

Financial Valuation of Material Price Adjustment Clauses

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Uncertainty in material costs has been a serious challenge for state Departments of Transportation (DOTs) and contractors since the last decade. Uncertainty in the price of critical materials increases the risk of contractors in fixed-price contracts and can lead to price speculation and bid inflation. One of the most common strategies used to address inflated bid prices is price adjustment clauses (PACs) which guarantee an adjustment in payments to contractors based on the size and direction of material price changes. Contrary to the widespread application of PACs by state DOTs, there is little knowledge about the financial value of offering PACs in transportation contracts. This gap in knowledge makes it difficult for contractors and state DOTs to systematically evaluate the impacts of offering PACs on their risk profiles. The research objective of this paper is to develop a model that measures the financial value of PACs in transportation contracts. In this study, we apply real option theory to price the PACs in transportation projects. A market-based option pricing approach called risk-neutral valuation method is devised to determine the financial value of the PACs. The results of this study help state DOTs and contractors develop their economic risk profiles properly.

Key Words: Price Adjustment Clause, Financial Valuation, Real Option, Risk-Neutral, Binomial Lattice, Risk Profile, Transportation Projects

Introduction

Volatility in material costs has been a serious challenge for state Departments of Transportation (DOTs) and contractors since the last decade. Construction and maintenance of transportation infrastructure requires significant quantities of critical materials such as asphalt cement and fuel. The costs of these materials fluctuate significantly during the construction phase, and the fluctuation has increased significantly in the last ten years. For example, from 2003 through 2005, asphalt cement prices increased roughly 4% per year but between August 2005 and August 2006, asphalt cement prices spiked by 38% (Gallagher & Riggs, 2006). Figure 1 shows considerable volatility in the average price of asphalt cement in the state of Georgia from September 1995 to September 2015 (GDOT 2015).

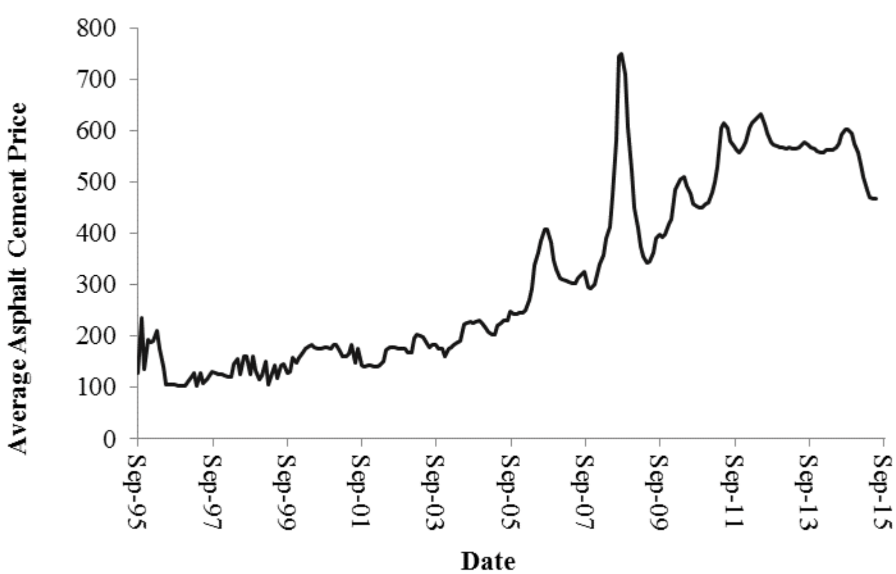


Figure 1: Average price of asphalt cement in Georgia

Considerable volatility in the price of major materials such as asphalt cement leads to significant uncertainties in cost estimations and increases the risks of contractors in fixed-price contracts. In response to the risks, contractors may consider extra risk premiums when submitting bid prices to secure their financial positions against possible rising prices. Higher risk premiums may lead to price speculation and inflated bid prices submitted by contractors (Damnjanovic et al. 2009). Thus, state DOTs often overpay for projects under fixed-price contracts due to increased risk premiums and hidden contingencies in contractors' submitted bid prices (Eckert & Eger, 2005). A common method used by state DOTs for handling the issue of extra risk premiums and avoiding overpayment to contractors is to offer Price Adjustment Clauses (PACs) in contracts (Skolnik 2011). A PAC is a risk sharing contractual mechanism that guarantees an adjustment in payment to contractors based on the size and direction of the material price change. In a contract with a PAC, a state DOT accepts at least a part of the risk for price escalation and pays the contractor for any increases above an agreed-upon threshold. Also, if the price decreases below the threshold, the state DOT benefits from the saving. This risk sharing strategy protects contractors against future material price escalation and encourages them to exclude extra risk premiums from their submitted bid prices.

In 2009, a survey done by the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Construction, Contract Administration Section, indicated that 40 DOTs offer PACs for asphalt cement, and 41 state DOTs offer PACs for fuel (AASHTO 2009). Contrary to the widespread application of PACs by state DOTs, there is little knowledge about the financial value of offering PACs in transportation contracts. This gap in knowledge makes it difficult for contractors and state DOTs to systematically evaluate the impacts of offering PACs on their risk profiles. The research objective of this paper is to develop a model that measures the financial valuation of PACs in transportation contracts. In this study, we apply real option theory to price the PACs in transportation projects. A market-based option pricing approach called risk-neutral valuation method is leveraged to determine the financial value of the PACs. The results of this study will enable state DOTs and contractors to develop their economic risk profiles and more precisely handle the risk of material price volatility. The rest of the paper is structured as follows. After presenting the research methodology, consisting of four major steps, real option model development is explained. Finally, an illustrative example is presented.

Research Methodology

Since the option of the some of the critical materials for PAC such as asphalt cement is not traded in the market, our proposed method is based on the approach of Marketed Asset Disclaimer (MAD) described by Copeland and Antikarov (2001) which does not rely on the existence of a traded replicating portfolio. Their approach aims to maximize shareholder value. The approach requires conducting a Monte Carlo simulation based on a random walk process to build a risk-neutral binomial lattice of the expected cash flows. In this study, we use the developed binomial lattice to create the risk profile of the underlying asset and consequently estimate the option (i.e. PAC) financial value. The methodology proposed in this paper consists of the following steps:

1- Gathering required input data, including PAC elements such as; trigger points, material price index, and adjustment calculation formula, project characteristics such as; duration of the project, let date, and estimated time of corresponding line items, and market data such as; material price growth rate, material price growth volatility, discount rate, and risk-free rate of return.
2- Developing a binomial lattice model to generate random future paths for material price and calculating the project revenue without a PAC using the Monte Carlo simulation technique.
3- Conducting life cycle cost and revenue analysis for the project under each random revenue path to develop a distribution for the project value and characterize the contractors' risk profile.
4- Adjusting the binomial lattice model of the revenue for the project with a PAC based on the risk-neutral option valuation approach and repeating steps 2 and 3 to analyze the effects of the PAC on the risk profile of the contractor and state DOT.

Real Option Model Development

Traditionally, Discounted Cash Flow (DCF) and deterministic Net Present Value (NPV) analysis have been used for financial analysis. These conventional methods are inadequate to quantify the financial valuation of PACs since they are not capable of capturing the uncertainty of future material price, which is the most important source of cost estimation uncertainty during the construction phase of the projects. Furthermore, the NPV approach is unable to address and properly value the offering of PACs as a risk sharing strategy between state DOTs and contractors. These limitations of the NPV approach encourage us to use dynamic approaches that can be applied to quantify the financial value of PACs. The Real Option Analysis is a powerful financial engineering methodology that is capable of evaluating investment opportunities under dynamic market uncertainty (Dixit & Pindyck, 1994). The real option methodology has been applied in several different domains related to transportation projects. Ford et al. (2002) proposed a real option approach for proactively capturing project values hidden in dynamic uncertainties. They applied their model to a toll road project and concluded that using the real option approach in construction management can improve project planning and consequently increase returns. Zhao et al. (2004) developed a stochastic real option model for decision making in highway development, operation, expansion, and rehabilitation. They considered uncertainties related to traffic demand, land price, and highway deterioration in the highway projects. Ashuri et al. (2011) applied real option theory to price the combined Minimum Revenue Guarantee (MRG) and Toll Revenue Cap (TRC) in Build-Operate-Transfer (BOT) projects under traffic demand uncertainty.

Real option analysis covers a variety of different approaches with different underlying assumptions and conditions. Borison (2005) reviewed and discussed the application of several of the most important real option approaches. One of the most important factors for selecting an appropriate approach for real option analysis is the existence of a traded replicating portfolio. In many cases, finding a genuine replicating portfolio is a serious challenge. Copeland and Antikarov (2001) described the Marketed Asset Disclaimer (MAD) approach which does not rely on a replicating portfolio. They emphasized that their approach is applicable to a much broader range of investments than classic approaches which rely on a replicating portfolio. In this paper, we develop a risk-neutral valuation model based on the MAD approach to evaluate the financial valuation of PACs in transportation projects. The following four subsections explain the major steps of our analysis:

Gathering Required Inputs Data

The first step to develop the proposed model and conduct the analysis is to provide the required data. The first data set consists of the detailed characteristics of the project, such as; project let date, duration of the project, eligible materials for PACs, and the schedule of the corresponding line items related to the PAC. The second data set includes detailed information about the PAC design, such as; price indexes, project eligibility conditions, trigger points, payment caps, and formulas to calculate the price adjustment. The third data set contains market data like material price growth rate, material price growth volatility, discount rate, and risk-free rate of return.
To describe the uncertainty, we need to estimate the volatility of the material price index. We can use the historical material price index or subject matter experts' opinions to estimate the volatility of the material price. In addition, we need to determine the expected material price index growth rate (α) which can also be determined based on historical data and experts' opinions.

Developing Binomial Lattice Model

We use a binomial lattice model to address the uncertainty of future material price. A binomial lattice is a random walk model to capture uncertainty about a variable that grows over time plus random noise (Copeland & Antikarov, 2001). The material price index is known at the project let date (i.e. t_0). According to the model, the material price index at the beginning of the next month is one of only two possible values which are defined to be multiples of the price index at the previous period. With a probability of p, the price increases and is multiplied by u ($u > 1$). With a probability of $1-p$, the price decreases and is multiplied by d ($d < 1$). These three parameters (i.e. u, d, and p) are determined based on the expected material price index growth rate (α) and the monthly volatility of the price index (σ) (Hull 2008):

$$u = e^{\sigma\sqrt{\Delta t}} \tag{1}$$

$$d = e^{-\sigma\sqrt{\Delta t}} \tag{2}$$

$$p = \frac{e^{\alpha\Delta t} - d}{u - d} \tag{3}$$

Figure 2 shows a schematic binomial lattice model. Considering the binomial lattice formulation, material price index at the beginning of the i^{th} month $i = t_0+1, t_0+2, \ldots, N$ (N is the last month of the construction phase) is a random variable that follows a discrete binomial distribution. From the root of the binomial lattice (i.e. t_0), any node in the binomial lattice can be reached by several up and down movements. The probability to reach a node at the beginning of the i^{th} month can be calculated as follow:

$$prob\,(price\ index\ at\ month\ i = PI_0 \times u^k d^{i-k}) = \binom{i}{k} p^k (1-p)^{i-k} \qquad (4)$$

Where k is the number of possible upward movements ($0 \le k \le i$) and PI_0 is the material price index at the project let date.

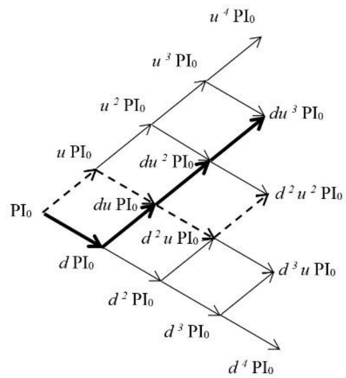


Figure 2: A schematic binomial lattice model

We use Monte Carlo simulation technique to generate a large number of random paths across the binomial lattice. At the end of this step, we can develop a probability distribution for material cost at the beginning of each month and calculate the monthly revenue of the project.

Developing Cost Distribution and Risk Profile

Each generated random cost path represents a possible revenue stream for the contractor. For each possible scenario run in the Monte Carlo simulation, we can develop a cash flow and consequently calculate monthly revenues. These randomly generated cash flows and monthly revenues can be transferred to NPV using the following formula:

$$NPV = \sum_{i=0}^{N} (BID_i - C_i - PI_i) \times TMT_i \times e^{-\rho \frac{1}{12}} \qquad (5)$$

Where,
NPV is the net present value of the total revenue
N is the length of construction phase
BID_i is the submitted bid price per unit of quantity
C_i is other costs (i.e. other materials, labor and etc.) per unit at i^{th} month
PI_i is cost of material per unit at i^{th} month
TMT_i is the total monthly tonnage of the material at i^{th} month
ρ is the annual discount rate

A sufficiently large number of simulation runs and calculations of all possible NPVs, in addition to their corresponding likelihoods, provides a systematic approach to address the uncertainty in the cost of the materials and value of the project. At the end of this step, we have a probabilistic distribution for the contractor's revenue in the absence of a PAC.

Conducting Risk-Neutral Valuation

In this step, we model the effects of offering PACs on the project revenue distribution and consequently contractors' and state DOTs' risk profiles. Comparing the results of this step with the results of the previous step can show the financial value of the PACs. The financial value of a PAC in a project depends on the uncertainty associated with the price of material. Contractors are typically risk-averse and expect returns for bearing uncertainty. In other words, considering the inherent uncertainties of the option payoffs, they have different risk assessments for projects without an option and require different discount rates. Therefore, the calculated expected values of the PAC payoffs need to be discounted using a proper risk-adjusted discount rate in order to determine the option value. However, determining the risk-adjusted discount rate accurately can be extremely complicated (Hull 2008). Alternatively, we can use an important principle in option pricing known as risk-neutral valuation. The general idea of the risk-neutral valuation is to first adjust the probabilities of future payoffs such that they incorporate the risk effects and calculate the expected payoffs of the PAC. Then, the expected payoffs should be discounted at the risk-free rate. The only appropriate condition for the use of risk-neutral valuation is when arbitrage opportunities are absent (Borison 2005). In order to implement the risk-neutral valuation approach, we need to replace the expected growth rate of material price index (i.e. α) with the risk-neutral expected growth rate of the price index which is defined as follows (Hull 2008):

$$\alpha_r = \alpha - \lambda\sigma \tag{6}$$

Where,
σ is the volatility of the price index and λ is the risk premium of the material price volatility. λ is defined as follows (Hull 2008):

$$\lambda = \frac{R - r_f}{\sigma} \tag{7}$$

Where,
R is the asset return
r_f is the risk-free rate of return

If we assume that the revenue risk of the contractor is caused only by material price volatility, the risk premium of the investment in the project (i.e. λ_p) is identical to the risk premium of the material price volatility (i.e. $\lambda = \lambda_p$). Furthermore, we can define R_p as contractor's return. Thus, $R_p - r_f$ is the excess return that encourages a contractor to invest in the project. Thus, $R_p - r_f$ is equal to ρ - r_f. That being the case, the risk premium of the material price (λ) or the risk premium of the project (λ_p) can be calculated as follow:

$$\lambda = \lambda_p = \frac{\rho - r_f}{\sigma_p} \tag{8}$$

Where σ_p is the project volatility.

Godinho (2006) developed a method to estimate the project volatility based on a two-level simulation procedure. At first step, the project cash flow is simulated in the first year using a Monte Carlo technique and a random walk process. Then, for each calculated cash flow at the end of the first year, the cash flow from year 1 until the end of the project is simulated and the average cash flows after the first year are calculated. Using the average cash flow after the first year, the present worth of the project at the end of the first year is determined. A random variable representing the continually compounded rate of return on the project between year 0 and 1 is calculated by the following formula:

$$k = \ln(\frac{PW_1}{MV_0}) \tag{9}$$

Where, MV_0 is the market value of the project at time 0 and PW_1 is present worth of the project at the end of the first year. The MV_0 is deterministic and is calculated based on the information available at the beginning of the project. In other words, MV_0 is the initial forecasted present value of the project based solely on the material price index at the let date and its deterministic forecasted future values by the contractor. However, PW_1 is a random variable calculated based on the generated random path of the cash flows after the first year. The project volatility is defined as the standard deviation of k. After revising the growth rate, we need to reconstruct the binomial lattice and calculate the contractor's probabilistic NPV with the PAC option. The market value of the PAC is the difference between the contractor's NPVs with and without the PAC.

Illustrative Example

In this part of the paper we present an illustrative example that demonstrates the application of the proposed methodology. For simplification, assume that a contractor is responsible for a part of a transportation project consisting of only one line item related to resurfacing. The line item represents the production and laying of 24,000 tons of asphalt concrete with 12.5 mm thickness. The duration of the project is 24 month and based on the schedule of the project, 1000 tons of asphalt concrete should be laid each month. The owner of the project is the Georgia Department of Transportation (GDOT) which offers a PAC for liquid asphalt cement for projects with a duration longer than one year. GDOT's PAC has a zero trigger point (i.e. any change in the price of asphalt cement activates the PAC) and a cap of 60% (i.e. maximum positive adjustment in the price is up to 60% of the price in the let date). The project was let in June 2015 in which GDOT asphalt cement price index was $466 per ton.

Assume that the submitted bid price is $45 per ton of asphalt concrete. Based on the design of the asphalt concrete, the percentage of the liquid asphalt cement is 5% (i.e. 0.05 ton per ton of asphalt concrete). Assume that the only source of uncertainty is the price of asphalt cement, meaning that the price of other materials and other costs (e.g. labor, equipment, and etc.) are constant and equal to $17 per ton of asphalt concrete. We assume that the contractor purchases the liquid asphalt cement at the same price as GDOT price index. So, if the price does not fluctuate over time, the expected revenue per ton of asphalt concrete is $4.7. The discount rate and risk-free rate of return are 8% and 5%, respectively. Thus, if the asphalt cement price does not fluctuate, the deterministic NPV of the expected revenue is $66,774. The contractor assumes one percent increase in asphalt cement price index each month and then calculate the deterministic NPV as $42,198. Based on a dataset consisting of GDOT asphalt cement price indexes between September 1995 and June 2015, the expected growth rate (α) and volatility of the asphalt cement price index (σ) are estimated 7.75% and 10.21%, respectively.

After gathering the required data, we need to calculate the three parameters of *u*, *d*, and *p* using the estimated growth rate and volatility of the asphalt cement price index. Then, we conduct the Monte Carlo simulation process to develop the binomial lattice for the future price of the asphalt cement price index. Figure 3 shows the developed binomial lattice.

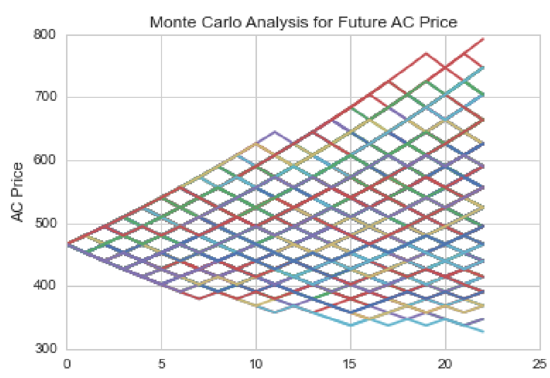
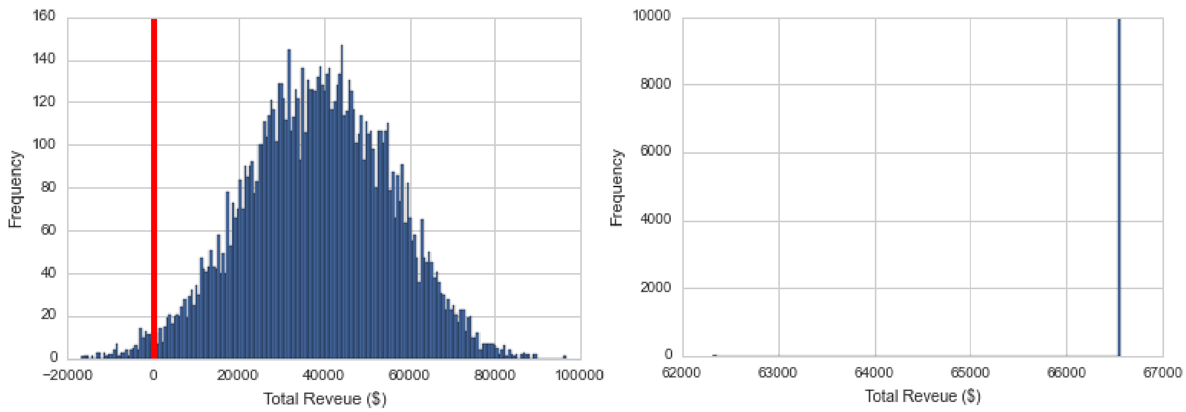


Figure 3: Binomial lattice model for future asphalt cement price index

After generating the random paths for future price of asphalt cement, we calculate the contractor's monthly revenue in the absence of a PAC. Figure 4a shows the distribution of the NPV of the total revenue indicating that the NPV of the total revenue ranges from -$18,000 to $97,000. The mean and the standard deviation of the distribution are $39,151 and $16,718, respectively. This distribution shows the risk profile of the contractor without a PAC. Although the deterministic NPV of the expected revenue is positive (i.e. $42,198), the distribution indicates that with the probability of 1.25% the NPV will be negative which is not desirable.

The final steps are to apply the proposed real option analysis model (i.e. risk-neutral valuation approach) to capture the effects of offering a PAC in the project, develop the distribution of the NPV of the total revenue, and compare the risk profile of the contractor with and without a PAC. In order to implement the approach, we need to revise the expected growth rate of the material price using equation 6, update the probability of an increase in price in equation 3, create a risk-neutral binomial lattice, and develop the probabilistic distribution of the total revenue NPV. The volatility of the project (i.e. σ_p) is calculated as 0.779 using the method proposed by Godinho (2006). Thus, considering equation 8 the risk premium of the project is 0.0387. Using the calculated risk premium in equation 6, the risk-neutral expected growth rate of the price index is 0.0717. Now, we reproduce the binomial lattice model using the risk-neutral expected growth rate and then develop the probabilistic distribution of the NPV of the contractor's total revenue when a PAC is included in the contract (Figure 4b).



(b) (b)

Figure 4: Total profit distribution of the project without PAC (a) and with PAC (b)

The results indicate that offering the PAC affects the contractor's risk profile significantly. The probabilistic distribution has a negligible variation. The expected mean revenue is $66,562 which is significantly higher that the calculated mean for the project without the PAC. Furthermore, the standard deviation is equal to just $143 which is extremely lower than the standard deviation of the revenue absent a PAC. In the real world, a transportation project consists of many tasks and faces numerous types of risk. In addition, other cost factors of asphalt line items (e.g. labor, machinery) may pose their own financial risks. However, the illustrative example described above demonstrates how to analyze the effects of offering PACs on contractors' financial risk profile, and how to quantify their financial valuation.

Conclusion

Significant volatility and uncertainty in the price of critical materials such as asphalt cement and fuel in transportation projects can lead to price speculation and inflated bid prices. Many state DOTs offer PACs in their projects to shift the risk and encourage contractors to exclude the extra risk premiums from their submitted bid prices. In this paper, we conducted a real option analysis to develop a model to quantify the financial value of a PAC. Considering the challenges of finding an accurate replicating portfolio for transportation projects, we developed a risk-neutral valuation model based on the Marketed Asset Disclaimer (MAD) approach which does not rely on a replicating portfolio. This model analyzes the effects of offering PACs on contractors' risk profile and consequently quantifies the financial value of a PAC in transportation projects. After describing the proposed method, a simple illustrative example was explained. The results of the illustrative example show how offering a PAC in transportation projects can decrease the risk of material price volatility for contractors.

This model can help contractors to price PACs and determine their submitted bid prices with greater accuracy. Many large contractors have the opportunity to work in different states that may or may not offer PACs. This model helps them evaluate the financial value of potential projects and compare the expected revenue from projects with and without PACs. Furthermore, in some state DOTs, such as Illinois, contractors have the opportunity to decide if they want a PAC in the contract or not. This model helps them make a more accurate decision based on a quantitative analysis. The results of this study can help state DOTs as well. Using the proposed model, they can evaluate the financial value of the PACs that they offer and assess the received bids more accurately. Moreover, they can conduct a sensitivity analysis to review the effects of a change in design elements, such as trigger points, on the performance of a PAC. Analyzing volatility and uncertainty in the price of the material and finding the proper time to offer PAC based on market conditions can be a basis for future studies.

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