CIFE Seed Proposal
Real Options in Material Procurement Contracts

Abstract
Much “management” research in the construction industry has been on facility and project design/management – dealing with the “physics” of construction management. We believe that the time has come to focus research on the information and finance side of construction management, which will provide huge payoff for the industry. This research proposal defines a project that will examine how real options could be constructed in material procurement contracts in the construction industry. The optimal policy of how (if and when) to exercise the real options can then be turned into supply chain decision support software. Real options can provide buyers with valuable operating flexibility to minimize inventory cost and price volatility. It can also help suppliers diversify their price risks and smooth out production schedule. Therefore, this concept has a large potential in the construction industry to increase profit margin for many parties along the supply chain by minimizing wastes and increasing efficiency. Similar concepts have been applied to the semiconductor industry in production capacity reservation contracts of foundries. We identify three major problems that would have to be overcome: 1) Identify the types of materials and the types of real options to embed into the procurement contracts of these materials. 2) Reduce the number of dimensions/state variables in dynamic programming to make calculation feasible. 3) Propose incentives for buyers and sellers to change the current way of doing business. We believe that 1) can be solved by conducting surveys of contractors, owners, distributors and manufacturers and numerical modeling using historical data; 2) through clever formulation of the temporal decision problem to reduce problem dimension and to de-couple separable components; and 3) through working with buyers and suppliers on real contracts to identify the correct incentives.

Introduction
In the construction business, a general contractor solicits take-offs (quotes) from suppliers for his bid preparation but will not place an order until the developer awards him the contract. Therefore, his orders are usually short-term project based and are subject to fluctuation in price (or price volatility). This and the competitive nature of the industry lead to extremely low profit margin of general contractors, typically less than 5%, which is lower than the return of risk free treasury bonds. General contractors, especially construction management firms, rely on subcontractors to purchase most of the materials. However, they do purchase some materials such as structural steel, lumber, concrete, GFRC, and rebar. In this project, we would like to focus on materials purchased by large general contractors who have the volume to realize the value introduced by real options and the power to negotiate complicated long-term contracts with suppliers. Our goal is to introduce real option embedded contracts into the material procurement process and solve for the optimal policies of exercising these options. These policies can be incorporated into other supply chain management software and help industry professionals make better procurement decisions. We believe that information technology can transform the Architecture, Engineering and Construction (or AEC) industry not just in design and facility management but also in finance and supply chain management. Currently, most Internet based supply chain management software fail because they offer simplistic capabilities: sending RFQ and receiving proposal is a mere replacement of facsimile while providing up-to-date inventory information does not improve the quality of decision making of a procurement manager. Some software provide support for collaboration and workflow but they lack decision support features. The next step is to use the algorithm developed by this project to provide contract development tools that evaluate and optimize terms and conditions. Then by accessing to templates for contracts and combining with the current requisition-approval workflow tools, we enable rapid development of real option embedded contracts that involve multiple parties within a construction firm over the Internet.

Option is the right but not the obligation to do certain things. For example, a financial call option on a stock is the right but not the obligation to buy a stock at the exercise price on (or before) a specific date written on the option contract. A real option differs from a financial option in the sense that the asset is not a financial instrument. Examples of real options are option to defer investment, option to expand, option to contract, option to shut down and restart, option to abandon for salvage value, option to switch to an
alternative, etc. Similar to financial options, real options provide a decision maker flexibility to adapt her future actions to market conditions in order to capture upside potential while limit downside loss.

This paper proposes a research project that will 1) identify the types of materials and the types of real options to be incorporated into procurement contracts of those materials that are most applicable to large general contractors and suppliers; 2) define decision rules and quantify the value of flexibility and risk management that real option embedded long-term contracts will bring, versus traditional project based short-term contracts; 3) propose incentives for general contractors and supplier to adopt this new type of contract. This proposal first discusses real options and their applicability to the construction industry. Then it brings up theoretical and practical problems we have to solve and propose possible solution strategy. Finally, it outlines the research milestones, methodology and how this research relates to CIFE members and goals.

Discussion
This section discusses real options from several perspectives. First, we present a hypothetical scenario illustrating the problem that a general contractor faces when ordering plywood. We then introduce how the semiconductor industry has started to incorporate real options in supply contracts and how similar contracts can improve a general contractor’s profit margin.

Scenario – Purchasing plywood for a residential complex
General contractor NorthBay is bidding for a $10M contract to build a townhouse community in Redwood City. The project manager, Donald, is responsible for preparing the bid. He estimates his cost on plywood by referring to the Plywood Market Report and calling a local distributor of Georgia Pacific, Condon & Sons. He gets takeoffs of $500 per thousand square feet from both sources. Then he turns on his TV and the news reports that an environmental group is holding picket line at a Georgia logging site. Donald understands that a shortage of supply could increase price of plywood by 40% easily and he will not know whether he will win the contract or not for another 3 to 4 weeks. He is well aware that the bidding is very competitive and competitors such as DHR, WebCon, and S & R are all submitting very competitive bids. He has a few alternatives but none of them sound very attractive. If he submits a bid with an estimate of plywood at $500 per 1000 sq. ft., his profit of the entire project can be wiped out if plywood price goes up to $700 per 1000 sq. ft.. If he bids with an estimate of plywood at more than $600 per sq.ft., he may lose the entire contract. If he places an order for plywood now, he will be stuck with the plywood if he does not win the contract. His fellow project leader, Tony, may be able to use it if Tony wins another contract but Tony thinks his chance is only 30%. If he subcontracts the plywood out to his subcontractors, he is transferring the risk to another party and he wants to maintain good relationship with his subcontractors. Is there a better way?

Real options in the semiconductor industry
Due to large capital investment in building a wafer fabrication facility (in excess of $2 billion) and the highly uncertain market demand, many integrated circuit (IC) manufacturers do not own fabrication facilities. Instead, they design computer chips and rely on subcontractor called foundries for wafer fabrication. In order to cover demand upside, they reserve capacity to assure future supply. However, this will expose them to penalty for unused capacity when market goes south. Therefore, some of them signed real option embedded contracts with foundries like Taiwan’s TSMC for the usage of capacity for a number of years. Typically, the contract would consist of two parts, a fixed amount of “take-or-pay” capacity and additional capacity reserved as options. An IC manufacturer would have to pay an upfront premium for the right to have this option and would tell the foundry six month before delivery its final capacity commitment, exercising the option if necessary. Therefore, the premium for the option can be viewed of as the premium for the ability to defer a decision until more information is available. The foundries, on the other hand, would sign similar contracts with a number of IC manufacturers to diversify their risk and they are often able to fill excess capacity with low margin memory ICs.

Real options in the construction industry
The need for similar real option contracts in construction industry is apparent. This is especially true for commodity-like products with decent price volatility that general contractors buy over and over again in large quantities—products such as structural steel, plywood, concrete, gypsum, electrical wire. For
example, if NorthBay usually buys around 2 million sq. ft. of plywood every year and price of plywood fluctuates by about 40% around a mean of $500 per 1000 sq. ft., it can negotiate to buy 1 million sq. ft. of plywood at $525 per 1000 sq. ft. from Georgia Pacific through Condon & Sons with the option to expand up to 1.5 million sq. ft. and the incremental quantity at $575 per 1000 sq.ft.. The rest of the plywood could be purchased in the spot market in the old fashioned way. Therefore, if price of plywood goes up, NorthBay is protected because it has locked in the price without incurring inventory cost; if price of plywood drops, it can minimize its loss by simply not activating the option and buy from the spot market instead. Besides, the delivery of plywood is less likely to be delayed because the order was placed well in advance.

**Problems of real options embedded contracts**

We identify three major problems that have to be overcome for real option embedded contracts to work. 1) Identify the types of materials and the types of real options that are most applicable. 2) Reduce the number of dimension/state variables so that the resultant dynamic programs can be practically solvable. 3) Propose incentives for industry decision makers to change their current purchase practices.

**Identify the types of materials and types of real options**

- **Types of Material** – In the construction industry, different general contractors buy different kinds of materials. Some general contractors buy concrete, some buy plywood, and some buy structural steel. Construction management firms typically buy less material than other general contractors, leaving the majority of material procurement to subcontractors. We would like to identify commodity materials that general contractors buy in large quantities and with high price volatility. This is because the value of real options is bigger when volume is bigger and price fluctuates more. Intuitively, if you can pay 50 cents instead of 60 cents for an apple, you save more when you buy 1000 apples than 500 apples. Also, your option to buy apples at 50 cents each is more valuable when price of apples fluctuate between 30 to 70 cents than between 45 and 55 cents. It is because sometimes you may be able to pay 50 cents for a 70-cents apple, saving 20 cents. Furthermore, commodity products are more suitable for a long-term contract (than custom or engineer products) because general contractors are more likely to buy them over and over again.

- **Types of Real Options** – On the other hand, there are many types of real options: option to buy more, option to buy less, option to defer purchase, option to cancel purchase, option to switch brands, option to stop and restart purchase, compound options, etc.. However, not all of them are applicable to material procurement in the construction industry and not all of the relevant ones can be studied in depth in the time frame of this research project. We have to identify the most valuable and applicable options. More in-depth research will be pursued in a larger scale after this proposed research provides proof-of-concept.

**Reduce the number of dimension/state variables of dynamic programs**

Dynamic programming is the right tool to solve many real option problems because it captures sequential decision making and the interdependence of information and decisions that come at different times. In a dynamic program, a problem can be divided into stages and each stage has a number of states. The objective of the decision maker is to find the optimal policy to transform the current state into the next in her best interest. However, a dynamic program can become too complicated to solve if the problem is non-Markovian (the optimal policy for the remaining stages is dependent on that of the previous stages) and there are many decision variables. In general, even if we can solve a complex dynamic problem, the optimal policy is very sophisticated. It is much easier to gain acceptance of and to implement the optimal policies that are simple and intuitive.

**Propose incentives for industry decision makers to practice real options**

The construction industry is conservative. It is because the stake is big and margin is slim, any error could wipe out the profit of the entire project. When introduced to a new way to purchase materials, most of them would see it as incurring some additional risks. We have identify the following difficulties:

- **Cash flow risk** – Most of the general contractors do not pay the subcontractors and suppliers until developers have paid them. Therefore, they are reluctant to commit to any upfront payment in long-term contracts.
• **Inventory cost** – Most general contractors do not have a lot of space to store excess materials and are unwilling to take up any inventory cost. This is why most of them do not buy in large quantities in advance.

• **Relationship with subcontractors** – Some general contractors mainly provide construction management services to owners and developers and do not buy many materials. They rely on the subcontractors to provide both labor and material. If they take away material procurement from subcontractors and ask the subcontractors to provide only labor, the subcontractors may see it as threatening their profit margin and resist.

**Proposed Solutions**
We believe that the problems described above can be solved systematically. Our intuition is that through working closely with industry decision makers as well as framing the problem and making realistic assumptions, we can introduce real options embedded supply contracts into the construction industry.

**Identify the types of material**
We would like to pick one or two commodity material that general contractors buy in large quantities frequently and have decent price volatility. We would:

• Survey General Contractors -- Survey 5-10 large general contractors with volume at least US $100 million per year on what commodity materials they buy in bulk for most projects.

• Price and volatility study – Collect data on prices of the identified materials for past projects from general contractors. Collect market data for spot and future prices from industry periodicals (e.g. Plywood Market Report), suppliers, online marketplaces, and future commodity markets. Afterwards, identify the common causes for price fluctuation and model the price trend using mathematical processes (e.g. Brownian motions) or probability distributions (e.g. beta distribution).

• Understand the supply chain – Identify the number of players in the supply chain of those materials and the relationships among the manufacturers, distributors and suppliers. Identify how prices are set, what the margins are and which party is responsible for delivery, insurance, etc.

**Identify the types of real options**
We would like to identify one or two types of real options that are most valuable and applicable to the material procurement process of the construction industry. We have identified three types of options but will aim to narrow it down to at most 2 by interviewing buyers and suppliers.

• Option to defer – General contractors may find it attractive if they have the option to defer delivery in case weather is bad or there is a delay in obtaining building permits, signing off of a design, the predecessor step, etc.

• Option to alter scale of procurement – Given a certain lead time, general contractor may find it useful if they have the option to order units in addition to the “take-or-pay” amount or decrease their order size. This would give them flexibility when market condition changes because construction is a cyclical industry.

• Option to switch – In a fast track project, change orders are commonplace. Besides, prices and availability of products may force him to switch to a substitute product. Therefore, a general contractor may find it valuable if he can switch among similar products supplied by the same distributor.

**Solving real option problems**
The following bullets highlight the complexity of dynamic programs, which we will discuss and speculate on appropriate approaches to derive intuitive and relatively simple decision policy.

• Making reasonable assumptions when framing the problems and identifying decision variables--There are many variables in a dynamic program, some deterministic and some random, while others are decision and state variables. The challenge is to model which as what, since such determination defines the size of a dynamic programming. Assumptions will be made based on historical data and feedback from industry experts. For example, in a contract to supply a fixed amount of steel every month with an option to order more given one month notice, we may have to assume that the lead time is (a deterministic) one month, the price is $x per ton for the fixed
volume, the monthly demand has a normal distribution, the buyer can only increase the order size up to y% for $z per ton, the option costs $p, and leaving how many tons of fixed order the only decision variable. If we assume that the price of option increases with volume, then we may have one additional decision variable—the number of tons of steel to reserve as option.

- Breaking the problem into components—many dynamic problems are solved by breaking into simpler problems of dimension one or two if certain conditions are met. See NingXiong Xu, Ph.D dissertation.
- Numerical Techniques—Some complex problems, especially those involve multiple interacting real options, have no analytic solutions. There are generally two types of numerical techniques to evaluate options: 1) Approximate the underlying stochastic processes by Monte Carlo simulation or by binomial lattices, and 2) Approximate the resulting partial differential equations by numerical integration and finite-difference schemes.

Incentives for buyers and sellers to try real option embedded options
When setting up sample contracts, we will take into consideration practical difficulties that buyers and sellers have expressed in the surveys. For example:

1. In the supply contracts, general contractors do not have to pay in advance the cost of the material to be delivered except may be the option premium. They will pay after delivery or a penalty if they choose to cancel or decrease the size of a delivery. It is because general contractors typically do not have a lot of cash, they simply hand over the developer’s money to the suppliers and subcontractors.
2. Delivery of material will have to be as frequent as if the general contractors are ordering from project to project. It is because most of them do not have storage space or are unwilling to incur additional storage cost that eats into their already thin margin.
3. We will try to work with larger general contractors who buy materials directly, have the power to negotiate complicated long-term contracts with suppliers and induce subcontractors to transfer the material procurement to them.
4. We will have to use either data of past projects or real-time data to prove to general contractors that real options can improve their project margin with minimal risk.

Milestones
The research project will be completed in three phases

Phase I. (End of Autumn Quarter 2001) Survey general contractors and suppliers and collect historical data to:
- Identify at most 2 types of materials
- Identify at most 2 types of real options to be embedded
- Create price models
- Understand the structure of the supply chains
- Identify possible incentives

Phase II. (End of Spring Quarter 2002) Set up mathematical models and solve for optimal decision policies
- Define objective
- Define time horizon, state variables, constraints, and decision variables
- Identify similar works in this field
- Solve for optimal decision policy

Phase III. (End of Summer Quarter 2002) Verify value of the model using historical data. If time allows, we would like to work with a couple of buyers and suppliers on real contracts.

Deliverables
- Final CIFE Technical Report to be submitted upon conclusion of the research
- One to two journal articles at the conclusion of the research
- Web documentation of the ongoing and finished research
- At least one workshop for CIFE members
- Real-life supply contracts if time allows
**Industry Participation**
As mentioned above, industry decision-makers will participate actively in Phase I and III during the framing and verification of the problem.

**Anticipated Risks**
We anticipate the following risks that could jeopardize the success of the project:
- Dynamic programs too complicated to solve – a dynamic program to solve a realistic real option problem may prove to be too complicated to solve while a solvable program too abstract to be applicable to the construction industry. We will mitigate this problem by making necessary but not overly strong assumptions. We will also try to use simulation or other methods mentioned above in case an analytic solution is not possible. Furthermore, there are a lot of problems to choose from—given the prices and demand forecast, how much and when to order; quantify the value of flexibility given better information, how much to reserve in option; how to set premium for option to alter order size; how much should a distributor overbook to diversify its risks, etc.
- Scope of project – This project is exploratory and therefore large in scope by nature. We will mitigate this problem by continuously focusing the project as it proceeds.
- Lack of participation of industry decision makers – This project may looked upon as too radical by some industry players who are not eager to participate. We will leverage our existing relationship with leading general contractors and suppliers to create interest among buyers and sellers. In order to prove concept, we do not need more than 3 general contractors and 3 suppliers to participate.

**Relation to CIFE Goals**
This research supports CIFE goals for modeling construction supply chains and applying advanced information technologies to improve the productivity of the AEC industry. We believe advanced ideas on capacity reservation from the semiconductor industry can improve the material procurement process in construction. This research will partly be based on dynamic programming and real option valuation techniques developed in the Management Science and Engineering department and hence the project is interdisciplinary.

**Relation to other CIFE Research**
This research falls within two CIFE thrust areas, “Supply Chain Management and E-Commerce” and “Management of Technology”. It relates to IT and software support for supply chain management and material procurement because the policies developed can be programmed into software agents. Furthermore, it supplements a previous CIFE research in the technology management area – “The Make vs. Buy Decision for Specialty Contracting: Economic Analysis of the Choice of a Long Contracting”.

**Funding Sources for Continued Research**
We will continue to search for other funding sources for the further research in real option embedded supply contracts and develop decision support software based on them. We will explore both Federal (NSF, NIST) as well as industry funding. The chance for industry support after the first year is high because the research result can have a positive impact on the profit margin as well as uncertainty reduction for the general contractors.

**Budget**

**Related Works**