CCO's being generated through the sourceOfClaims object and move to the preventionInput object. If prevention is not chosen as part of the DRL, then CCO moves to the negotiationInput object where a similar check is preformed. If prevention is part of the chosen DRL, then the CCO moves to preventionQueue where it awaits resolution through prevention. Next, it moves to preventionDelay to simulate the time required to resolve the CCO through the chosen prevention technique. The CCO then moves to preventionOutput where it either escalates to negation (i.e., moves to negotiationInput object) if resolution was not achieved through prevention, or exits the system through the preventionSink object if resolution is achieved at the prevention level of the DRL. This process is repeated throughout the whole system until all CCO are resolved through the first attempt at resolution through all the ADR in the DRL or returned for another round of resolution if necessary as described in the previous section.

The Anylogic platform implements Java as a high-level language for defining data types and data transformations. In addition to the built in features for each of the objects shown in Figure 8, a Java code is developed to guide the object behavior during the model simulation and implement the mathematical formulations described earlier in the paper.

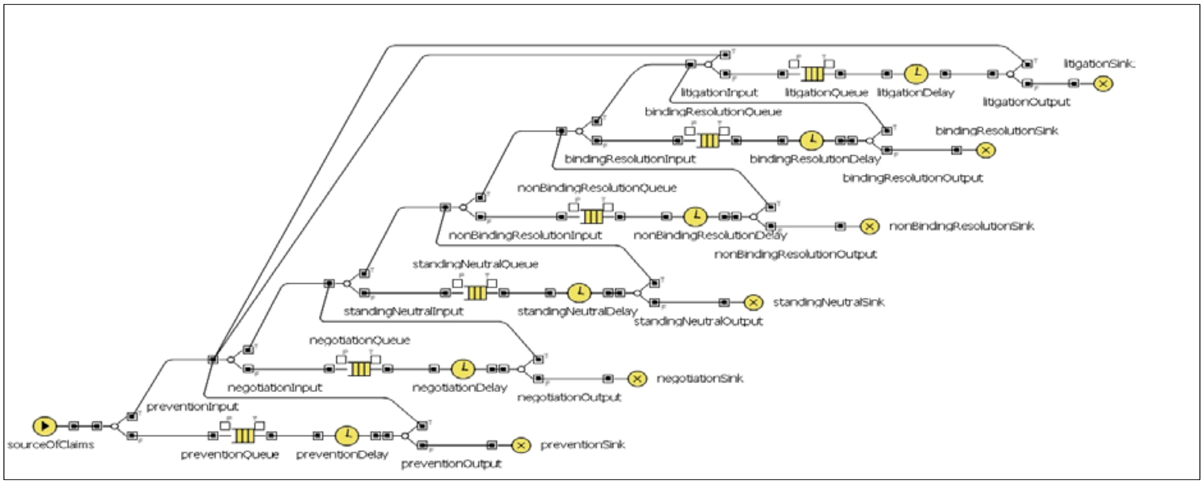

Figure 5: Process Centric Model of the DRL Process

7 DRL INVESTMENT MODEL APPLICATION

The application of the presented DRL investment model is illustrated in this section through a case study involving a real construction project.

7.1 Project Description

The case study project involves a large scale seismic retrofitting endeavor undertaken on a 5.5 mile bridge between 2000 and 2005. This project was awarded to the lowest bidder at a total value of $485 million. Due to the fact that the contract documents also included a liquidated damages clause requiring the contractor to pay the owner a sum of $25,000 per day for each and every calendar's day delay in finishing the work, the work on this project was completed as originally planned in 1,450 working days or 5 calendar years (i.e., project duration = 5 years). However, the project had an actual cumulative amount of CCO's by end of construction (C_T) equal to $283 million or 58 percent increase over the award amount. This $283 million is distributed as follows: 555 change orders ($148 million total value), 47 potential claims ($55 million total value), and 12 claims ($80 million total value). Based the actual CCO information related to time of occurrence of each CCO and amount claimed per CCO (c_{ci}), the model input values are determined as follows: (1) Average rate of CCO (t_{ci}) occurrence is 10 per month (or 0.333 per day); (2) Minimum value of CCO is zero; (3) Average value of CCO's in the project is $490,912. Given that the amount of CCO's generated by the model has a uniform distribution, the maximum value of CCO is $921,825; and (4) Expected Maximum number of claims in 614. This information is input in the model via the graphical user interface for Project Information as shown in Figure 6.

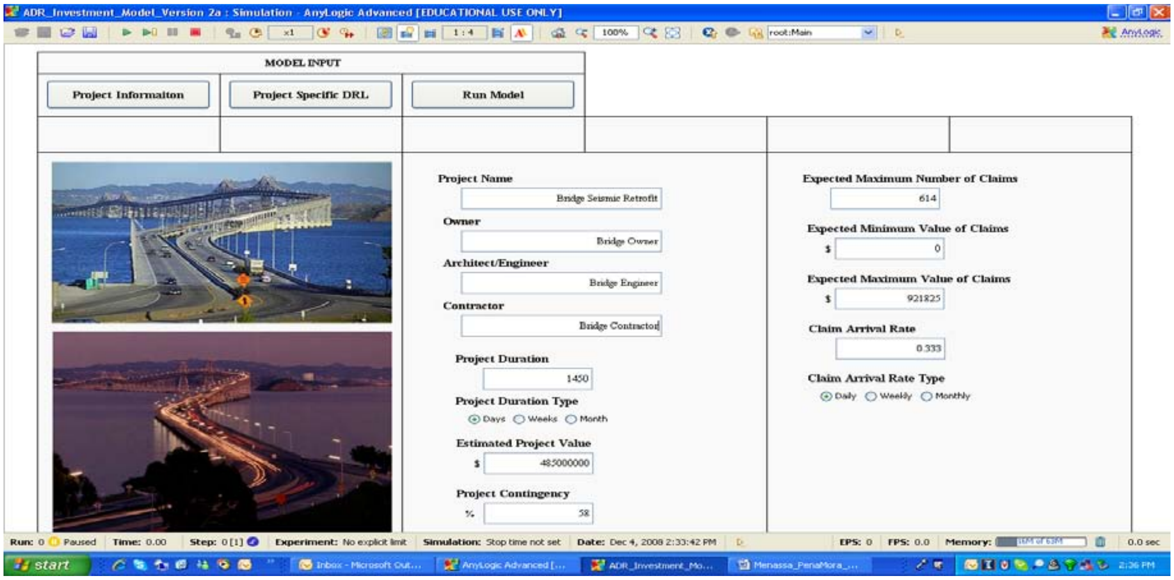

Figure 6: Graphical User Interface – Project Input Data (Bridge Photos in the interface obtained from MTC 2008)

7.2 Project-Specific DRL

The DRL implemented by the owner in the contract documents to address all CCO's occurring during the construction phase consists of three-ADR steps. Once a CCO occurs at any given time tci, it goes through a 20 day negotiation (ADR1) period at the initial level of resolution, if it is not resolved by that time then it escalates to a DRB (ADR2) hearing for a maximum of 2 days, and if that also fails then it goes to arbitration (ADR3) until a binding decision is rendered by the arbitrator. The owner estimated unit cost during the negotiation phase is $425 per day for an on-site engineer reviewing the CCO's. At the DRB stage, three DRB members cost $3,300 per day distributed equally between the owner and the contractor (DRBF 2006). Thus, in addition to the costs of the owner's engineers attending the DRB hearing meetings, the owner incurs a total of $1,650 per day paid out to the DRB panel. At the arbitration level, the cost of arbitration is estimated to be 20 percent of the value of the CCO to cover the owner's incurred legal costs. This information is input in the model through the graphical user interface created for each ADR. Figure 7 illustrates the input for negotiation. Based on this, the owner estimated actual total cost of the DRL was $21.4 million distributed as follows:

1) 555 change orders resolved through ADR1-negotiation. The total cost of resolution is: 4.72 million.
2) 47 potential claims resolved at ADR2-DRB level. The total cost of resolution is: $0.55 million.
3) 12 claims resolved at ADR3-arbitration. The total cost of resolution is $16.1 million.

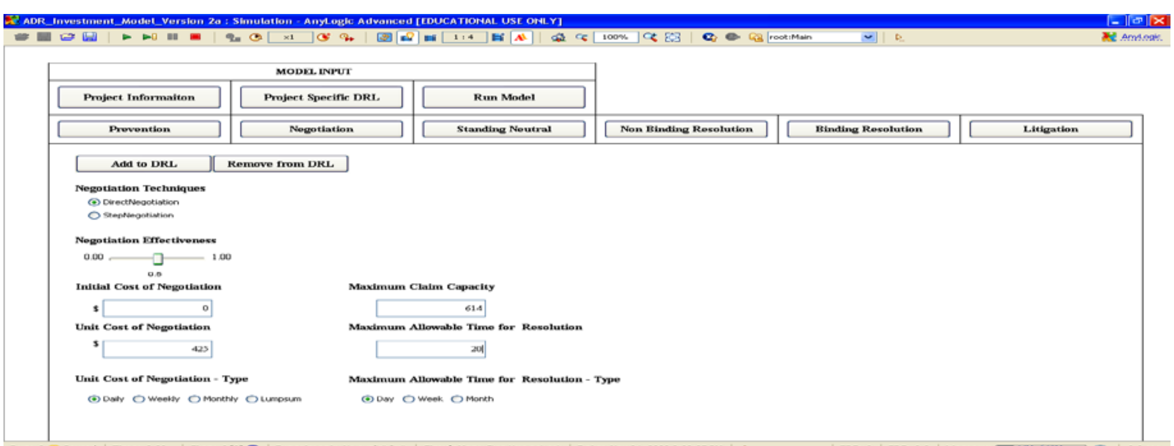

Figure 7: Graphical User Interface – ADR Input Data (Input data for negation is shown here)

7.3 Simulation of the Input

The actual amount of settlement for each individual CCO (s_{ci}) is not readily available due to confidentiality issues in the project; however, the project data indicates that the actual total amount of settlement S at project completion was $268 million, or 95 percent of the actual cumulative amount of CCO's (i.e., S/CT=$268/$283=0.95). Thus, the model is initially simulated by assuming an ADR effectiveness ratio of 0.95 for all CCO's occurring in the project. The model logic and the results of the simulation are shown in Figures 6 and 7 respectively.

The results in Figure 6 indicate that 536 CCO's are resolved through negotiation, 51 CCO's are resolved through DRB, and 27 CCO's are resolved through arbitration. These results indicate that 24 out of the total 614 CCO's simulated in the system have to go through a second cycle of resolution when they were not resolved through early stages of arbitration. Of these 24 CCO's, 18 are resolved through a second round of negotiation, 5 are resolved through DRB after failing to be resolved through the second round of negotiation, and finally one CCO had to go back to arbitration for final resolution.

Figure 7 shows the output results from simulating the model for the particular project input data. The first part of Figure 7 shows the distribution of the amount claimed and the amount settled for each of the 614 CCO's generated by the model. The second part of Figure 7 shows the change in the expected amount of savings in the project C_T due to the occurrence and resolution of the 614 CCO's through the DRL with time. This Figure indicates that the expected savings in the project decreases with time as CCO's occur in the project. For this simulation, the final value of the cumulative amount claimed (i.e., saved) at project completion C_{cn}' is $13.5 Million. Since the ADR effectiveness was assumed to be 95 percent for this simulation, the jump in expected amount of savings each time a CCO is resolved in the project is not very noticeable. Finally, the last part of Figure 7 shows the change in the total cost of implementing the DRL between NTP and project completion. These results indicate that the cost of implementing the DRL increases as more CCO occur with time. The final total cost of implementing the DRL is determined from the model simulation to be $10.5 Million. Therefore, the value of the investment in the DRL VOn is obtained using (8) to be $3 Million (i.e., VO_n = $13.5 Million - $10.5 Million). This indicates that there are some savings realized in the project due to the implementation of the chosen project-specific DRL.

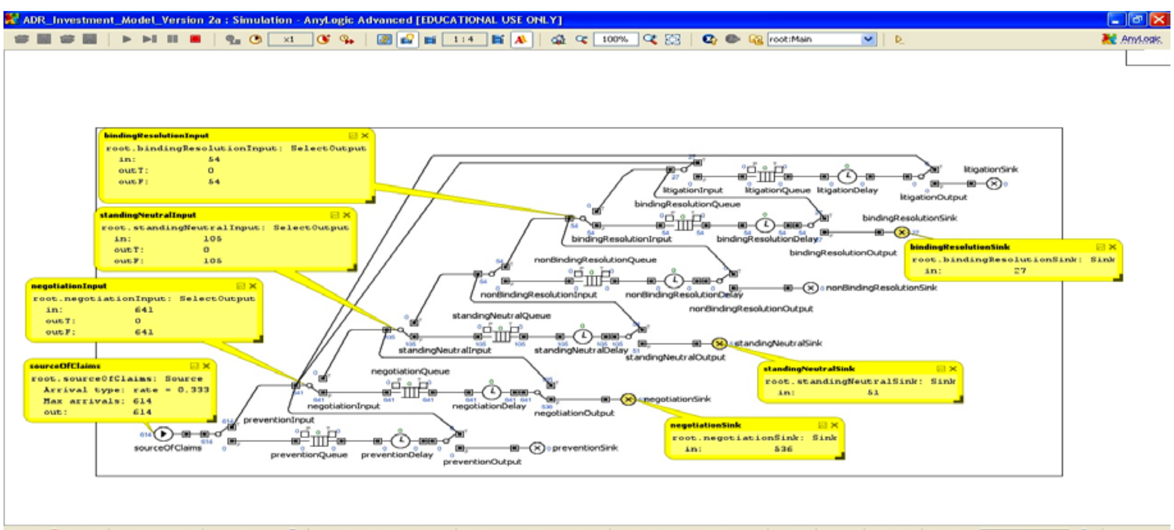

Figure 8: Case Study Project – Model Logic

7.4 Sensitivity Analysis

In this section, the sensitivity of the results obtained from the model simulation is investigated relative to the change in the probability of resolution assumption in the ADR_Delay entity described under section entitled "Modeling the Project-Specific DRL Process". Therefore, three values of the probability of resolution are assumed 0.25, 0.5 (base case scenario from previous section) and 0.75. Table 1 shows the change in the number of CCO entering each of the three levels of ADR in the project-specific DRL (i.e., negotiation, DRB and arbitration), as well as the number of CCO that were resolved at each level of ADR. As can be seen from Table 1, the number of CCO resolved at the negotiation level decreases from 588 to 453 with the increase of the probability of resolution from 0.25 to 0.75. On the other hand, the number of CCO resolved through DRB and arbitration increase with the increase in probability of resolution from 19 to 84 and 7 to 77 respectively. This is an expected result given that the increase in probability of resolution decreases the chance of a CCO being resolved at lower levels of ADR in the project-specific DRL. The last row of Table 1 shows the number of CCO that were returned from arbitration to negotiation for a second attempt at resolution. Again, the number of these CCO increases with the increase in probability of resolution indicating the adverse effect of having ADR in the project where the resolution of a given CCO through the DRL only occurs if the randomly drawn probability of resolution is high.

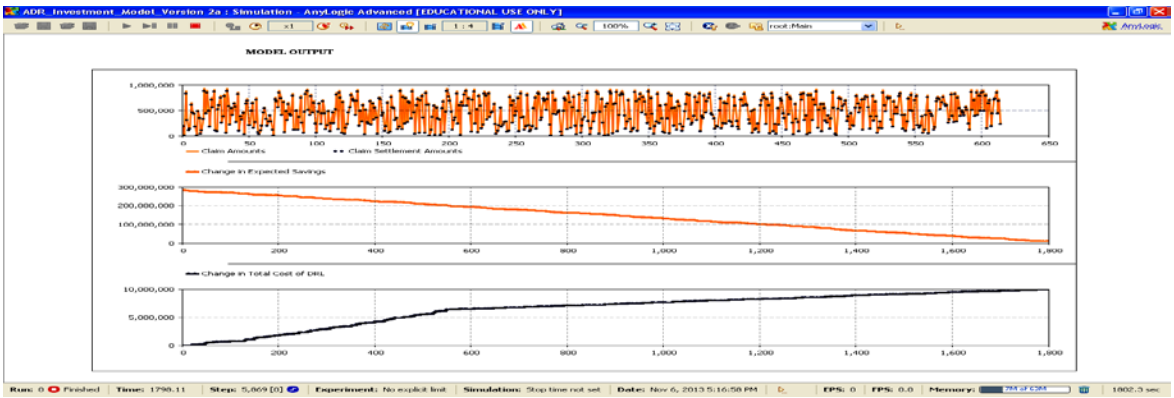

Figure 9: Case Study Project – Model Output

In addition to the effect on the distribution of the number of CCO's resolved through each ADR level in the project-specific DRL, a change in the probability of resolution also affects the average time and cost of resolution for a given CCO in the project. This in turn affects the total cost of implementing the DRL In, and the overall value of the investment in the DRL VOn. The results obtained from simulating the model for the three probability of resolution values (i.e., 0.25, 0.5 and 0.75) are presented in Table 2. In line with the results discussed in Table 1, the average time to resolution per CCO as well as the average cost of resolution increases when the probability of resolution increases. On the other hand, the value of the investment in the DRL decreases due to the increase in the total cost of implementing the DRL. For this particular example, the results indicate that the value of the investment in the DRL VOn decrease from $13.6 Million for a probability of resolution equal to 0.25 to -$5.0 Million for a probability of resolution equal to 0.75. The main reason for this decrease in value of the investment in the DRL is the fact that as the probability of resolution increases, the number of CCO resolved at lower and less expensive ADR levels (i.e., negotiation) decreases while the number of CCO resolved at more expensive levels of ADR (i.e., DRB and arbitration) increases as illustrated in Table 1.

Table 1: Example Project – Number of CCO at Each ADR Level in the DRL Versus Probability of Resolution

Probability of Resolution	**p = 0.25**		**p = 0.5**		**p = 0.75**	
DRL Level	**CCO In**	**CCO Out**	**CCO In**	**CCO Out**	**CCO In**	**CCO Out**
Negotiation	616	588	641	536	772	453
DRB	28	19	105	51	319	84
Arbitration	9	7	54	27	235	77
Number of CCO Returned to Negotiation	2		27		158	

Table 2: Example Project – Effect of Change in Probability of Resolution on Time, Cost and Value of Investment in the DRL

Probability of Resolution	**p = 0.25**	**p = 0.5**	**p = 0.75**
Mean Time to Resolution	20.3 days per CCO	22 days per CCO	27 days per CCO
Means Cost to Resolution	$9,415 per CCO	$17,025 per CCO	$45,900 per CCO
Cumulative Amount Claimed C_{cn}'	$19.4 Million	$13.5 Million	$23.5 Million
Total Cost of Resolution - I_n	$5.8 Million	$10.5 Million	$28.5 Million
Value of Investment in DRL – VO_n	$13.6 Million	$3.0 Million	-$5.0 Million

8 CONCLUSIONS

The DRL valuation model presented in this paper provides project participants with a methodology to monitor the occurrence and resolution of the CCO's through the implementation of the DRL during the project construction phase. Therefore, the main advantage of this model is that it provides project participants with a tool to compare the costs associated with a DRL implementation in the project with the perceived benefits. In doing so, it provides the user with a detailed analysis that shows the number of CCO resolved at each level of ADR in the DRL and the cost associated with each CCO resolution. These costs include the sunk costs from failed attempts to resolve the CCO at lower levels in the DRL in addition to the cost of implementing the ADR at which resolution was achieved. Another main advantage of the model is that it allows the project participants to monitor the time each CCO spends in the DRL. This will allow them to tackle any delays in the process and try to address them to ensure effective and economic resolution of all CCO occurring in the project. Finally, the integration of the three methodologies (i.e., real options with exogenous competition, system dynamics, and process centric modeling) provides a suitable framework for project participants to be able to simulate the CCO occurrence and resolution process as well determine the value of the investment in the chosen DRL.

Therefore, the proposed model contributes to the field of conflict and dispute resolution in construction projects because it highlights the importance of monitoring the CCO resolution process to ensure that the chosen DRL implementation is efficient and economic. However, there are a lot of challenges that still need to be addresses in this domain. These challenges focus on the collection and analysis of data from a large number of construction projects to verify and validate the results obtained from the model. The results of this study will improve the model capabilities for application in real construction projects.

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