

Evaluation Framework of Construction Alternative Dispute Resolution Methods through an Integrated Model of Real Options, Probabilistic Analysis and System Dynamics

by

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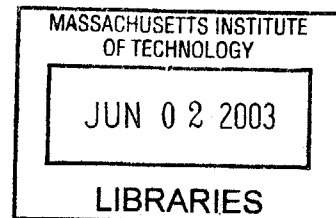
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Abstract

The construction industry plays a major role in the US economy and infrastructure project delivery, representing \$878 billion or 8.6% of the national GDP in 2003 [CNN, 2003]. A critical characteristic of the construction industry, however, is the high costs incurred by the resolution of arising disputes in projects, reflecting the need for drastic improvement of dispute avoidance and resolution techniques (DARTs). The rapid development of DART since the 1990s has marked a new era in the construction industry, encouraging the various entities to shift from an adversarial system toward a collaborative atmosphere [ENR, 1994].

The purpose of this thesis is to provide a model, a methodology and a tool for understanding and evaluating the complex and dynamic interaction of conflicts and implemented DARTs on a project; and also, to develop quantitative methodologies for performing a cost-benefit analysis on a project in order to compare and select the most appropriate techniques to be applied to a project based on its characteristics.

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Chapter 1 – Introduction

I. Background of Research

The construction industry plays a major role in the US economy and infrastructure project delivery, representing \$878 billion or 8.6% of the national GDP in 2003 [CNN, 2003]. However, a critical characteristic of the construction industry is the high costs incurred by the resolution of arising disputes in projects. Indeed, approximately \$60 billion (i.e., more than 7% of the revenues) [ENR, 2002] are spent annually on construction-related lawsuits in the US. In addition, construction litigation expenditures are increasing at a rate of 10% per year [ADR, 2003]. These alarming figures reflect the need for drastic improvement of dispute avoidance and resolution techniques (DARTs).

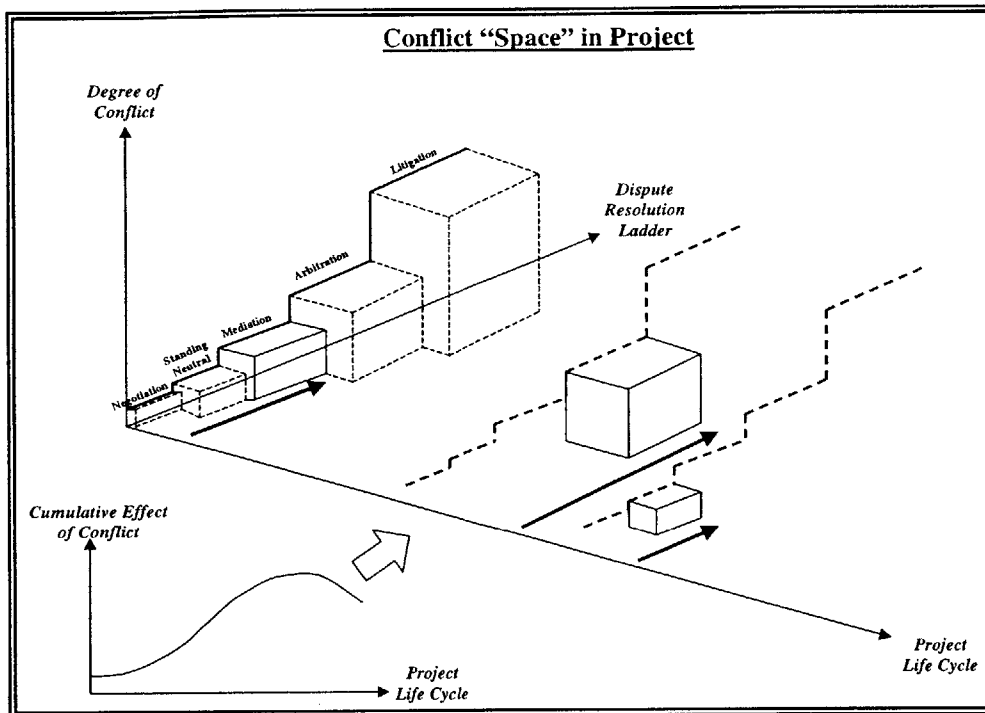
Thus, due to the importance of finding a way for more effective dispute resolution methods, several research efforts have been undertaken since the 1990s to develop innovative means of preventing and efficiently resolving disputes [ENR, 1994]. New approaches like total quality management [ENR, 1996] and risk sharing [Vega, 1997] are encouraging various entities to shift from an adversarial system toward a collaborative atmosphere. Some industry experts claim that the industry is going back to the “old-fashioned way of doing business,” when quality, service and collaboration among parties were the norm, and disagreements “were settled on the jobsite at an informal meeting between the resident engineer and the contractor on the basis of a handshake” [Treacy, 1995].

The adoption rate of DART in construction projects has been constantly increasing in the last couple of decades. However, the rate is still low and professionals in the industry have a tendency to be skeptical to changes in their way of doing business [AAA, 2003]. New techniques, like economic price adjustment [Zack, 1997], joint project scheduling [Zack, 1997], and A+B bidding [ADOT, 1999] are constantly being created and tested to resolve conflicts in construction project, yet there is a lack of understanding and quantification on the way these techniques affect the conflict profile of the project (i.e.,

the characteristics of potential sources of conflicts in the project, the nature of the escalation process of conflicts (see Figure 1), and the impact of the conflicts on the project), as an individual or combination of these techniques are applied to a project. The purpose of this thesis is to provide a model, a methodology and a tool for understanding and evaluating the complex and dynamic interaction of conflicts and their effects on a project; for understanding and evaluating the complex and dynamic interaction of DART techniques and their effects on a project; and finally, to develop a quantitative model for performing a cost-benefit analysis on a project in order to compare and select the most appropriate techniques to be applied to a project based on its characteristics of the project and the context in which the project is being developed.

For the development of the model, methodology and tool, we will use the power of system dynamics for modeling the dynamic effects of conflicts and DART implementation on conflict potentiality and escalation during the life of construction projects. We will also use probabilistic analysis to define a more realistic characterization of conflicts that would incorporate the uncertainty of conflict occurrence, and to analyze the combination of these potential conflicts in order to develop a more accurate conflict profile for projects. Finally, we will apply option-pricing theory to develop a quantitative assessment of the financial implications of potential DART implementations in the project, considering the possibility to invest in the initial implementation of a DART as a “real” option (as opposed to a financial one), with initial investments leading to follow-up opportunities of reduced conflict profile.

Finally, the model, methodology and tool together with the conflict profile will be incorporated in a Conflict Management Plan. The Conflict Management Plan looks at each project individually to establish a set of criteria for managing conflicts. It assesses how much conflict one will encounter, how severe each conflict might be, then presents cost effective ways to avoid conflict and curb these disputes. All the discussions, research and cost-benefit analysis related to the decision-making process to avoid and resolve conflicts contribute to the elaboration of the Conflict Management Plan.



Thus, the proposed research will help us understand and model the complex and dynamic interactions of both conflict occurrences and DART implementations, introduce the random nature of conflict occurrence in the perception of construction projects and conflict profiles through a probabilistic approach, apply these concepts to a cost-benefit analysis of DART policy based on the results of the system dynamics model and option-pricing theory, and finally develop a framework for decision-making resulting in enhanced conflict management plan applied to dispute avoidance and resolution in real-world large-scale construction projects.

II. The Challenge: Managing Uncertainties in Decision-Making

Marked by increasing complexity in projects and rising competition in a highly segmented industry, the construction business has been forced to develop and experiment with alternatives to litigation to find more effective and inexpensive ways of dealing with uncertainty and solving disputes. Leaders in the industry are striving to adopt new

business strategies, including supply chain integration and greater use of information technology [AAA, 2003].

Drastic escalation of disputes and high costs related to conflicts in construction projects could be avoided, or at least minimized, through better organization, risk profiling methods and more adapted risk strategies at the outset of the project, catalyzed by the use of technology and computerized methods, which would lead to an increase in efficiency [AAA, 2003]. Previous efforts have been made to understand the complexity of dispute avoidance and resolution and to model the escalation of disputes in large-scale construction projects [Pena-Mora et al., 2001]. This research was based on an initial identification and analysis of the complexity of construction projects and their conflict-prone nature. It also included a review of a significant number of new and innovative ways of promoting collaborative environments to resolve disputes in the construction industry. This research concluded with the development of a system dynamics model to simulate the conflict profile of a project in terms of the evolution of the number of issues in a construction project, depending on the DART that were adopted by the participants. This approach was a major innovation in the use of computerized tools for dispute avoidance and resolution in construction projects, since it could provide a means for the participants to forecast the number of conflicts arising in their project and assess the impact of different resolution procedures.

This research also identified the need for a mechanism to effectively formulate the complex combination of dynamic and random factors that initially result in the appearance of conflicts in the project. One area that has been identified as required for further improvement is the input of the model; i.e., the number of issues arising in the project (a set of data varying over the life of the project), which was initially defined as a curve that seemed most likely to the participants of the project, based on their personal experience and on historical data. An enhancement of this issue would result in obtaining a more realistic conflict profile of the project that would take into account the uncertainty of conflict occurrence. Conflict avoidance plans based on these forecasts will then be optimized, incorporating the risk of unanticipated conflicts; preventive DARTs and option pricing studies. This would allow the allocation of the budget for conflict avoidance and mitigation techniques to be more realistic.

In addition, previous research led by Pena-Mora et al. did not focus on the financial implications of using certain DART in a project. The model certainly allowed the comparison of benefits resulting from the implementation of different DARTs through the number of outstanding conflicts, but it did not focus on the real factor of comparison should be the final expenditures for addressing all the conflicts. The financial implications of the possible DART implementations need to be introduced in Pena-Mora et al.'s model

In an effort to address these challenging concerns, exploration and initial research clearly pointed out the following issues: (1) need of a probabilistic model to capture the interactions of potential random conflict sources in a construction project, (2) enhancement of available simulation engines to combine probabilistic occurrences of conflicts and the relationship between escalation of disputes and DART implementation, leading to an inexact definition of conflict profile in the project, (3) further consideration of the financial concerns in the simulation models, so as to observe the consequences of possible DART implementations from the critical viewpoint of budget concerns and be able to perform cost/benefit analysis and option pricing, and (4) development of existing methods to provide solid numerical comparisons of different conflict avoidance and resolution technique implementation costs to the decision-level, and thus to contribute to a more solid conflict management plan.

III. Objectives of the Proposed Research

As mentioned previously, the objective of the proposed research is to understand and model the complex and dynamic interactions of both conflict occurrences and DART implementations, to introduce the random nature of conflict occurrence in the perception of construction projects and conflict profiles through a probabilistic approach, to apply these concepts to a cost-benefit analysis of DART policy based on the results of the system dynamics model and option-pricing theory, and finally to develop a framework for decision-making resulting in enhanced conflict management plans applied to dispute avoidance and resolution in large-scale construction projects.

The proposed research would: (1) develop a better understanding and conceptualization of the random but quantifiable occurrence of conflicts and conflict profiles in construction projects with the help of probabilistic analysis; (2) provide project managers with insight into the dynamic cost implications of dispute avoidance and resolution techniques' implementation during the life of the project; (3) enable the project managers to perform an option-theory based cost-benefit analysis after having captured the dynamic cost implications, considering each possible DART implementation as a real option (as opposed to a financial one); and (4) enhance optimized conflict management plans and budget allocation to the projects' contingencies for disputes. The proposed model is expected to benefit the entire life cycle of construction projects by minimizing costs related to conflict management, reducing decision-time concerning the implementation of the appropriate DART, establishing a more collaborative working environment, and improving project management in general. Following are three groups of specific research questions, hypotheses, significance, and goals that we plan to address in the proposed research, as shown in Table 1.

Table 1: The Research Questions

Group	Research Questions	Hypotheses	Significance	Goals
1. Conflict Profile and Occurrence of Conflicts	What are the characteristics of the potential conflicts?	The conflict profile of a project can be defined with a distribution curve (such as the normal distribution).	Identification and quantification of uncertain conflict factors and their impacts.	Probabilistic definition of input and construction process dynamics. Development of an accurate conflict profile.
2. Cost of DART Implementation and Option-Pricing	What would be the impact of a certain DART implementation on the number of outstanding issues and on the money spent on dispute avoidance and resolution?	The implementation of a DART affects the number of outstanding issues in the ulterior stages of the project and on the total money spent on dispute avoidance and resolution. These effects can be modeled and minimized.	Cause-effect relationships and cost-benefit analysis.	Complete dynamic model with financial analysis of possible DART implementations, backed up by option-pricing theory.
3. Conflict Management Plan	Considering the various options of the various DART implementations, which ones (if any) are worthwhile to be undertaken?	The effectiveness of avoidance and resolution can be modeled, analyzed and minimized.	Mitigation of impact & adaptive response.	Model-based decision framework concerning DART adoption, allocation of a budget for contingencies, and development of enhanced conflict management plan.

IV. Significance of Research

The significance of this research lies in the integration of research, industry and education to develop a simulation-based decision framework to help managers in the construction industry understand and deal with the complexity of today's conflict management environment in construction projects through the development of a conflict management plan tailored to each project. We believe the proposed research will lead to the advancement of new technologies that can realistically deal with the uncertainty of conflict management in large-scale construction projects. The scope of the project will

closely integrate methodologies, model, industry and academia so that students will obtain complex real-world experiences by leveraging the research and the industry partners involved in this proposal. At the same time, it would allow the practitioners to rethink the conflict avoidance and resolution process through a set of robust methods for modeling and analyzing conflict management techniques in today's construction projects.

Chapter 2 – Research Methodology

I. Research Methodology

The research process described in this paper is aiming to: (i) identify critical risk variables for disputes and related costs; (ii) identify the appropriate probability distributions to model these variables; (iii) assign “range” values to the critical variables, to form the input data points for the probabilistic model; (iv) use probabilistic programs to perform Monte Carlo simulation; (v) use the results of the probabilistic estimate as an input to a system dynamics model representing the dynamic escalation process of disputes in construction projects, in the presence of DARTs; (vi) evaluate the costs incurred by the occurrence and escalation of disputes, reflected by the financial variables of the system dynamics model; (vii) price the real options to perform a cost-benefit analysis for the potential DARTs to be adopted; (viii) propose a framework for developing an adapted and enhanced conflict management plan, based on the previous analyses.

The major methodologies that will be used in the research can briefly be described as follows (an entire chapter will be devoted to each of them later in this thesis):

I-1. System Dynamics

System Dynamics was developed to apply control theory to the analysis of industrial systems in the late 1950s [Richardson, 1985]. System dynamics has been applied to many complex industrial, economic, social, and environmental systems of all kinds [Turek, 1995]. In this research, system dynamics is adopted to represent the realities of dynamic complexities in the origin and escalation of disputes in construction projects, with its powerful analytical capability and simulation ability.

In 1999, Pena-Mora et al. developed a system dynamics model for the analysis of DART implementation consequences on the number of outstanding issues in a construction project. Based on the number of issues arising during the life of the project, the model

allowed the comparison of outcomes based on the DART implemented at different levels of conflict escalation. One of the goals of this work will be the improvement of the current model so as to introduce a more sophisticated notion of uncertainty in conflict occurrence (and therefore to obtain a more accurate conflict profile), as well as the addition of a financial dimension to the model.

I-2. Probabilistic Analysis

Probabilistic analysis can be described as an analytical form of analysis where multiple elements of risk can be treated as random variables. Once the elements of risk, or random variables, have been identified for a specific project, the study and analysis of their individual characteristics lead to the attribution of the most appropriate probability distribution to each of these variables. In this analysis, then, the next step is to determine the effect of their combinations, in other words to define the resulting probabilistic distribution. Combining different types of distributions is a complex problem that requires the use of simulation programs. Computer simulations (see Monte Carlo Simulations, described below) are utilized to generate a most likely outcome based on thousands of computer generated what-if scenarios.

In our study, a probabilistic profile will be assigned to the conflicts so as to comprise the uncertain nature of its occurrence that will affect the adoption of a certain DART as a preventive measure at the outset of the project. The probabilistic characteristics of a random variable are described completely if the form of a distribution function (or its probability density function) and the associated parameters are determined. However, in practice, the form of the distribution function is often unknown. For this reason, an approximate description of a random variable becomes necessary, as will be described in more detail in Chapter 4.

Probabilistic analysis is effective not only as a model for quantitative decision-making, but is also a powerful qualitative tool with special importance for communications and marketing presentations to audiences with vested interest in the project. Indeed, it gives a better sense of the uncertainty related to the outcome of the project, and enables the participants to appreciate the existence of multitude of scenarios that might affect the initial predictions related to the project's different aspects.

Monte Carlo Simulations are increasingly being used as an important tool for analysis of project uncertainties. For complicated problems, Monte Carlo simulation generates random outcomes for probabilistic factors so as to imitate the unpredictability inherent in the original problem. In this manner, a solution to a rather complex problem can be inferred from the behavior of these random outcomes. Namely, we will be able to simulate the number of arising disputes based on the predefined probability distribution of risk factors, or potential sources of conflict. In our study, Monte Carlo will be used to simulate the interaction of the random risk variables, so as to be inserted as an input of the system dynamics model, which will affect the overall response of the model towards more accurate results.

I-3. Real Option Pricing

A project embeds a real option (as opposed to a financial one) [e.g. Sick, 1990; Nichols, 1994; Trigeorgis, 1995 and 1996] when it offers management the opportunity to take some future action (such as abandoning, deferring, or scaling up the project) in response to events occurring within the firm and its business environment. In this thesis, we will deal with real options when the possibility of investing in the initial measures of a dispute avoidance process arises, before the need of its actual implementation. More practically, the pricing of the possible real options will enable the project managers to quantify the benefits and tradeoffs of the potential DART implementations before the actual start of the project. The decisions taken by the managers relating to conflict resolution methods will be reflected in the elaboration of the conflict management plan.

II. Proposed Research

The proposed research will start with the *identification and probabilistic characterization* of project conflict variables. The risk variables will be determined in accordance with the participants' anticipation of conflict occurrence in a particular project, and the historical reports of conflict problems on similar projects. The combination of the project conflict variables will then be assessed by performing a *Monte Carlo simulation*, in order to get a probability distribution of the total number of conflicts that would arise in the project.

This characterization of the issue occurrence profile will then be used as an input of a *system dynamics model*, to simulate the number of resolved and outstanding issues at the different steps of DART resolution, as the input of the system.

The results of the simulation will be analyzed to perform a valuation of the different DART implementation that could be applied, and to develop an enhanced Conflict Management Plan. The project managers will be able to assess the necessity of adoption of dispute avoidance techniques such as Partnering before the actual beginning of the project (i.e., for conflict *avoidance* purposes), as well as the appropriate conflict management plan for the project. The analyses will also be used during the project to quantify the impact of different dispute resolution techniques on the number of outstanding issues (i.e., for conflict *resolution* purposes). Figure 2 shows the components of the proposed research.

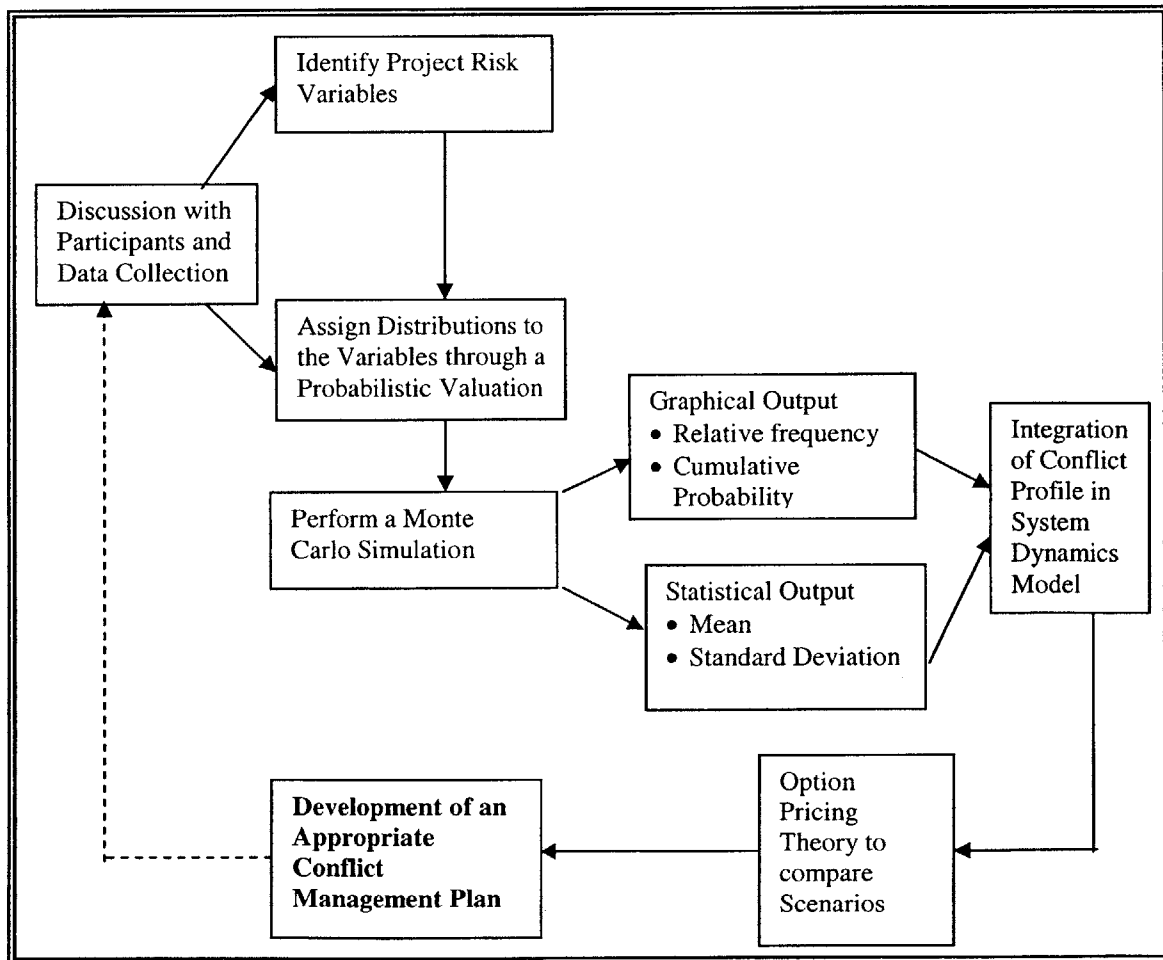


Figure 2: Research Components

III. Research Deliverables

This research will provide:

- Models and tools for better understanding and analyzing the conflict profile of projects.
- Optimized DART implementation strategies that can absorb the impact of identified iterative cycles.
- A project management framework that can improve project performance by projecting and quantifying the effect of uncertain conflicts and the cost implications of potential DART implementations.
- An improved approach to the Conflict Management Plan that can capture the uncertain nature of conflict occurrence in construction projects and provide the appropriate contingencies.

IV. Future Work

Future work on the topic should include:

- Gathering data from past and on-going large-scale infrastructure projects to corroborate the hypothesis of normal distributions for the project risk variables, and show the correlation between project size and conflict occurrence.
- Gathering data from large-scale infrastructure projects and legal organizations to corroborate the hypothesis of triangular distributions for the cost of DART implementations.
- Gathering data on the time of occurrence of conflicts during the life of construction projects.
- Further develop the system dynamics model developed by Pena-Mora and Tamaki. Indeed, some limitations have been spotted in the model but were not considered as a priority in this paper. Basically, the research group would need to conduct data gathering searches in order to evaluate with greater precision the

effect of DARTs on conflict avoidance and resolution (i.e., improve the formulations of factors such as Agreement Rates, Time for Decision-Taking , Effect of DART on Decision-Making in the existing System Dynamics model, Table for Time Uncertainty).

- Also, the system dynamics model can be expanded to account for impacts on schedule, performance, quality, nature, social and political issues. Contact should be established with David Kreutzer, an academic involved in the development of system dynamics for dispute resolution.
- Improvement of probabilistic analysis to take into account the potential correlation between the random variables.
- Test the decision-frameworks proposed at the start of a project, and estimate the impacts of the new techniques on the number of occurring conflicts and the conflict avoidance and resolution costs.
- Organize workshops and conferences, and publish papers to bring about the dissemination described earlier.
- Develop an application that would automatically integrate distribution allocation to the risk variables, Monte Carlo simulation, and real option pricing methods, simply based on a few inputs required from the project manager.

V. Broader Impact of Proposed Research

The potential broader impact of this research can be summarized as follows:

- Optimization of managerial decision-making related to conflict avoidance and resolution, as well as an improvement of DART implementation.
- Reduction of conflict occurrence in large-scale infrastructure projects.
- More precise contingency allocation in the conflict avoidance and resolution budget of construction projects.

- Development of modern tools in construction management, with enhanced use of MIS and Information Technology.
- Enlargement of construction management approach, to include feedback from industry and research.
- Increase in the applicability of simulations in project management.
- Enhancement of learning in construction management.

Chapter 3 – System Dynamics Modeling of Conflict Escalation

I. What is System Dynamics?

Complex systems such as a construction project have unique characteristics that make them difficult to model by a traditional mathematical model. These characteristics are:

- Transfer of problems between sectors; frequently, the most rapid solution of a difficulty for one sector is to blame another sector for the problem. For example, an engineering team can accuse the designers for a structural problem.
- Trade-off between present and future. In complex systems it becomes very difficult to analyze the behavior of a variable without separating present and future. This separated analysis can hide critical characteristics of the system.
- Resistance to policy changes or changes on how the work should be done. They are always sectors that feel their interests are damaged by the new policies and they will make their best effort to resist the changes.
- Very few high-leverage policies. In general, policies are implemented to solve short-term problems and they do not take into account side effects that can ruin the long-term horizon.

These characteristics require special treatment to model them. System dynamics can be used to achieve this objective. System dynamics is a method for studying physical systems around us. Unlike other scientific modeling techniques, which study systems by breaking them up into smaller pieces, system dynamics takes a more global approach. The field developed initially from the work of Jay Forrester, who began applying what he had learnt about systems during his work in electrical engineering (i.e., control theory) to everyday kinds of systems. The central concept of system dynamics that Professor Forrester developed explains how all the objects in a system interact with one another [Forrester, 1961]. The system mentioned before can be anything from a steam engine, to a bank account, to a basketball team. The objects and people in any system interact

through “feedback” loops, where a change in one variable affects other variables over time, which in turn affects the original variable, and so on.

Using these ideas, the purpose of system dynamics is to understand the basic structure of a system, and thus understand the behavior it can produce. Many of these systems and problems, which are analyzed, can be built as models on a computer. In this case, system dynamics takes advantage of the fact that a computer model can be of much greater complexity and carry out more simultaneous calculations than can the mental model of the human being.

Another significant advantage of system dynamics is that it helps us prevent our natural tendency to view the world as a succession of events, blinding us to the structures in which we are embedded and the dynamics they generate. The event oriented worldview leads to an event-oriented approach to problem solving.

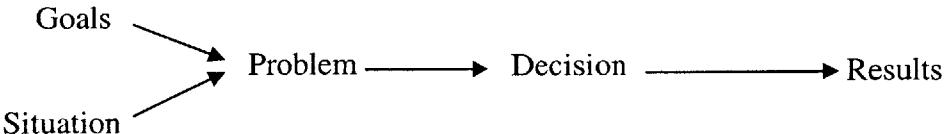


Figure 3: Event-Oriented View of the World

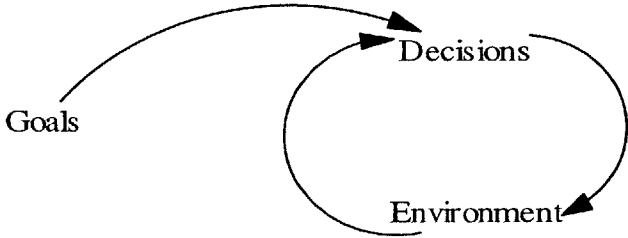


Figure 4: The Feedback View

However, in the real world, the results of our actions define the situation we face in the future and a causal loop relationship is formed. The new situation alters our assessment of the problem and the decisions we take tomorrow. As our actions alter the state of the system, other people react to restore the balance we have upset. Our actions not only affect the environment in ways we intend, but may also trigger side effects.

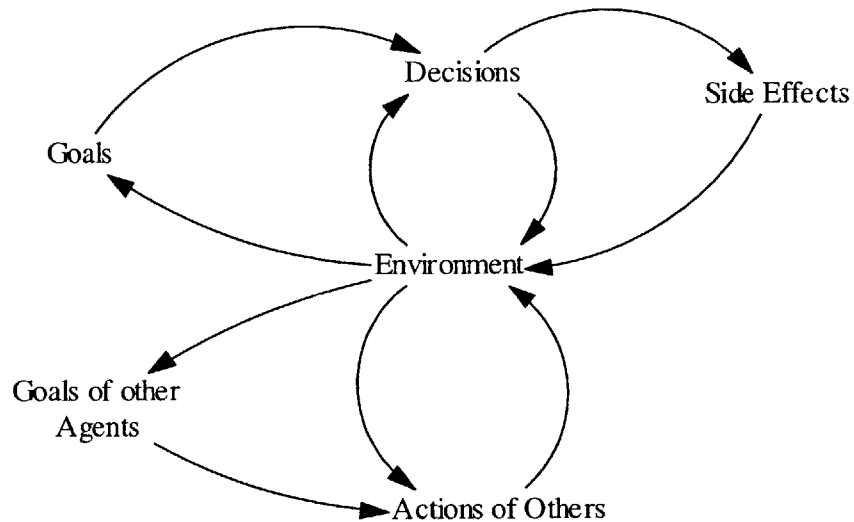


Figure 5: The Feedback Complete View

When we take actions, there are various effects. The effects we had anticipated, or which had a partial effect, we call the main or intended effects. But, there are always effects that we had not planned, and consequences that fed back to undercut our policy (see Figure 5). Unanticipated effects arise because too often, human beings act as if cause and effect were always closely linked in space and time. But in complex system such as the large-scale infrastructure projects, cause and effect are often distant in space and time.

II. Preliminary System Dynamics Model

In this research, system dynamics will be used to model and analyze the impact of potential Dispute Avoidance and Resolution Techniques' (DARTs) implementation on the number of outstanding conflicts in construction projects. The system dynamics

approach allows the integration of numerous factors that add to the complexity of dispute avoidance and resolution in large-scale infrastructure projects. The real-life elements that reflect the non-linear behavior of the system (i.e., the large-scale infrastructure project) and the need for a simulation tool are the following:

- The perception rate of conflicts
- The uncertainty related to the conflict profiles and conflict occurrence
- The time for complete DART implementation
- The likely fraction of agreement at each step of the ADR ladder
- The competitive position at each DART level
- The effect of $DART_{n+1}$ on $DART_n$'s process competitiveness

Figure 6 represents the different steps in the dispute resolution ladder.

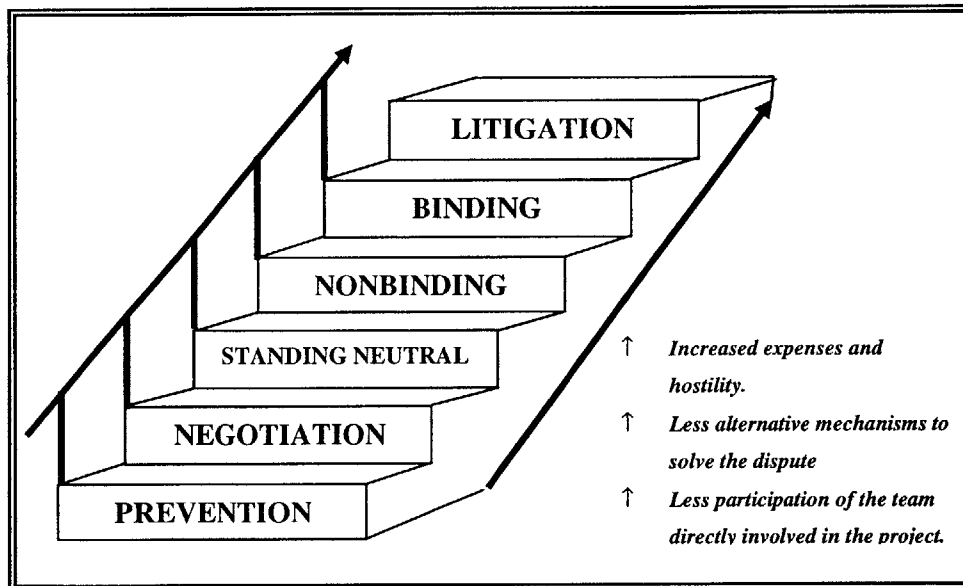


Figure 6: The Dispute Resolution Ladder [Findley, 1997]

The PIs have developed a preliminary functional model of the DART system that is able to analyze different scenarios, based solely on the DART policy adopted, to predict the amount of conflict that will occur on a given project. The model can be broken down to its main components as follows:

- **Division of all possible conflicts occurring in construction projects into three main categories.** The conflict groups were set as: Project Uncertainty (referred to as PC₁), Process Issues (PC₂), and People Problems (PC₃). (*Note:* When referring to these conflict groups without specifying which one of the three, the notation PC_i will be used). This categorization was required to be able to adapt the sub-models to the characteristics of each type of conflicts. Table 3 defines each category in more detail. Obviously, further division of conflict types among the mentioned categories can be performed, but at this stage it is believed that it would add unnecessary complexity to the model.
- **Development of a model for each step of the Dispute Resolution Ladder.** Each stage was broken down into all its existing DARTs (see Table 2), and the combined effect of the chosen DARTs were summed up to capture their influence on the applicable PC_i. Figure 8 depicts the model that was developed for the Prevention stage.
- **Development of a model for each conflict category.** At this point, all the information and sub-models are combined to develop a model for each of the PC_i, so as to represent the evolution of the number of outstanding conflicts related to Project Uncertainty, Process Issues or People Problems throughout the different stages of the Dispute Resolution Ladder. Figure 7 shows the model that was defined to represent the escalation of conflicts related to project uncertainty, or PC₁. Moreover, a variable defined as the Degree of Conflict was introduced as an overall measure of the system's performance, and set equal to a weighted average of the number of issues at each stage:

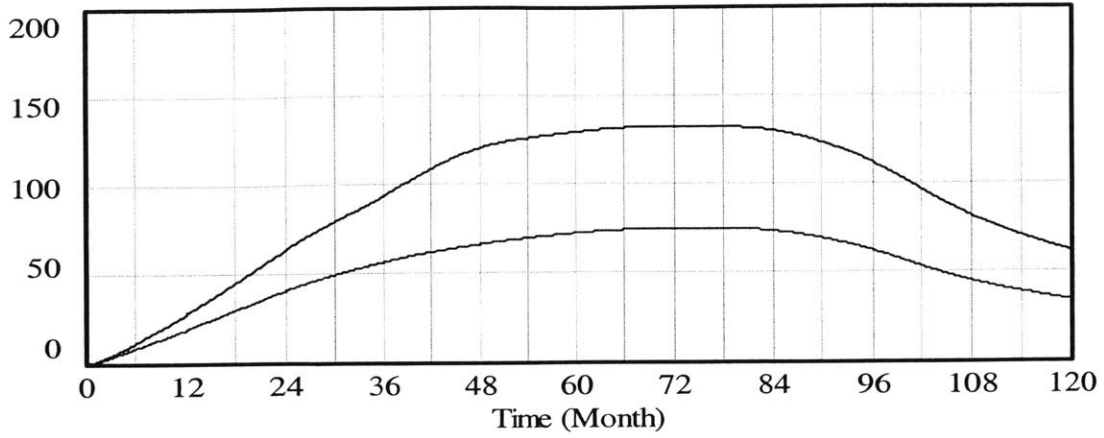
$$\begin{aligned}
 \text{Degree of Conflict} = & \text{Issues at Negotiation} + 2 * \text{Issues at Standing Neutral Process} \\
 & + 3 * \text{Issues at Non-Binding Arbitration} + 4 * \text{Issues at Binding Arbitration} + 5 * \\
 & \text{Issues at Litigation.}
 \end{aligned}
 \tag{Equation 1}$$

For instance, let us assume that we are interested in the effect of partnering on the Degree of Conflict. The number of arising conflicts related to project uncertainty is set to 600, whereas for issues caused by process issues and people problems, the constant is set to

250. Graph 1 is obtained after simulating the model, and shows the decrease in the amplitude of the degree of conflict after the implementation of partnering.

Table 2: The DARTs of the Dispute Resolution Ladder's Stages

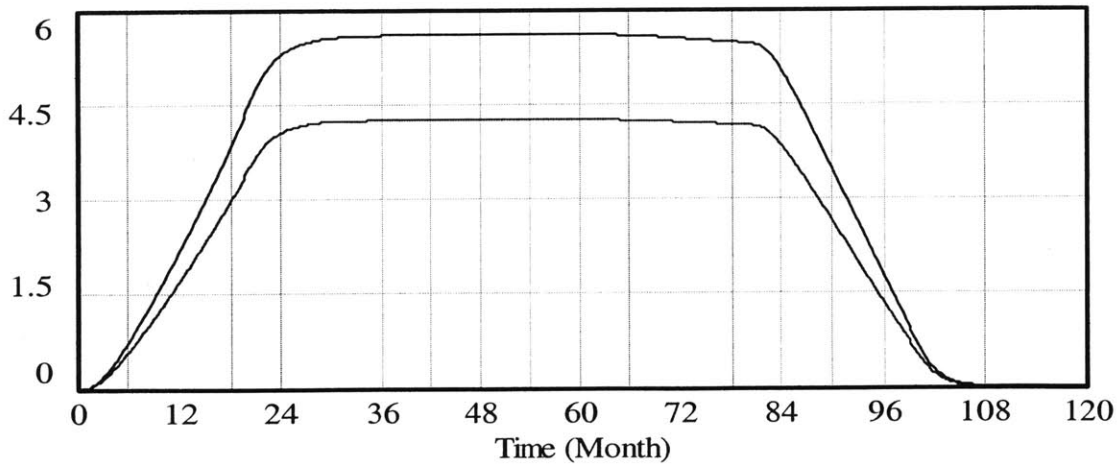
Step, or Stage, of the Dispute Resolution Ladder	Eventual DART Category	DARTs of the Stage
Prevention	Equitable Risk Sharing	<ul style="list-style-type: none"> • Economic Price Adjustment • Geotechnical Baseline Report • Third Party Beneficiary Clause
	Project Award and Delivery Mechanism	<ul style="list-style-type: none"> • Negotiated Compressed Process • A+B Bidding • PEpC Delivery System • Bridging Design-Build Gap
	Incentive Programs	<ul style="list-style-type: none"> • Cost and Schedule Incentive Matrix • Subjective Determination of Fee • Superior Time Management Allowance
	Cost and Schedule Control	<ul style="list-style-type: none"> • Cost Statement Submittal • Certified Payroll Submittal • Negotiated Equipment and Labor Pricing • Joint Project Scheduling • Schedule Audits • As-Built Schedule Submittal • Forward Price Change Orders • Right of Refusal • Subcontractor Payment Requirements
		<ul style="list-style-type: none"> • Escrow Bid Documents • Constructability Analysis • Dispute Resolution Clause • Training and Development • Partnering
Negotiation		<ul style="list-style-type: none"> • Structured Negotiations • Step Negotiations • Facilitated Negotiations
Standing Neutral		<ul style="list-style-type: none"> • Neutral Advisor • Owner Agency Review Boards • Dispute Review Board • On-Call Contractor
Non-Binding Resolution		<ul style="list-style-type: none"> • Mediation • Conciliation • Advisory Mediation • Fact-Based Mediation • Minitrial or Executive Trial • Summary Jury Trial • Voluntary Settlement Conference
Binding Resolution		<ul style="list-style-type: none"> • Mediation / Arbitration • Adjudicator Expert Determination • Single Arbitration • Baseball Arbitration • Shadow Mediation
Litigation		<ul style="list-style-type: none"> • Court Appointed Experts • Judge Pro Tem • Trial by Reference



Degree of Conflict : Base _____ Dimensionless
 Degree of Conflict : Partnering _____ Dimensionless

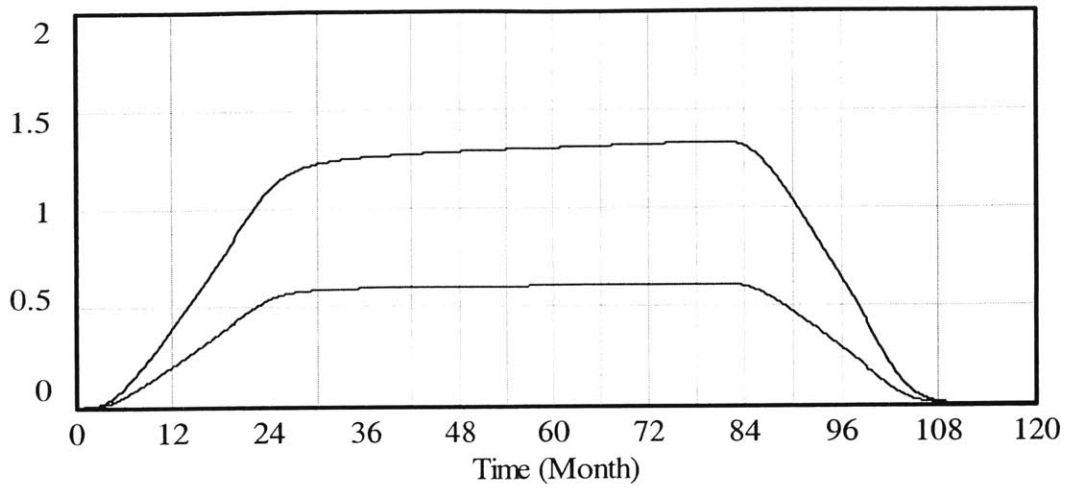
Graph 1: Effect of Partnering on the Degree of Conflict, in a Time Frame of 120 months

The following graphs represent the number of outstanding issues at some stages of the Dispute Resolution Ladder.



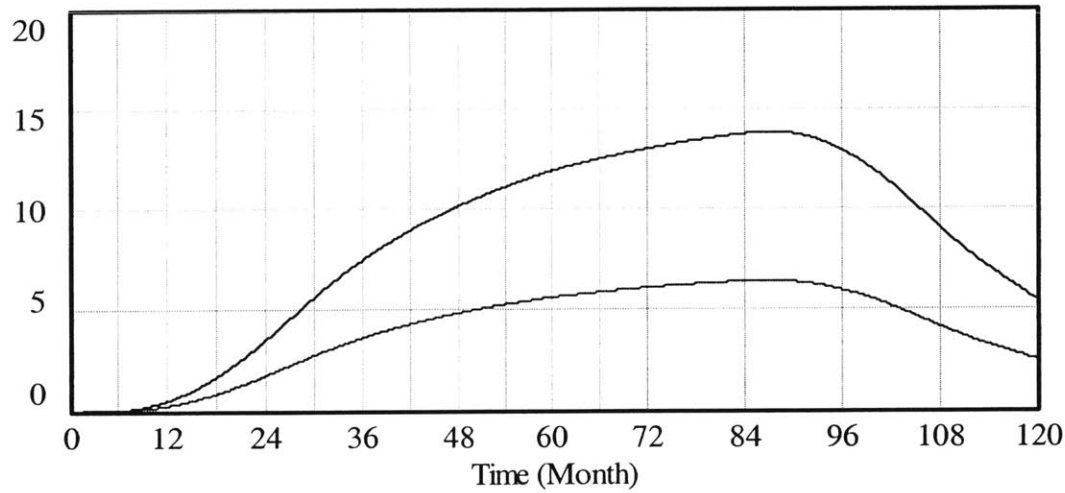
"Issues at Negotiation (PC1)" : Base _____ Issue
 "Issues at Negotiation (PC1)" : Partnering _____ Issue

Graph 2: Issues at Negotiation Level (PC1)



"Issues at Non-Binding Arbitration (PC1)" : Base _____ Issue
 "Issues at Non-Binding Arbitration (PC1)" : Partnering _____ Issue

Graph 3: Issues at Non-Binding Arbitration (PC1)



"Issues at Litigation (PC1)" : Base _____ Issue
 "Issues at Litigation (PC1)" : Partnering _____ Issue

Graph 4: Issues at Litigation (PC1)

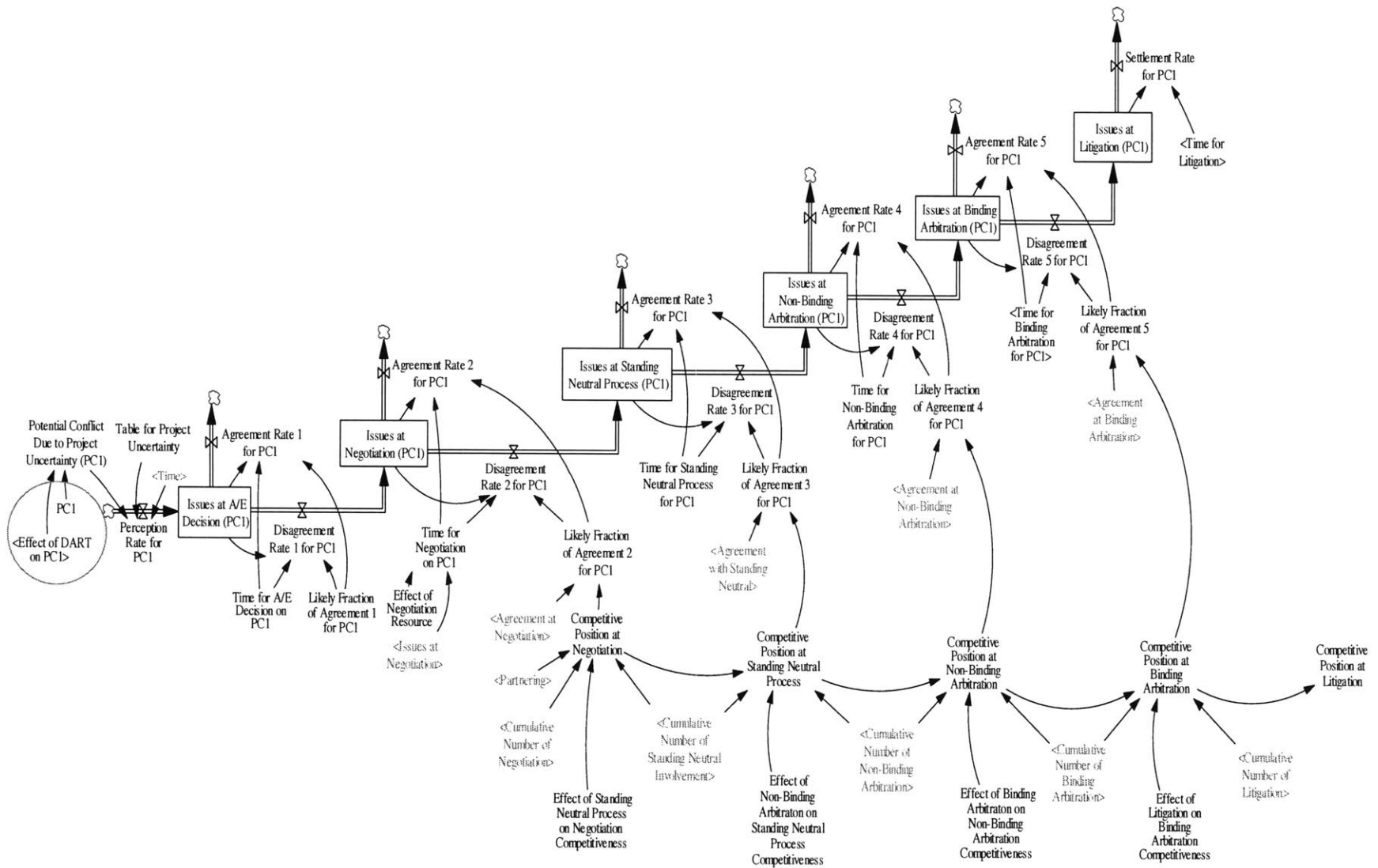


Figure 7: Part of the System Dynamics model representing the Escalation of the Number of Outstanding Issues in the DART ladder. This view focuses on the issues related to “Project Uncertainty” (named PC1).

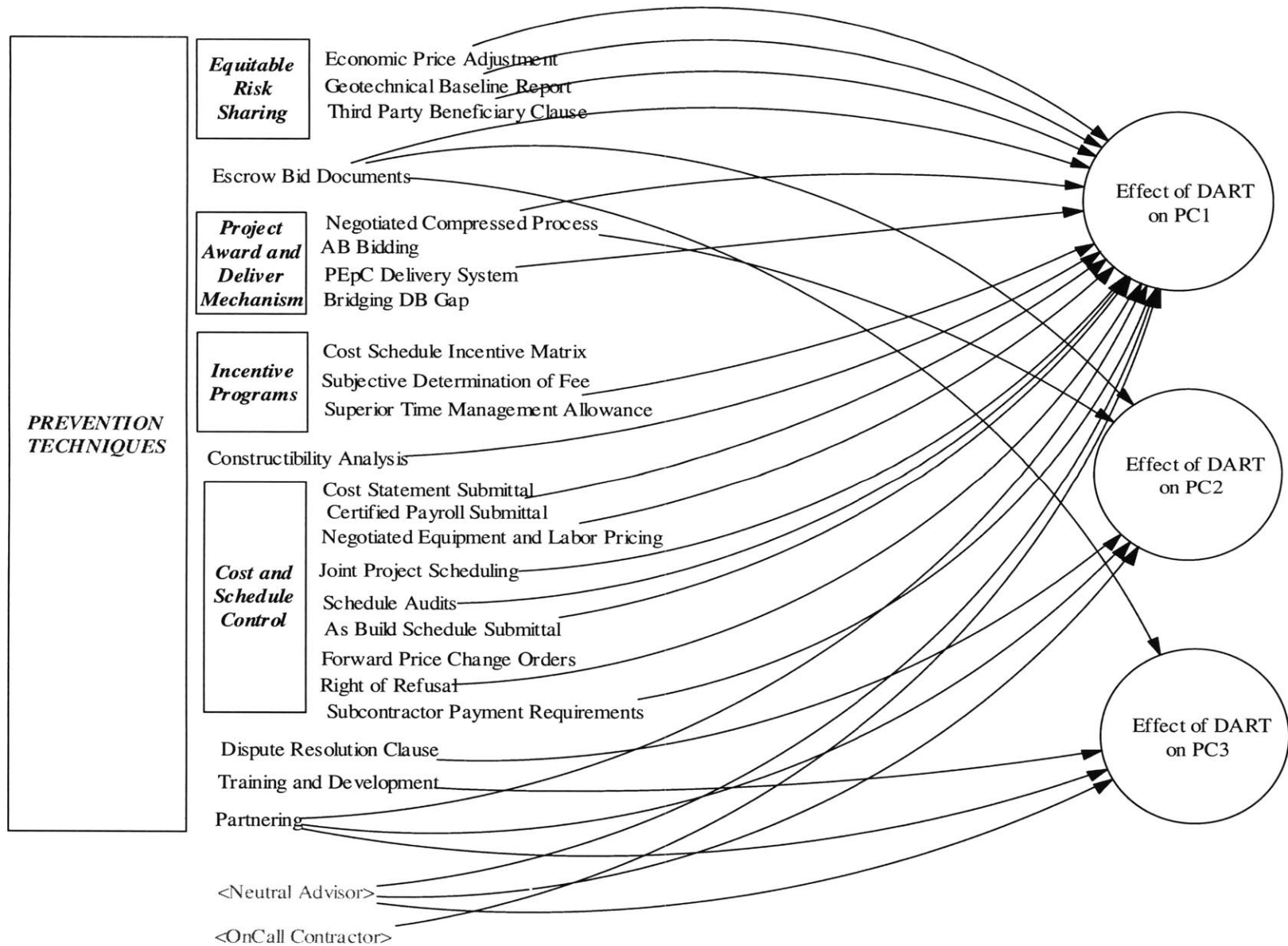


Figure 8: Part of the System Dynamics Model, representing the Effect of Prevention Techniques on the Escalation of Conflicts

III. Development of the Existing Model

III-1. Limitations of the Model

- The Forecasted Number of Arising Conflicts

The circled area on the model represents one of the main areas of improvement in this paper. The model developed in previous research set the “PC1” variable to a constant (600 issues), based on the assumption that this would be the number of the conflicts arising due to people issues. The user had the possibility to change the assigned value to another constant if needed. This initial model’s major goal was to be able to analyze the conflict profile of the project based on the selected DART implementations. In this thesis, we will consider both the number of arising conflict and the selected DART implementations as variables. Therefore, the first amelioration to be made to the model should be a characterization of the input variable (named PC1 in the model, representing the number of conflicts expected to arise) that would take into account the uncertain nature of the system.

Another input of the model that will need improvement is the “Table for Uncertainty”, which used as an arbitrary variable to represent the uncertainty based on the time of occurrence of the conflicts during the project. Although this issue will not be dealt with in this paper, ulterior research should collect data from real-life projects to study the time of occurrence of conflicts and define a time-related profile of occurrence that would be closer to the reality of construction projects.

Moreover, the existing model classifies risk variables in three major categories, which are Project Uncertainty, Process Issues and People Problems. As will be later shown in Table 3, another category could be added for the “Structure Issues”, i.e., conflicts related to delivery systems, inappropriate contract type, contract documents, contract terms, and law. This concern is not critical and will not be addressed in this paper; the Structure Problems will be classified in the same category as the Process Issues (PC2).

- Financial Evaluation of Possible DART Implementation

The number of outstanding issues and the implementation of the DARTs affect, and are affected, by budget constraints. For this reason, the conflict management plan should be developed in a way to account for potential risks and provide appropriate contingencies. The existing model lacks to provide grounds for financial evaluation of the potential DART implementations. Financial variables need to be added to the model to translate the results in a way to help the project managers decide on the possible DART adoptions during the life of the project and on the appropriate conflict management plan.

III-2. Additions to the Model and Modifications

- **Profile of Arising Conflicts**

The purpose of the probabilistic characterization of risk variables introduced in the system dynamics model is to replicate in the model the real-life uncertainty of conflict occurrence. The proposed amelioration is to introduce the uncertainty in conflict occurrence by assigning a probability distribution to the PC1 factor (or similarly to PC2, process conflicts, and PC3, structure conflicts), based on the Monte Carlo simulation described in the next chapter. In other words, the purpose of the ameliorated model is to provide more robust grounds for decision-making as far as the Prevention DARTs are concerned, by developing a more accurate conflict profile at the outset of the project (comprising the probabilistic characterization of conflict occurrence), and also an optimal conflict management plan. This would be a significant step in the conflict avoidance area, since the prevention stage offers the greatest flexibility to improve communication and job performance by minimizing disagreements and helping the project team resolve those problems that arise before they become disputes or claims. In the next chapter, we will explain how and why probability distributions will be assigned to the definition of the PC_i , instead of an arbitrary constant.

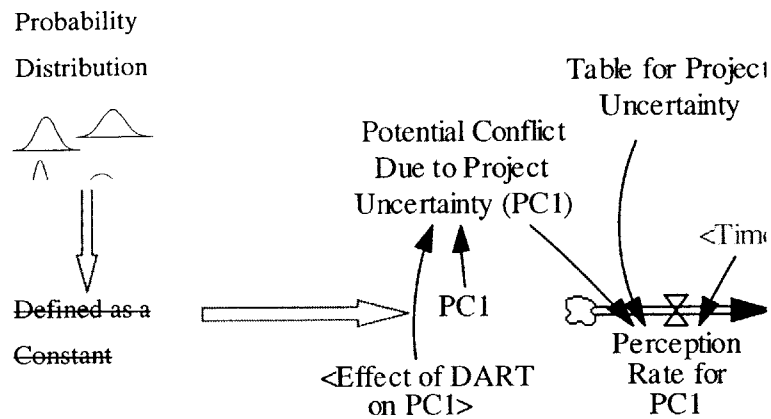


Figure 9: New Definition of the PC_i Input

- Financial Evaluation of Possible DART Implementation

Once a more accurate conflict profile and financial variables have been added to the model, the resulting forecasts will enable the project managers to take decisions based on real option pricing theory during the life of the project, and to allocate an adapted budget to conflict contingencies at the outset of the project. The application of the simulation results to the option pricing and enhanced conflict management plan will be explained in chapters 5 and 6.

Figure 10 shows the addition of financial variables related to PC₁ to track the costs of the potential DART implementations. The simulation then provides us with the total cost of avoiding/resolving PC₁ issues. The same concept is applied to PC₂ and PC₃ issues, in order to obtain the total cost of conflicts in the project (Figure 11). More precisely, the new variables are:

- Average Cost of Dealing with one PC_i issue per Month
- Cost of Dealing with PC_i Issues at each DART stage during the project
- Cumulative Cost of PC_i Issues at each DART stage over the entire project
- Total Cost of PC_i Issues in the Project
- Total Cost of Conflicts in the Project

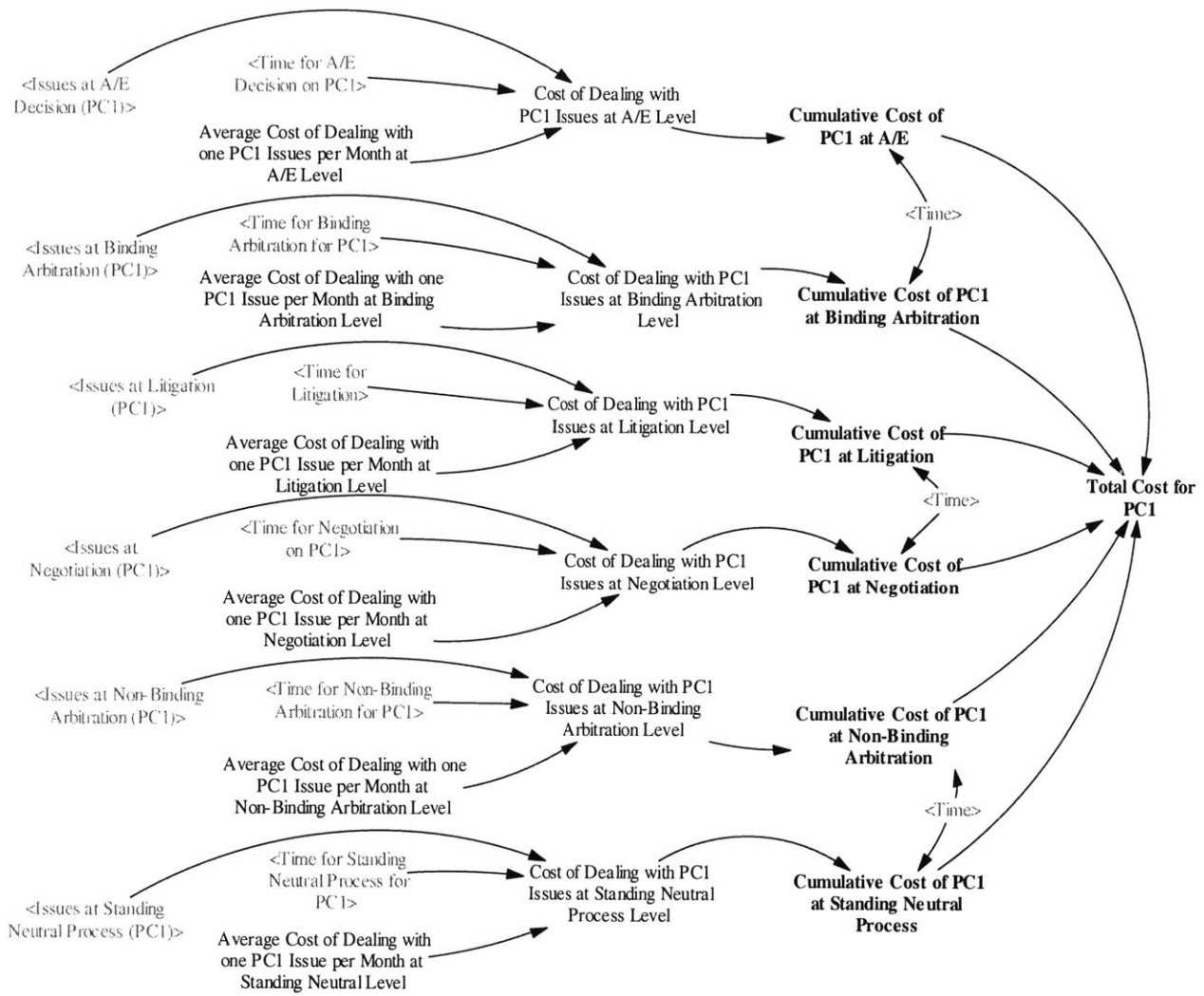
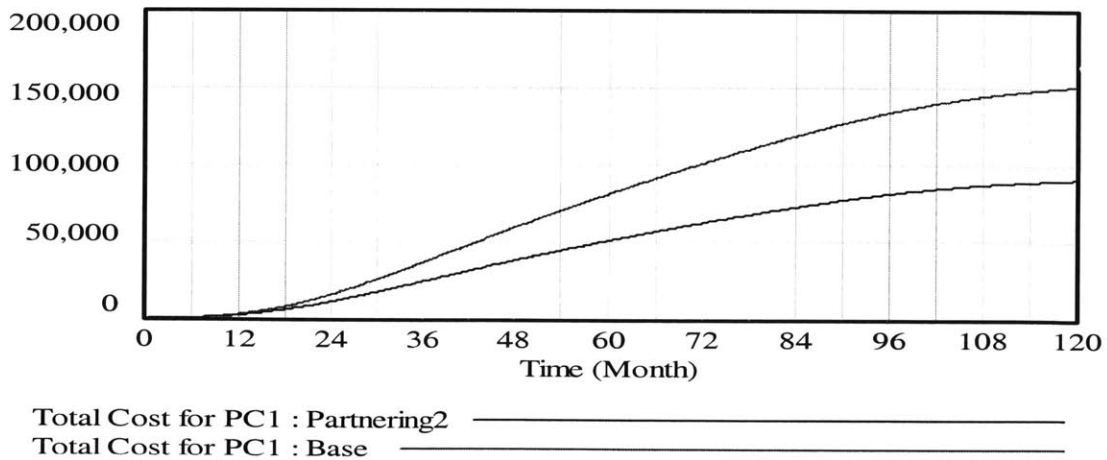


Figure 10: Addition of New View to the Existing Model – Total Cost for PC1 Issues



Graph 5: Total Cost of PC1 Issues (Two Runs: Base Case without DART & Implementation of Partnering)

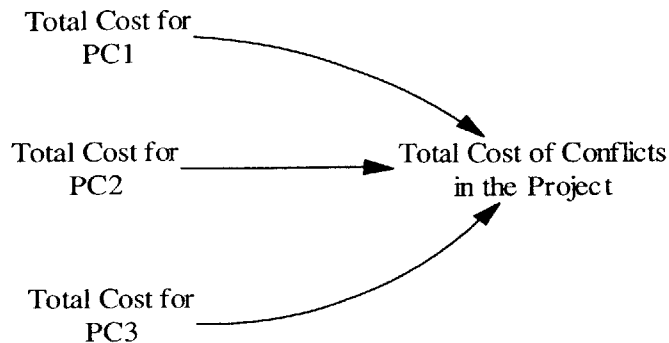


Figure 11: Total Cost of Conflicts in the Project

The variables were defined according to these equations:

- Cost of Dealing with PC1 Issues at A/E Level = Average Cost of Dealing with one PC1 Issue per Month at A/E Level * Issues at A/E Decision (PC1) * Time for A/E Decision on PC1.
- Cumulative Cost of PC1 at A/E = INTEG (Cost of Dealing with PC1 Issues at A/E Level / Time), 0).
- Total Cost for PC1 = Cumulative Cost of PC1 at A/E" + Cumulative Cost of PC1 at Binding Arbitration + Cumulative Cost of PC1 at Litigation + Cumulative Cost of PC1 at Negotiation + Cumulative Cost of PC1 at Non-Binding Arbitration + Cumulative Cost of PC1 at Standing Neutral Process.
- Total Cost of Conflicts in the Project = Total Cost for PC1 + Total Cost for PC2 + Total Cost for PC3.

(Equation 2)

The comparison of the Total Cost of Conflicts in the Project with different DART implementations will be the basis of the trade-off analysis and option-pricing discussed in Chapters 5 and 6.

Chapter 4 – Probabilistic Analysis of Conflicts and Monte Carlo Simulations

I. Random Variables

I-1. Defining Random Variables

Many random phenomena of interest are encountered in engineering and the physical sciences which are associated with numerical outcomes of some physical quantity. The possible outcomes of random phenomena can be identified numerically, either naturally or artificially. In both cases, an outcome or event can be identified through the values of a function. Such a function is a random variable, and the value of this random variable then represents a distinct event. For instance, if X states the number of conflicts related to people issues in a given project, then $X > 100$ stands for the occurrence of a number of conflicts higher than 100 issues. s

Since the value of a random variable represents an event, it can assume a numerical value only with an associated probability or probability measure. The rule for defining the probability measures of all the values of the random variable is a probability distribution, or probability law. If X is a random variable, the cumulative distribution function (or CDF) will be used to describe the probability distribution. For a continuous random variable, probabilities are associated with intervals on the real line; consequently, at a specific value of X , such as $X = x$, only the density function is defined. Therefore, for continuous random variables, the probability law can also be described by the probability density function (PDF). The distribution function is:

$$F_X(x) = P(X \leq x) = \int_{-\infty}^x f_X(\xi) d\xi \quad (\text{Equation 3})$$

Accordingly, if $F_X(x)$ has a first derivative, then:

$$f_X(x) = \frac{dF_X(x)}{dx}$$

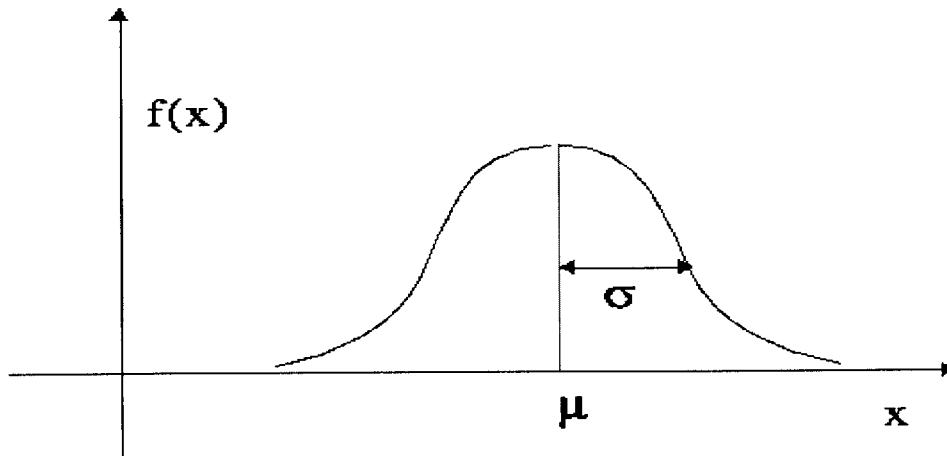


Figure 12: Example of PDF for a Normal Distribution Function
 (μ represents the mean and σ the standard deviation)

The probabilistic characteristics of a random variable would be described completely if the form of a distribution function (or its probability density function) and the associated parameters are determined. However, in practice, the form of the distribution function is often unknown. For this reason, an approximate description of a random variable becomes necessary. The key quantities, or main descriptors, of random variables are its central value (mean value) and a measure of its dispersion from the central value (variance and standard deviation). Moreover, even when the distribution function is known, the main characteristics of the random variable remain useful, because they contain the information on the properties of the random variable that are of first importance in practical applications.

I-2. The Need for Probabilistic Analysis in Our Study

As mentioned earlier, this paper is aiming to provide a characterization of arising conflicts in construction projects that would convey the uncertainty of their occurrence. For this reason, we will consider the number of arising conflicts as a random variable, whose distribution needs to be determined based on historical data. The combination of these numerous conflict profiles will then be obtained through a Monte Carlo simulation, and then used as an input to the system dynamics model developed above. The following sections describe in more detail how the probabilistic characterization is brought about.

Probabilistic analysis is most usefully conducted at the planning time of a construction project, when the level of line-item and unallocated contingencies, as well as the total project budget, is being reviewed and the conflict profiles are being determined. Then, during the bid time, the forecasts on the risk variables and the corresponding contingencies reflected in the conflict management plan can be modified or defined with more precision, as potential participants expose their viewpoints on the project and contingency levels are being negotiated. A probability distribution needs to be selected in order to model each critical variable. Probability distributions can be specified from two sources: either by fitting the distribution of past observations against an assumed model distribution, or by choosing a distribution from subjective judgments of the experts involved at the initial stage of the project cycle.

II. Identification of the Risk Variables

The first step in the probabilistic approach is to assess risk or measure the probability of cost overrun due to the potential emergence of conflicts in construction projects by identifying project variables that might contribute to the appearance of conflicts. These project variables, or risk variables, are the elements that due to their uncertain profile will be the random variables at the core of our probabilistic analysis.

Previous research done in this area [Howell et al., 1988, cited by Vorster, 1993] has identified the major categories of sources of conflict and dispute in construction projects (Table 3). Based on discussion with different parties and experts involved in a specific project, as well as any historical data on similar projects, the critical sources of potential conflict and dispute need to be selected and prioritized. At this stage, the identification of the risk variables does not require a robust quantified characterization. Indeed, this task will be achieved during the phase of probabilistic distribution attribution to the risk variables.

Probabilistic analysis can be useful in focus groups and negotiations where all parties have an incentive to estimate risk accurately. Cumulative probability

functions resulting from a probabilistic analysis can usefully adapt to a “Which shall we do?” approach, versus a potentially confrontational “How about this?” Probabilistic risk assessment may be a useful tool to facilitate risk communication, through its ability to measure risk continuously or probabilistically and therefore clarify risk quantification.

Table 3: Sources of conflict and dispute

Area	Discipline	Sources of Dispute
Organizational Issues	Structure	Internal/external organizational structure, delivery systems, inappropriate contract type, contract documents, contract terms, law
	Process	Performance, quality, tendering pressures, payment, delays, disruption, acceleration, administration, formal communication channels, information sharing, reports and poor communication
	People	Misunderstandings, unrealistic expectations, culture, language, communications, incompatible objectives, management, negligence, work habits, and lack of team spirit
Uncertainty	External	Change, variations, environmental concerns, social impacts, economics, political risks, weather, regulations , and unforeseen site conditions
	Internal	Incomplete scope definition, errors in design, construction methods and workmanship

The participants need to select and prioritize the risk variables for their specific project from the previous table. The variables, after having been defined probabilistically, will be studied in detail through the system dynamics model, with the Uncertainty factors (both external and internal) constituting the PC₁ category, and the Organizational factors split between PC₂ (structure and process issues) and PC₃ (people problems).

III. Defining the Probabilistic Distributions for the Risk Variables

III-1. Theoretical Concerns and Assumptions

The normal distribution is used to model many different types of real-life continuous data that tend to be distributed symmetrically about some "true mean". It is also often used to approximate discrete random variables. In our case, the random variables (number of arising conflicts) shall directly be considered as continuous. Indeed, there are no parameters that define and delimit one single conflict. Therefore, it makes sense for instance to attribute a value of 1 to a "large" conflict, and 0.5 to a "medium-sized" conflict, and to consider the number of conflicts rather like a "level" of conflict, treating it as a continuous variable.

If X is a normal random variable with parameters μ (mean value) and σ (standard deviation), then the PDF, mean, and variance are as follows

$$\begin{aligned} f(x) &= \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \\ E(X) &= \mu \\ \text{Var}(X) &= \sigma^2 \end{aligned} \tag{Equation 4}$$

The CDF of the Normal distribution is not readily available. Tables exist, however, for the standard normal random variable $Z \sim N(0, 1)$. Furthermore, we have the following theorem:

$$\text{If } X \sim N(\mu, \sigma^2), \text{ then } Z = \left(\frac{X - \mu}{\sigma} \right) \sim N(0,1). \tag{Equation 5}$$

Thus, if we have a Normal random variable X , to calculate CDF probabilities, we first standardize X to make it Z , and then use the tables for the standard normal.

In this paper, we will consider that the normal distribution is a good approximation for the probabilistic characterization of conflict occurrence in a typical large-scale construction project, basing our hypothesis on the Central Limit Theorem. Assuming that the possible numbers of conflicts are (1) random variables, and (2) are

independent and identically distributed, the Central Limit Theorem states that the sample mean is normally distributed:

Central Limit Theorem

If X_1, X_2, \dots, X_n are independent and identically distributed (iid) with mean μ and variance σ^2 , then the sample mean \bar{X} is distributed as -

$N(\mu, \frac{\sigma^2}{n})$. Alternatively, the sample total is distributed as $N(n\mu, n\sigma^2)$.

A corollary of this theorem details with sample sizes. If we want the probability that \bar{X} is within k units of the mean to be $z_{1-\alpha}$, then the

sample size we should take is given by $n = \frac{\sigma^2 z_{1-\alpha}^2}{k^2}$.

Note: The normal approximation to the Binomial (which is the sum of iid Bernoulli random variables), is also a corollary to this theorem.

The hypothesis of independence is a major one, because we are assuming that the sources of conflict have no correlation between each other. Also, even if our variables do not have the same exact distribution, it is enough if no random variable (no source of conflict) largely dominates the others. These two assumptions greatly simplify the probabilistic study. Future research on the topic should question the validity of these hypotheses, and possibly modify them. In this paper we are justifying theoretically the choice of the normal distribution. The collection of actual data would be the best basis of decision. Let us consider these assumptions as satisfactory for now.

The following facts further corroborate the choice of the normal distribution for the random variables: (1) the necessity of symmetry in the distribution, and (2) the close relationship between the size of the project and the number of conflict occurrences (the larger the project, the higher the mean number of occurrences, and the higher the volatility of this number). One other reason why the normal distribution is

relevant here is that many psychological variables, which play an important role in the occurrence of conflicts (mainly in the People Issues), are distributed approximately normally. Introversion, job satisfaction, and memory are among the many psychological variables approximately normally distributed. Although the distributions are only approximately normal, they are usually quite close.

The normal distribution is also widely used in probabilistic analysis because it is easy for mathematical statisticians to work with it. This means that many kinds of statistical tests can be derived for normal distributions. Fortunately, these tests work very well even if the distribution is only approximately normally distributed. Some tests work well even with very wide deviations from normality. Finally, if the mean and standard deviation of a normal distribution are known, it is easy to convert from raw scores to percentiles.

Similarly, triangular distributions shall be adopted as the cost profile of the adopted DARTs. Such distributions are frequently selected for use with probabilistic modeling, because of their simplicity and ease of use. Indeed, only three values (minimum, mean, and maximum) are necessary to completely define the distribution.

However, if discussions with the project members or historical data on a specific type of project contradict such assumptions, other distributions should be adopted for all variables or a certain set of variables. Indeed, this study is not based on the type of distribution chosen. Ulterior research should collect data to confirm the choice of the normal distribution for the risk variables, or suggest a more appropriate alternative.

III-2. The Probabilistic Characterization of the Risk Variables

At this stage, the risk variables, or the random variables, of the project have been selected, and it has been established that the normal distribution should be adopted for the characterization of the conflicts' occurrence uncertain profile, and triangular distributions for the cost of DART implementations.

Practically, for each identified risk variable, the values of mean and standard deviation are necessary and sufficient to perfectly define its profile. Based on historical data and on their experience, the project managers should set the mean of the distribution as equal to the most likely number of conflicts that would occur for each source of conflict (e.g., 15 conflicts are likely to arise due to delays, 5 due to poor communication, both contributing to Process Conflicts, or PC₂; 10 conflicts are likely to arise due to incomplete scope definition, and 7 due to unforeseen site conditions, both contributing to Project Uncertainty, or PC₂). Then, the standard deviation should be set as a measure of dispersion, or deviation from the most likely value (e.g., if conflicts related to delays have a potentiality to highly diverge from 15, then σ could be set to 2, whereas σ would be set to 0.5 for the communication problems, if the participants feel that there should be little dispersion). After the two critical measures have been set for all the risk variables and thus all conflict profiles have been determined, the Monte Carlo simulation will allow us to combine the different normal distributions for each PC_i category.

Also, the cost of the each DART implementations will be defined through the choice of three values, necessary and sufficient to determine a triangular distribution. For each DART, the project managers need to forecast the lowest, most likely and highest possible value of the DART implementation.

IV. Monte Carlo Simulations

IV-1. Definition and Purpose of Monte Carlo Simulations

Numerical methods that are known as Monte Carlo methods can be described as statistical simulation methods, where statistical simulation is defined in quite general terms to be any method that utilizes sequences of random numbers to perform the simulation. Monte Carlo methods have been used for centuries, but only in the past several decades has the technique gained the status of a qualified numerical method capable of addressing the most complex applications.

Statistical simulation methods may be contrasted to conventional numerical discretization methods, which typically are applied to ordinary or partial differential equations that describe some underlying physical or mathematical system. In many applications of Monte Carlo, the physical process is simulated directly, and there is no need to even write down the differential equations that describe the behavior of the system. The only requirement is that the physical (or mathematical) system be described by probability density functions (PDFs). Once the PDFs are known, the Monte Carlo simulation can proceed by random sampling from the PDFs. Many simulations are then performed (multiple "trials" or "histories") and the desired result is taken as an average over the number of observations (which may be a single observation or perhaps millions of observations). In many practical applications, one can predict the statistical error (the "variance") in this average result, and hence an estimate of the number of Monte Carlo trials that are needed to achieve a given error.

Assuming that the evolution of the physical system can be described by probability density functions (PDFs), then the Monte Carlo simulation can proceed by sampling from these PDFs, which necessitates a fast and effective way to generate random numbers uniformly distributed on the interval $[0,1]$. The outcomes of these random samplings, or trials, must be accumulated in an appropriate manner to produce the desired result, but the essential characteristic of Monte Carlo is the use of random sampling techniques (and perhaps other algebra to manipulate the outcomes) to arrive at a solution of the physical problem. In contrast, a conventional numerical solution approach would start with the mathematical model of the physical system, discretizing the differential equations and then solving a set of algebraic equations for the unknown state of the system.

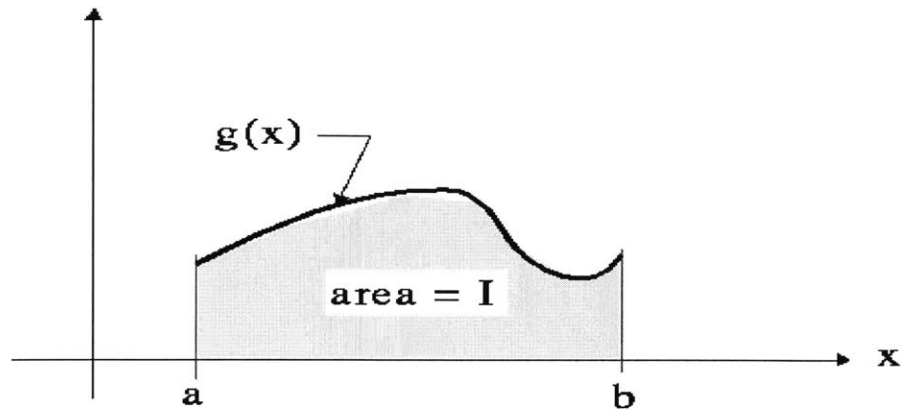


Figure 13: Example of Monte Carlo Integration

The second stage of a probabilistic analysis is the use of computer software (in our case, Crystal Ball ©) to conduct Monte Carlo simulation on the total number of arising conflicts, including the risk variables which have been identified, as described in the paragraph above. Monte Carlo simulation uses the selected probability distributions of the identified risk variables (sources of potential conflict) to perform random modeling: given the unique distribution of each project risk variable, the simulation produces repeated variables values by performing many (hundreds to several thousands) trials. The total number of arising issues based on the probabilistic characterization will then be used as an input of the System Dynamics Simulation.

IV-2. Results of Monte Carlo Simulation on the Risk Profiles

In this paper, Microsoft Excel© and Crystal Ball© were the applications used to perform the Monte Carlo simulations. Excel's Normsinv(Rand()) function returns a random number's (in the [0, 1] interval) inverse of the standard normal cumulative distribution, which we will call X. Then, the number generated by:

$$Y=X*\text{Mean} + \text{Standard Deviation} \quad \text{(Equation 6)}$$

for each random variable is computed during a certain number of trials (we chose 1000 trials in this study), based on the random value of X (in the [0, 1] interval) generated by the computer. The corresponding distribution is plotted by Crystal Ball©.

As an example, we considered the simple case where the PC1 variables were constrained to the Unforeseen Site Conditions (External Uncertainty) and Incomplete Scope Definition (Internal Uncertainty).

Table 4: Data Used for the Simulation of PC1 Conflicts (Example)

Source of Dispute (PC1)	Mean	Standard Deviation
<i>External</i>		
Unforeseen Site Conditions	15	0.5
<i>Internal</i>		
Incomplete Scope Definition	7	3
<i>All Sources of PC1 Disputes</i>	22	3.041381265

These figures were entered in the Excel© spreadsheet and the formulations described above led to the Monte Carlo simulation and the following distributions (Figure 14 and Figure 15):

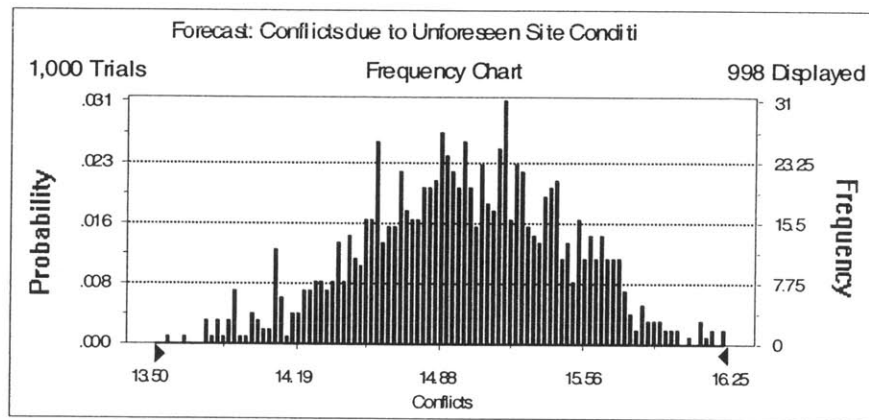
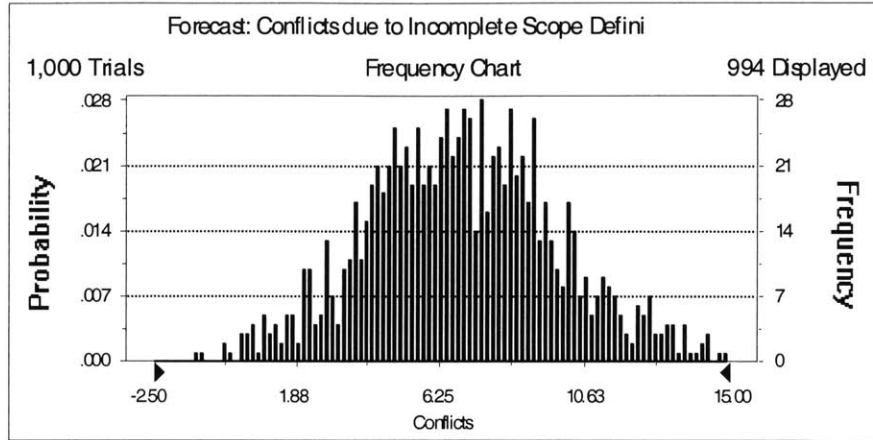


Figure 14: Forecasted Number of Conflicts due to Unforeseen Site Conditions (PC1 category) (Example)



**Figure 15: Forecasted Number of Conflicts due to Incomplete Scope Definition (PC1 category)
(Example)**

Since we are considering that the risk variables are *independent* (not exactly identically distributed), the following generalized formula relates the characteristics of each single random variable of the PC_i category to the characteristics of the PC_i category itself:

If X_1, X_2, \dots, X_n are independent and $X_i \sim N(\mu_i, \sigma_i^2)$, then:

$$\left(\sum_{i=1}^n X_i \right) \sim N \left(\sum_{i=1}^n \mu_i, \sum_{i=1}^n \sigma_i^2 \right) \quad \text{(Equation 7)}$$

In the chosen example, we have indeed $\mu_{PC1} = 15 + 7 = 22$, and $\sigma_{PC1} = \sqrt{0.5^2 + 3^2} = 3.04$. Using these figures, Crystal Ball© produces a distribution for the total number of PC1 conflicts (Figure 16). This method can be generalized to obtain the profile of the PC_i conflicts occurring in the project. Even if the risk variables had different types of distributions, Monte Carlo would be able to produce the distribution of their concatenation. We will limit this study to the interaction of risk variables with normal distributions. Once the profile of the PC_i has been obtained, it is introduced as an input to the system dynamics model. Based on the characteristics of Monte Carlo's output (i.e., of the PC_i distribution), the variables of the system dynamics model will vary in different ways, and affect the results of the option valuations described in the next chapter.

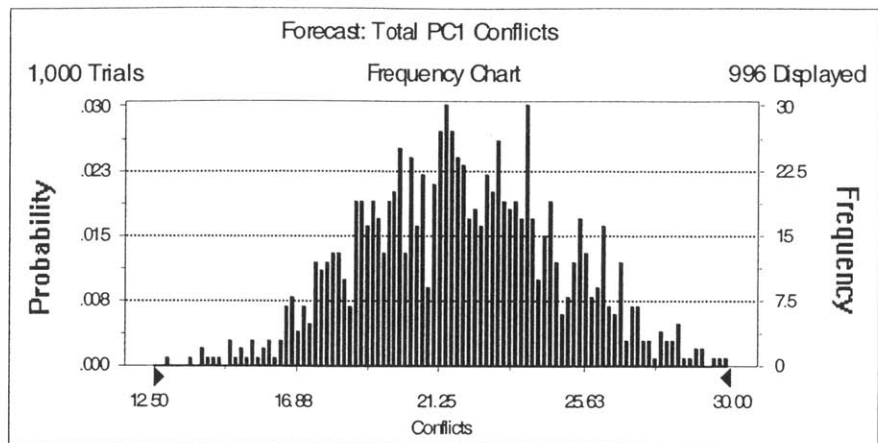


Figure 16: Forecasted Number of PC1 Conflicts (Example)

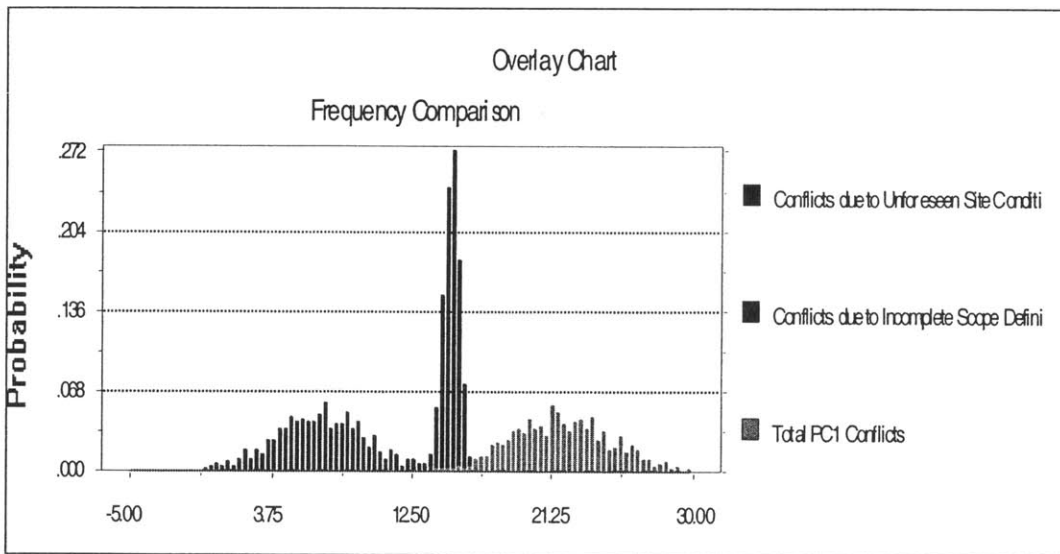


Figure 17: Overlay Chart of the Previous Forecasts (Example)

Table 5: Report Summarizing the Previous Simulations (Example)

Statistics	Conflicts due to Unforeseen Site Conditions	Conflicts due to Incomplete Scope Definition	Total PC1 Conflicts
Trials	1000	1000	1000
Mean	14.99	6.94	21.92
Median	15.00	6.91	21.84
Mode	---	---	---
Standard Deviation	0.49	2.99	3.05
Variance	0.24	8.92	9.28
Skewness	-0.16	0.09	0.03
Kurtosis	2.77	3.32	2.79
Coeff. of Variability	0.03	0.43	0.14
Range Minimum	13.46	-4.46	11.35
Range Maximum	16.32	17.01	30.15
Range Width	2.86	21.47	18.80
Mean Std. Error	0.02	0.09	0.10

If the participants would like to find the corresponding costs related to the simulated number of conflicts, other than through the system dynamics model, then they can combine the normal distribution of the risk variables with the triangular distribution attributed to the costs of conflict avoidance and resolution. For instance, the managers have made the following forecasts for the cost per PC1 issue in their project: 0.2 probability of low cost (\$1,000), 0.5 probability of medium cost (\$6,000), and 0.3 probability of high cost (\$15,000). These figures, combined with the profile obtained for the total number of PC1 conflicts, lead to the following distribution (Figure 18):

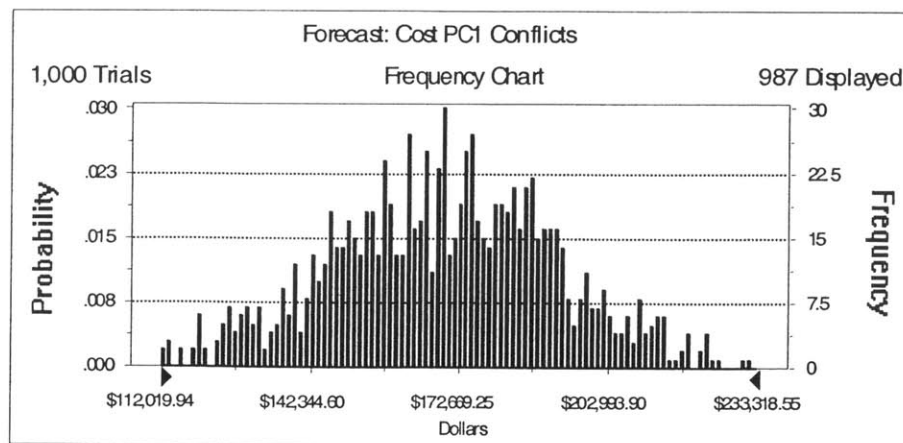


Figure 18: Forecasted Cost of PC1 Conflicts (Example)

Table 6: Part of Report Generated by Crystal Ball© for the Forecasted Cost of PC1 Conflicts

Summary:	
Display Range is from \$113,691.10 to \$229,883.30 Dollars	
Entire Range is from \$93,894.68 to \$255,333.15 Dollars	
After 1,000 Trials, the Std. Error of the Mean is \$718.83	

Statistics:	Value	Percentile	Dollars
Trials	1000	0%	\$93,894.68
Mean	\$169,951.27	10%	\$139,971.18
Median	\$169,672.87	20%	\$151,648.44
Mode	---	30%	\$158,040.96
Standard		40%	\$163,909.72
Deviation	\$22,731.47	50%	\$169,672.87
Variance	\$516,719,622.01	60%	\$176,107.41
Skewness	0.04	70%	\$181,669.38
Kurtosis	3.11	80%	\$188,711.11
Coeff. of		90%	\$197,839.15
Variability	0.13	100%	\$255,333.15
Range Minimum	\$93,894.68		
Range Maximum	\$255,333.15		
Range Width	\$161,438.47		
Mean Std. Error	\$718.83		

These results will then be used in the option pricing phase, detailed in the next chapter.

Chapter 5 – Option Pricing Theory

I. Real Options

At this point, we need to start focusing on the more pragmatic issue of managerial decision-making based on the more theoretical research done earlier by the participants. So far, we have dealt with the uncertainty related to the occurrence of conflicts during the life of the project. However, we also need to deal with the uncertainty associated with the efficiency of the proposed DARTs at the different levels of the escalation ladder. Investing in the establishment of a DART is a like buying an option to follow up on its implementation if needed later on in the project. This type of upfront investment is called a real option, as opposed to a financial option.

Financial options are divided into two main categories as to their nature: call and put options. Call options represent the option to buy an asset (a stock for example) at a specified exercise price, set at the time of the contract, on or before a specific date. Put options, on the other hand, represent the possibility to sell an asset at a specified exercise price, on or before a specific date. In practice, some options can be exercised only on the final exercise date: these are called European options. However, the most common type is the American option, which can be exercised any time before the final exercise date.

Real options on the other hand are found in capital investment projects, and involve real assets (as opposed to financial ones). The real options' response to uncertainty in real life projects is flexibility. Just as financial options seek to hedge the risk associated with trading securities, real options attempt to mitigate the risk associated with deploying business assets. To have a real option means to have the possibility for a certain period to either chose for or against something, without binding oneself upfront.

There are four types of real options:

- The option to make follow-on investments if the immediate investment project succeeds.
- The option to abandon a project.
- The option to wait (and learn) before investing.
- The option to vary the company's output or its production methods.

The real options method is an important way of thinking about valuation and strategic decision-making, and the power of this approach is starting to change the economic "equation" of many industries. One of this paper's goals is to familiarize the construction industry with the usefulness of the option theory approach when considering the adoption of DARTs in construction projects.

In this paper, we are interested in the real option holding value of follow-up investment opportunities. The question that we are aiming to answer is: In what cases is it profitable for the project managers to set the basis for possible DART implementation related to conflict resolution when needed during the project? By "setting the basis", we mean taking measures such as hiring lawyers, employing specialized professionals to follow and supervise the development of the project, providing workshops and training for the participants of the project to get accustomed to the possible DART implementation, providing the appropriate contingencies in the budget and conflict management plan, or adapting the organizational structure of the project to requirements of an eventual DART. If no such measures need to be undertaken before the actual implementation of the DART, then the comparison of costs resulting from potential DARTs and their trade-offs leading to the choice of the optimal technique is simply obtained by simulating the system dynamics model (Figure 10). The following section explains whether to choose or not to invest in the possibility of a certain DART implementation, assuming that the upfront measures cited above are preferable or necessary. Also, option theory is to be applied during the planning of the project, or at least at a time the undertaking of a DART implementation remains an "option", and not a

necessity, i.e., when the project managers are dealing with potential (and not actual) conflict occurrence. As for the decision-making concerning the possible implementation of preventive measures, the system dynamics model, with the new variables forecasting the reduction of costs related to dispute resolution during the project, provide the necessary figures to perform a cost-benefit analysis.

II. Application of Option Theory to Our Study

We suggest adopting the option pricing theory developed by Black-Scholes, and applied to the pricing of real options. Initially, the Black-Scholes model was developed in 1973 by Fisher Black and Myron Scholes to calculate the value of a European call option, utilizing the stock price, strike price, expiration date, risk-free return, and the standard deviation (volatility) of the stock's return. The Black Scholes Model is one of the most important concepts in modern financial theory, and is now frequently applied to the valuation of real options. The key is to map the project characteristics into option parameters and then use them in the Black-Scholes formula.

Table 7: The Variables of the Black-Scholes Formula

Variable	General Significance in Financial Option Valuation	General Significance in Real Option Valuation
S	Stock price	Present value of a project's operating assets to be acquired
X	Strike price	Expenditure required to acquire the project assets
t	Time to expiration	Length of time the decision may be deferred
r_f	Time value of money (Risk-free rate of return)	Time value of money (Risk-free rate of return)
σ	Cumulative volatility of the stock's return	Riskiness of the projects assets

The assumptions of the formula are the following:

- There is a single exercise date.
- All uncertainty is resolved by the time a decision needs to be made upon the exercising of the option.
- The initial uncertainty of the risk variables is normally distributed.

These hypotheses are easily transferable to our study:

- There is a single date when the project managers decide whether to proceed with the implementation of a DART or not. This date can be set according to the peak of the conflict profile simulated through the Systems Dynamic model.
- All uncertainty about the usefulness of the DART implementation is resolved by the “exercise date”, when the escalation of conflicts will require an absolutely necessary DART implementation.
- The conflict profiles have a normal distribution.

Given these assumptions, the Black-Scholes model can be applied to the valuation of DART implementations.

Table 8: The Variables in the Black-Scholes Formula Corresponding to our Study

Variable	General Significance in Real-Option Valuation	Applied to our Model
S	Present value of a project's operating assets to be acquired	Present value of costs to be avoided by resolving the issue efficiently, using DART
X	Expenditure required to acquire the project assets	Cost of DART implementation
t	Length of time the decision may be deferred	Time at which the PC _i conflicts reach their peak. (*)
r _f	Time value of money (Risk-free rate of return)	Time value of money (Risk-free rate of return)
σ	Riskiness of the projects assets	Standard deviation of the PC _i distribution (*)

Note (*): PC_i will correspond to PC1, PC2 or PC3 depending on their impact on the DART.

The value of the European call option, c , can then be written in the following way:

$$c = S * N(d_1) - X * e^{-r_f * t} * N(d_2) \quad \text{(Equation 8)}$$

Where $N(x)$ represents the probability that a random draw from a standard normal distribution will be less than x , and:

$$d_1 = \frac{\ln\left(\frac{S}{X}\right) + \left(r_f + \frac{\sigma^2}{2}\right) * t}{\sigma\sqrt{t}} \quad \text{(Equations 9)}$$

$$d_2 = \frac{\ln\left(\frac{S}{X}\right) + \left(r_f - \frac{\sigma^2}{2}\right) * t}{\sigma\sqrt{t}} = d_1 - \sigma\sqrt{t}$$

In practice, project managers should apply the option pricing to the cost estimates obtained with the system dynamics model (as shown in Figure 10). In this paper, we are setting the framework for future research on these topics. At this point, the new variables related to financial issues have not completely been added to the existing system dynamics model. For this reason, we will use the estimates related to the costs of possible DART implementation that are provided by the Crystal Ball© reports rather than the system dynamics variables.

We had previously obtained forecasts related to the costs of PC1 conflicts. Now we would like to price the option of undertaking measures for Prevention. Figure 19 shows the report generated by Crystal Ball©.

Summary

Display Range is from \$15,219.92 to \$118,232.30 Dollars

Entire Range is from \$6,419.07 to \$135,651.13 Dollars

After 1,000 Trials, the Std. Error of the Mean is \$615.87

Statistics

Trials	1000
Mean	\$67,150.53
Median	\$67,076.36
Mode	---
Standard Deviation	\$19,475.46
Variance	\$379,293,710.42
Skewness	-0.04
Kurtosis	2.97
Coeff. of Variability	0.29
Range Minimum	\$6,419.07
Range Maximum	\$135,651.13
Range Width	\$129,232.06
Mean Std. Error	\$615.87

Percentile

0%	\$6,419.07
10%	\$41,026.95
20%	\$50,222.82
30%	\$57,427.96
40%	\$62,500.83
50%	\$67,076.36
60%	\$72,696.62
70%	\$78,268.33
80%	\$83,879.47
90%	\$91,299.55
100%	\$135,651.13

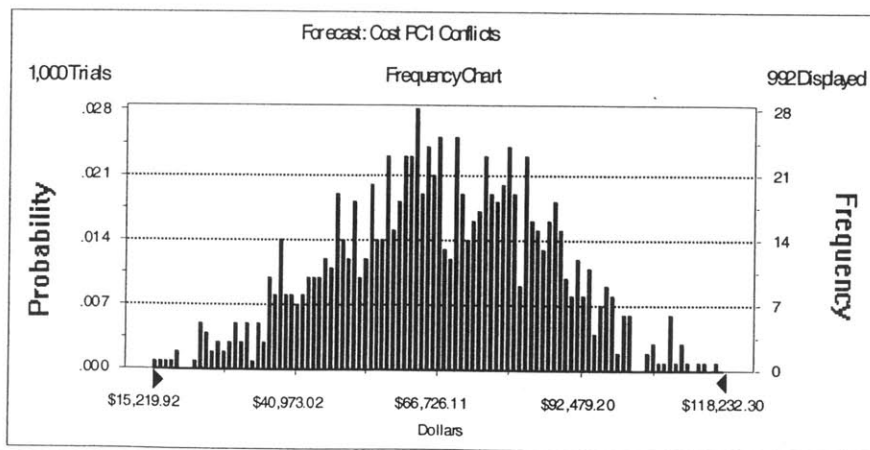


Figure 19: Crystal Ball© Report for PC1 Costs with Partnering

Table 9: Figures Used for the Simulation of PC1 Costs (With / Without Partnering)

OCCURRENCE OF PC1 CONFLICTS	Unforeseen Site Conditions	Incomplete Scope Definition	All Sources of PC1 Conflicts
<i><u>Without Partnering</u></i>			
Mean	15	7	22
Standard Deviation	0.5	3	3.04
<i><u>With Partnering</u></i>			
Mean	7.5	3.5	11
Standard Deviation	0.5	3	3.04

COST OF CONFLICTS FOR PC1	Probability	Amount Spent per Conflict
<i><u>Without Partnering</u></i>		
Low	0.2	\$1,000
Medium	0.5	\$6,000
High	0.3	\$15,000
<i><u>With Partnering</u></i>		
Low	0.4	\$3,000
Medium	0.5	\$7,000
High	0.1	\$15,000

Let us imagine the situation where a project manager is wondering whether to involve all the participants of the project in the Partnering Process. Given that this process comprises five phases (building a long-term strategy, training, team building, on-site implementation, and project close-out), the project manager wants to make sure that it will be worthwhile to invest in the initial phases of the DART implementation. We assume here that the conflicts related to the PC1 source are limited to the unforeseen site conditions and incomplete scope definition. A normal distribution is assigned to the description of the conflict profiles, and the triangular distribution for the costs of their resolutions. Table 9 summarized the figures that

were chosen to define the characteristics of these distributions, depending on whether the Partnering Process is undertaken at the beginning of the project.

Moreover, we assume that the cost for the initial partnering measures (first three phases) amounts to \$20,000 (which corresponds to the exercise price, X). If we take the mean of the distribution obtained with the simulations, the cost of the PC1 cost without partnering would be equal to \$169,951.27, and to \$67,150.53 with the implementation of partnering. Applying these figures to the Black-Scholes formula (Equations 8 and 9):

$$S = PV(169,951.27 - 67,150.53) = \$43,598$$

$$X = \$20,000$$

$$t = 10 \text{ years}$$

$$r_f = 10\%$$

$$\sigma = 29\%$$

$$d_1 = 3.15 \text{ therefore } N(d_1) = 0.9992$$

$$d_2 = 2.24 \text{ therefore } N(d_2) = 0.9875$$

$$c = \$39,930$$

Therefore, taking into consideration the cost of the upfront costs of partnering in the project, as well as the potential savings that could be generated, the call option has a value of \$39,930, and is worthwhile being undertaken. A real option is worthwhile being undertaken if the computation of its value (c) is greater than 0 (indeed, the costs of the option as well as the related cost savings are already taken into account).

The following chapter details the development of the Conflict Management Plan, based on the forecasting and evaluation methods explained in the previous sections.

Chapter 6 – Applications to the Conflict Management Plan

I. Defining the Traditional Conflict Management Plan

A conflict management plan allows the owner to allocate responsibility concerning potential arising conflicts and to develop a plan to handle discrepancies. By doing this upfront and with each subsequent review, everyone involved agrees to follow this plan, reducing the push for lengthy, costly court proceedings. The conflict management plan looks at each project individually to establish a set of criteria for managing conflicts. It assesses how much conflict one will encounter, how severe each conflict might be, then presents cost effective ways to avoid conflict and curb these disputes. Similar to the contract documents it should be complete, unbiased, understood, and accepted by all parties involved. Figure 20 shows the four steps of the conflict management process. We will now review in more detail the stages of the traditional conflict management plan's development, based on the previous research performed by Pena-Mora et al. (2002).

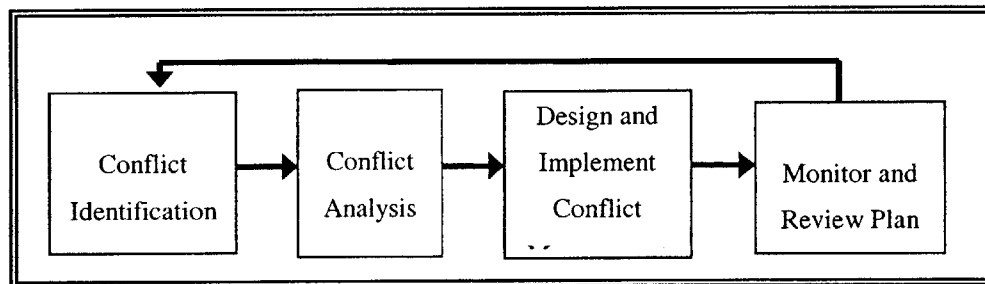


Figure 20: The Conflict Management Process

I-1. Conflict Analysis

We have already covered the Conflict Identification phase earlier in this paper. In traditional project management, what is meant by “Conflict Analysis” is the study of the individual conflicts’ probability of occurrence and their impact on the project. Typically, the participants develop three scenarios (Optimistic, Most Likely and Pessimistic), in which they review the selected potential conflict (both in the Organizational and Uncertainty categories), then allocate a probability of occurrence

$P(c)$, an impact on the project $L(c)$, and the combined conflict exposure E which is obtained by multiplying the two former factors. In most cases, historical data is used to help the participants assign values to these variables.

More specifically, the participants need to quantify the occurrence of all the potential conflicts among the issues related to organization and uncertainty. In Table 3: Sources of conflict and dispute, we have enumerated 15 potential conflict sources in the organizational issues, and 10 in both the external and internal uncertainties. This gives us in total 25 potential sources of conflict. $P(c)$ represents the combined probability of the conflicts that might potentially rise in a particular project.

$$c = \bigcup_{i=1}^{25} c_i$$

$$P(c) = \sum_{i=1}^{25} P(c_i)$$

If a certain issue i is judged irrelevant when analyzing a certain project, then $P(c_i) = 0$. In any case, $P(c) \leq 1$, with $P(c) = 1$ in case of an assured occurrence of conflict.

In order to take account all the possible combinations of conflict sources, n scenarios are planned. Typically, $n=3$, with the 3 scenarios being: large, medium or minor problems occurring in the course of the project. For each scenario, a different $P(c)$ is computed, which can be written as $P_j(c)$, with $j=1$ to $j=n$.

For each of the scenarios, the impact $L(c)$ must be quantified. In the same way as the probability of occurrence $P(c)$, the impact of the conflict can be written as $L_j(c)$, with $j=1$ to $j=n$, for the n different scenarios.

The risk exposure in each scenario j , noted E_j , is the product of the probability of occurrence P_j and the impact of conflict L_j . The total conflict exposure E is obtained by adding the E_j , i.e. adding the pondered impacts of the conflicts in the n different scenarios:

$$E_j(c) = P_j(c) \times L_j(c)$$

$$E = \sum_{j=1}^n E_j(c)$$

If only one scenario is analyzed, i.e. n=1, the conflict exposure is directly determined by computing the product P(c) X L(c).

Table 10 is an example of Conflict Exposure calculation, expressed as a percentage of the initially budgeted cost of the project, for all the potential conflicts in a fictional project in one scenario. In order to obtain the total conflict exposure, the participants need to sum all the individual exposures of the risk variables (25.1% of the total cost, in this case).

Table 10: Traditional Calculation of the General Conflict Exposure (Example)

Source of Conflict (c)	Probability of Occurrence P(c)	Impact of Occurrence L(c)	Combined Conflict Exposure (E)
Miscommunication	High (0.9)	Very High (20% C)	Very High (18% C)
Performance/Quality	High (0.9)	Med (5% C)	Med-High (4.5% C)
Management	Med (0.5)	Med (5% C)	Med (2.5% C)
Contract Type	Low (0.1)	Low (1% C)	Low (0.1% C)

A similar study of the impact of the conflicts can be performed for other issues that can be crucial to the owner, like the impacts on schedule, quality, performance, nature, social issues, and political issues.

Another example is based on a \$200 million project without any mitigation strategy. It predicts that there is a 40% chance of encountering conflict that will result in a \$25 million impact to the project. There is a 50% chance that conflict on the project will result in a \$5 million impact and a 10% chance that conflict on the project will have \$1 million impact. In this case, it is assumed that the probability that conflict will not occur at all is negligible. The calculations for the total conflict exposure are represented in Figure 21.

occur at all is negligible. The calculations for the total conflict exposure are represented in Figure 21.

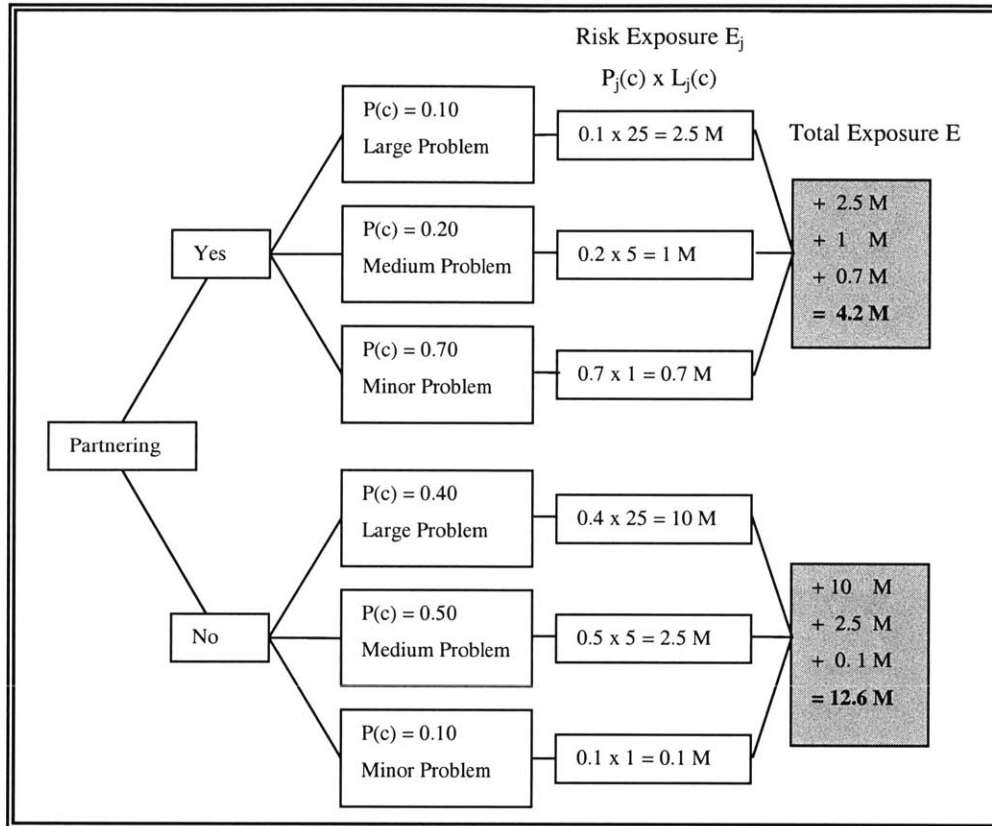


Figure 21: Calculating the Total Conflict Exposure on a Project (Example)

I-2. Design and Implementation of the Conflict Management Plan

The design and implementation of the conflict management plan is traditionally performed through the successive stages stated below:

- *Prioritization of the sources of conflict based on their exposure.* Once the conflict exposure is calculated for each of the identified potential conflicts, they can be grouped into priority levels. They can be categorized into one of the following three groups according to a Pareto Optimal Categorization:
 - Group A: 10–20% of the top conflicts with high potential of realization, which together account for roughly 60% or more of the total potential impacts the project.
 - Group B: all activities not members of group A or C.

- Group C: large percentage of the bottom conflicts in terms of potential of realization, which account for 10% or less of the total potential impacts.
- *Implementation of DART to avoid/prevent conflicts* using techniques in Stage 1 of the dispute resolution ladder (i.e., Prevention) and Partnering.
- *Implementation of DART to resolve conflicts*, using techniques in Stages 2 through 5 (i.e., Negotiation, Standing Neutral, Nonbinding Dispute Resolution, and Binding Dispute Resolution).
- *Cost/Benefit Analysis of the Conflict Management Plan*. One way to do this is by reviewing the combined conflict exposure developed when analyzing the conflicts and comparing them with the cost of the mitigation strategy identified from the prevention stage. One should implement these techniques if the cost of the mitigation strategy and the resultant conflict exposure is less than no management strategy and its corresponding conflict exposure.
- *Development of a contingency plan*. A contingency plan is basically a list of possibilities for both of the parties. These should outline the conflict management plan's strengths and weaknesses. It can happen that the cost of implementing various DART may exceed the benefit. Therefore, by not implementing these DARTs, the participants are actually conceding that conflict in this area may occur and no strategy is in place to prevent them from happening or mitigate their impact if they do occur. The contingency plan identifies these areas where conflict is expected to arise.
- *Review and update* with all participants as necessary.

I-3. Monitoring and Review Plan

Sometimes going overboard on a plan not only increases the dollar costs of a management plan, but can ruin relationships, slow the project and lead to litigation quicker than having no plan at all. This is where review and acceptance of the plan by all the parties involved becomes important. For instance if a project has all six steps in the dispute resolution ladder, a contractor might be hesitant to bid on the job.

If the claim goes all six steps, it might take years to receive money on a valid claim, possibly putting the contractor out of business.

Forcing a dispute resolution plan on a party forms an adversarial relationship from the start. This can lead to a lack of participation from the other parties, a key element in resolving conflicts. By including all the participants in the final decision of what conflict management plan to adopt, the interests become aligned and all are more willing to faithfully participate.

This review of the Conflict Management Plan should be done at various stages in the life cycle of a project such as planning, design, pre-bid meeting, award of bid, at project milestones, and project close-out. In the planning stage an initial concept should be developed, and refined in the design stage to be almost complete. Reviewing the plan during the pre-bid meetings (if any are held) provides opportunity to engage the contractors in the process as well as alert them to how conflicts will be handled before they bid on a project. When the award is made, the plan should be review thoroughly with all the parties involved. This review has two major objectives; inform all the parties involved, and make them a partner of the process. By making them a partner in the process, they are jointly responsible for the design of this plan; therefore, when conflict arises they are more apt to participate without protest. Another important step at the project close-out is the overall review and effectiveness of the plan.

II. Developing the Traditional Conflict Management Plan

The previous section provided a description of the traditional approach to the conflict management plan. We will now explain the improvements this paper suggests should be made to it, based on our results related to the conflict profile of the project, the system dynamics simulation and the option pricing model.

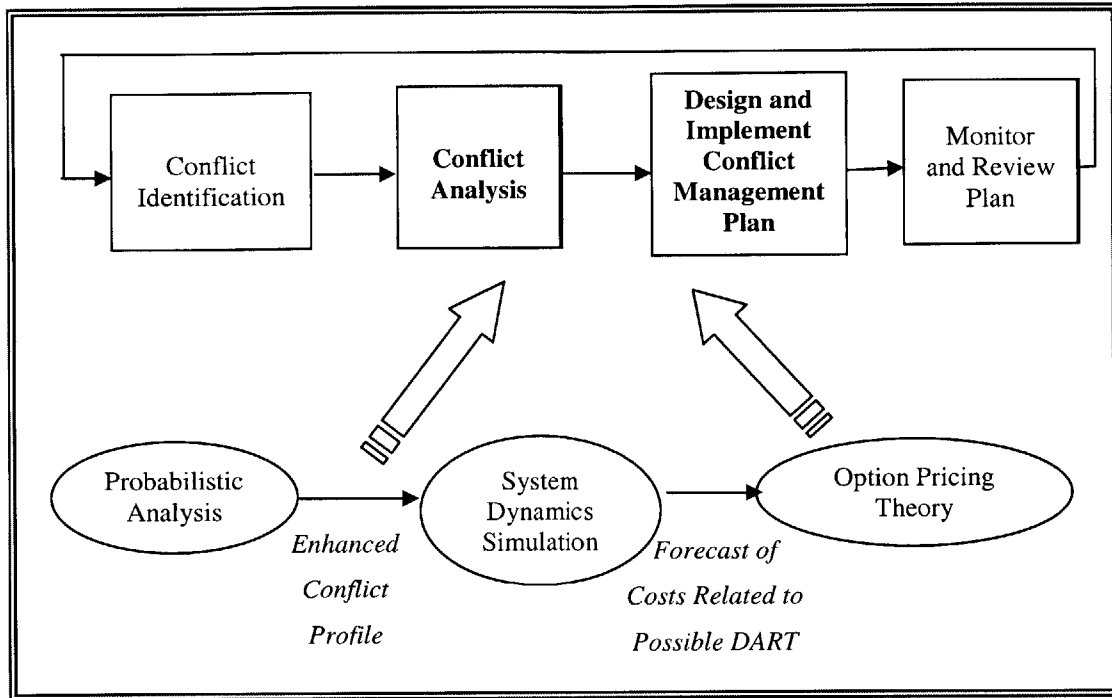


Figure 22: Modified Conflict Management Process

The studies presented earlier in this paper affect the conflict management process at two different levels, depending if the project managers are dealing with potential conflicts (that could occur) or actual conflicts (that have already occurred).

II-1. Conflict Avoidance

▪ Improved Conflict Analysis

The enhanced conflict profile resulting from the probabilistic analysis leads to the replacement of the probability of occurrence forecast by the study of the corresponding distribution profile. According to the previous methods elaborated in this paper, the participants are required to estimate the mean and standard deviation related to the occurrence of an identified risk variable following a normal distribution. The conflict profile can then provide an “optimistic”, “most likely” and “pessimistic” estimates of the number of conflict occurrences. These results can be easily obtained through the reports developed by Crystal Ball©. Indeed, we can make the following correspondences for the number of conflicts occurring due to a given source of conflict (an example is given in Table 11):

- Optimistic Scenario: 25% percentile
- Most Likely Scenario: 50% percentile (or median)
- Pessimistic Scenario: 75% percentile.

The number of conflicts for each conflict source in a given scenario is then multiplied by the forecasted average impact of the conflict on the rest of the project (considering issues related to cost, schedule, performance, quality, nature, society or politics), to finally obtain the conflict exposure related to that source of conflict.

Table 11: Number of Conflict Occurrences due to Unforeseen Site Conditions (Example)

<u>With Partnering</u>		
Percentile	Scenario	# Conflicts
0%		6.02
25%	Optimistic	7.16
50%	Most Likely	7.49
75%	Pessimistic	7.85
100%		9.19
<u>Without Partnering:</u>		
Percentile	Scenario	# Conflicts
0%		13.30
25%	Optimistic	14.68
50%	Most Likely	15.02
75%	Pessimistic	15.35
100%		16.33

In the traditional stage of conflict analysis, the participants usually would for example multiply the pessimistic probability of occurrence of *one* conflict related to a specific source, by the *pessimistic impact* of this conflict. In this new approach for Conflict Avoidance considerations, we will multiply the pessimistic number of *all conflicts* related to a specific source by the *average impact* of this source of conflict. The two methods are practically equivalent. The average impact of the sources of conflict will have been already assessed during the system dynamics phase, since it is one of the variables of the model.

- **Improved Design and Implementation of the Conflict Management Plan**

The major areas that will now be modified due to the new tools and techniques in the design and implementation of the conflict management plan at the avoidance stage

are the methods of DART selection, the cost benefit analysis. Let us review the steps mentioned previously:

- *Prioritization of the sources of conflict based on their exposure.* Once the conflict exposure is calculated for each of the identified potential conflicts, they can be grouped into priority levels. They can be categorized into one of the following three groups according to a Pareto Optimal Categorization:
 - Group A: 10–20% of the top conflicts with high potential of realization, which together account for roughly 60% or more of the total potential impacts the project.
 - Group B: all activities not members of group A or C.
 - Group C: large percentage of the bottom conflicts in terms of potential of realization, which account for 10% or less of the total potential impacts.
- *Implementation of DART to avoid/prevent conflicts.* The DARTs are selected in this avoidance stage according to the option pricing theory (in case upfront investments are required) and to the cost minimization forecasts obtained through the simulation of the system dynamics model.
- *Cost/Benefit Analysis of the Conflict Management Plan.* This has been covered during the selection of the optimal DART implementation to be launched for conflict avoidance.
- *Development of a contingency plan.* At this point, a contingency plan can be developed to assess the budget amounts to be allocated for conflict avoidance and resolution concerns during the project. The figures will be based on the forecasts provided by the system dynamics model.
- *Review and update* with all participants as necessary.

More specifically, the major steps of all the methodologies and analyses covered in this paper that need to be performed in order to develop and design the conflict management plan for conflict avoidance concerns are summarized in Figure 23.

Finally, Table 12 presents an example of typical information sheet of the conflict management plan for a potential source of dispute.

1. Identify the sources of conflict (set a label for ID purposes), among the Organizational Issues and Uncertainty, based on historical data and discussions with the participants.
2. Describe each potential source of conflict in detail.
3. Explain who will be the formal and informal parties from the organizational chart taking part in the conflict, and allocate responsibilities should the conflict actually occur.
4. Decide which probability distribution would be best suited for the characterization of this source of conflict.
5. Set the characteristic measures for this risk variable's probabilistic distribution (e.g., for a normal distribution, set the mean and standard deviation of the number of conflict occurrences for this source of conflict). At this point, the *conflict profile* of this source of dispute is obtained.
6. Perform Monte Carlo simulation to obtain the combined distribution for each PCi category. At this point, the *conflict profile* of each PCi category is obtained.
7. Discuss the average impact of the conflict and set an average value for the cost impact on the project (and also the exposure for the schedule, quality, performance, nature, social and political issues).
8. Enter the information related to the conflict profile and average impact in the system dynamics model.
9. Run the system dynamics model, in order to observe the impact on cost (and all other factors mentioned in point 7) depending on the potential implementation of a DART or combination of DARTs.
10. Compare the different alternatives using the results of the simulation and *option pricing theory*, and taking into account the cost of the DART implementations to perform *cost-benefit analysis*. Select the optimal DART options.
11. Calculate the project exposure to cost (and possibly to schedule, quality, performance, nature, social and political issues) in three scenarios: multiply the 25% percentile of the conflict profile of the PCi by the average impact of the PCi on cost for the Optimistic Scenario. Respectively replace the 25% percentile by the 50% and 75% percentiles for the Most Likely and Pessimistic Scenarios.
12. Set the criticality of the conflict according to the Pareto Optimal Classification (Pareto categories are the groupings of all type A, B and C conflicts under the potential scenario (best, expected and worst)).
13. Group the conflicts of a potential Pareto category.
14. Calculate the reduced conflict exposure if the prevention strategy is used.
15. Validate your numbers with project personnel and document their reactions.

Figure 23: Checklist for the Conflict Management Plan Design Process

(Conflict Avoidance Concerns)

Table 12: Information Sheet for Potential Conflicts

Conflict Information Sheet						
Conflict ID:	Criticality:			Date:	Conflict Profile – Mean: Standard Deviation:	
Description:						
Parties Involved:						
Sources and Corresponding Conflict Categories (e.g., PC1):						
Recommended Avoidance Strategy:						
Value of the Optimal Avoidance Strategy Option:						
Cost of Upfront Investment in Avoidance Strategy:						
Forecasted Cost of Avoidance Strategy Complete Implementation:						
<i>Optimistic # of Occurrences (O)</i> With Avoid. Str.: Without Avoid. Str.:		<i>Most Likely # of Occurrences (M)</i> With Avoid. Str.: Without Avoid. Str.:			<i>Pessimistic # of Occurrences (P)</i> With Avoid. Str.: Without Avoid. Str.:	
Average Costs	Without Avoidance Strategy			With Avoidance Strategy		
Average Impact on Cost (I1):	Conflict Exposure on Cost (CE1) –			Reduced Conflict Exposure on Cost (CE1) –		
	(O)	(M)	(P)	(O)	(M)	(P)
Average Impact on Schedule (I2):	Conflict Exposure on Schedule (CE2) –			Reduced Conflict Exposure on Schedule (CE2) –		
	(O)	(M)	(P)	(O)	(M)	(P)
Average Impact on Quality (I3):	Conflict Exposure on Quality (CE3) –			Reduced Conflict Exposure on Quality (CE3) –		
	(O)	(M)	(P)	(O)	(M)	(P)
Average Impact on Performance (I4):	Conflict Exposure on Performance (CE4) –			Reduced Conflict Exposure on Performance (CE4)–		
	(O)	(M)	(P)	(O)	(M)	(P)
Average Impact on Nature (I5):	Conflict Exposure on Nature (CE5) –			Reduced Conflict Exposure on Nature (CE5) –		
	(O)	(M)	(P)	(O)	(M)	(P)
Average Impact on Social Issues (I6):	Conflict Exposure on Social Issues (CE6) –			Reduced Conflict Exposure on Social Issues (CE6) –		
	(O)	(M)	(P)	(O)	(M)	(P)
Average Impact on Political Issues (I7):	Conflict Exposure on Political Issues (CE7)–			Reduced Conflict Exposure on Political Issues (CE7)–		
	(O)	(M)	(P)	(O)	(M)	(P)
Total Impact:	Total Conflict Exposure –			Total Reduced Conflict Exposure –		
	(O)	(M)	(P)	(O)	(M)	(P)
Current Status of Conflict:						
Preparer:				Person-in-Charge:		

Note: Figures for Costs and Conflict Exposures are expressed in dollars.

II-2. Conflict Resolution

The conflict resolution purpose of the conflict management plan becomes necessary when conflicts have actually occurred during the project, either because they hadn't been accounted for during the development of the conflict avoidance plan, or because the prevention techniques hadn't been sufficient or appropriate. The same types of analysis and methodologies as in the conflict avoidance approach need to be applied. Figure 24 summarizes the steps for the elaboration and design of the conflict management plan for actual conflicts (Note: (O) stands for the Optimistic Forecast, (M) for Most Likely, and (P) for Pessimistic). Table 13 is an example of typical information sheet of the conflict management plan for an actual source of dispute.

1. Identify the Actual On-going Conflicts (set a label for ID purposes), among the Organizational Issues and Uncertainty.
2. Describe the conflict in detail.
3. Explain who will be the formal and informal parties from the organizational chart taking part in the conflict, and allocate responsibilities to handle the conflict.
4. Discuss the *occurred impact and the future average impact* of the conflict source and set an average value for the cost impact on the project (and also the exposure for the schedule, quality, performance, nature, social and political issues). Three scenarios (Optimistic, Most Likely and Pessimistic) should be considered.
5. Enter the information related to the number of actual conflicts related to the source and average impact in the system dynamics model.
6. Run the system dynamics model, in order to observe the total impact on cost (and all other factors mentioned in point 4) depending on the potential implementation of a DART or combination of DARTs.
7. Compare the different alternatives using the results of the simulation and taking into account the cost of the DART implementations to perform *cost-benefit analysis*. Select the optimal DART options.
8. Calculate the project's total exposure to cost (and possibly to schedule, quality, performance, nature, social and political issues) in the three scenarios, considering again actual and future impacts of the conflict source.
9. Set the criticality of the conflict according to the Pareto Optimal Classification (Pareto categories are the groupings of all type A, B and C conflicts under the potential scenario (best, expected and worst)).
10. Group the conflicts of a potential Pareto category.
11. Calculate the reduced conflict exposure if the prevention strategy is used.
12. Validate your numbers with project personnel and document their reactions.

Figure 24: Checklist for the Conflict Management Plan Design Process

(Conflict Resolution Concerns)

Table 13: Information Sheet for Actual Conflicts

Conflict Information Sheet										
Conflict ID:					Criticality:		Date:			
Description:										
Parties Involved:										
Source of Conflict:										
What Characteristics of the Project made this Conflict Predictable?										
Recommended Resolution Strategy and its Implementation:										
Cost of Recommended Resolution Strategy Implementation:										
Actual Impacts		Without Recommended Resolution Strategy				With Recommended Resolution Strategy				
Actual Impact on Cost (I1):	Total Forecasted Impact on Cost (I1):	Conflict Exposure on Cost (CE1):			Total Forecasted Reduced Impact on Cost (I1):			Reduced Conflict Exposure on Cost (CE1) –		
	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	
Actual Impact on Schedule (I2):	Total Forecasted Impact on Schedule (I2):	Conflict Exposure on Schedule (CE2):			Total Forecasted Reduced Impact on Schedule (CE2):			Reduced Conflict Exposure on Schedule (CE2) –		
	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	
Actual Impact on Quality (I3):	Total Forecasted Impact on Quality (I3):	Conflict Exposure on Quality (CE3):			Total Forecasted Reduced Impact on Quality (I3):			Reduced Conflict Exposure on Quality (CE3) –		
	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	
Actual Impact on Performance (I4):	Total Forecasted Impact on Performance (I4):	Conflict Exposure on Performance (CE4):			Total Forecasted Reduced Impact on Performance (I4):			Reduced Conflict Exposure on Performance (CE4) –		
	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	
Actual Impact on Nature (I5):	Total Forecasted Impact on Nature (I5):	Conflict Exposure on Nature (CE5):			Total Forecasted Reduced Impact on Nature (I5):			Reduced Conflict Exposure on Nature (CE5) –		
	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	
Actual Impact on Social Issues (I6):	Total Forecasted Impact on Society (I6):	Conflict Exposure on Society (CE6):			Total Forecasted Reduced Impact on Society (I6):			Reduced Conflict Exposure on Society (CE6) –		
	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	
Actual Impact on Political Issues (I7):	Total Forecasted Impact on Politics (I7):	Conflict Exposure on Politics (CE7):			Total Forecasted Reduced Impact on Politics (I7):			Reduced Conflict Exposure on Politics (CE7) –		
	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	(O) (M) (P)	
Current Status of Conflict:										
Preparer:					Person-in-Charge:					

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