Empirical Study of Impact of Price Adjustment Clauses (PACs) on Highway Construction Bid

Mohammad ILBEIGI¹, Baabak ASHURI² and Soheil SHAYEGH³

1 Graduate Research Assistant, Economics of the Sustainable Built Environment (ESBE) Lab, School of Building Construction, Georgia Institute of Technology, Atlanta, Georgia. email: ilbeigi@gatech.edu
2 Director, Economics of the Sustainable Built Environment (ESBE) Lab, Assistant Professor and Chair Integrated Project Delivery Systems, School of Building Construction Georgia Institute of Technology, Atlanta, Georgia. email: baabak.ashuri@coa.gatech.edu
3 Graduate Research Assistant, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia. email: soheilsh@gatech.edu

ABSTRACT
Volatility in price of critical materials used in transportation projects, such as asphalt cement, leads to considerable uncertainty about project cost. This uncertainty can lead to price speculation and inflated bid prices submitted by highway contractors to protect against possible price increases. One of the most common risk sharing strategies widely used by transportation agencies is price adjustment clauses (PAC) that divide potential upside and downside risk of material prices between contractors and owners. However, it is not clear whether offering PAC reduces risk premium of bids submitted by highway contractors. The research objective of this paper is to assess the impact of offering PAC for asphalt cement on submitted bids of one of the most common asphalt mixture line items. Data on 1520 highway projects consisting of the asphalt line item bid out in the state of Georgia from 1998 to 2013 were collected to analyze the impacts of PAC on bid prices. Multivariate regression analysis was conducted to evaluate the effect of several factors, such as project size, number of bidders, asphalt cement price, and availability of PAC on unit price bids material prices submitted by highway contractors. It is found that eligibility for PAC is not a statistically significant explanatory variable to explain the variation of submitted bid prices for the asphalt mixture items.

INTRODUCTION
A significant volatility in the price of critical materials such as asphalt cement is one of the most important challenges of transportation agencies and contractors in transportation projects. Considerable volatility in the price of material can lead to uncertainty about project cost. Cost uncertainty increases the risk of contractors in fixed price contracts. Figure 1 shows asphalt cement price index in the state of Georgia from January 1995 to May 2012. An appropriate method of pricing a product or service to meet expected profit is to quantify risks and develop a strategy for a riskless rate of return plus compensation for individual risk factors (Fischer and
Consequently, contractors consider significant risk premium in their submitted bids to protect against possible price increases. Empirical results indicate that governments usually overpay for projects under the fixed price contracts that transfer the risk to contractors, because of the risk premium or large hidden pricing contingencies that contractors include in their bids (Eckert and Eger 2005). Transportation agencies of Kentucky, New Hampshire, Pennsylvania and Washington reported that they may pay more to the contractor than the added cost to the material price increase (Holmgren et al. 2010).

A common method to handle the problem of extra risk premium in submitted bids and avoid overpayment is Price Adjustment Clause (PAC). PACs share the potential upside and downside risk of material prices between contractors and owners. This shift in risk may benefit the owners through contractors’ willingness to submit lower bids (Skolnik 2011). A survey by AASHTO in 2009 indicates that 40 state Department of Transportation (DOT) use PAC program for asphalt cement. In contrary to the vast application of PAC in transportation projects, it is not clear whether offering price adjustment clauses reduces the risk premium of bids submitted by highway contractors. A few qualitative and quantitative investigations on the effectiveness of PAC have been done in some states (Eckert and Eger 2005; Holmgren et al. 2010; Skolnik 2011; and Kosmopoulou and Zhou 2011). However, the results are inconsistent and do not confirm each other. The inconsistency between the results of previous investigation in different states might be based on the different design of PAC program.

Skolnik (2011) used regression analysis to assess the effectiveness of PAC and its characteristics such trigger points in transportation projects. His data set consists of the bid prices from a group of four states with PAC of any type that was compared to the control group of the four states with no PAC. However, other regional factors such as average size and type of the projects may reflect differences between submitted bid prices in those states. Furthermore, all projects in a state with PAC are not eligible for this program and states have different criteria for PAC eligibility. But one of the most important outcomes of that research is the fact that the performance of PAC in different states is not similar. Thus, instead of comparing the

![Figure 1. Monthly asphalt cement price index in Georgia](image-url)
bid prices in different states with and without PAC, evaluation of PAC program in different states separately and comparison of bid prices for eligible and ineligible projects in a state can be a reasonable solution.


In this paper, the impact of offering PAC for asphalt cement in the state of Georgia on unit price bids submitted by highway contractors for hot mix asphalt concrete is assessed. Data on 1520 highway projects bid out in the state of Georgia from January 1998 to July 2013 were collected to analyze the effect of price adjustment clauses on bid prices. It is expected that this work helps transportation agencies empirically examine the significance of price adjustment clauses on bid prices.

Price Adjustment Clause in Georgia

The Price adjustment clause for asphalt cement in the state of Georgia was offered for the first time in September 2005. If the asphalt cement price for the current month is greater than the asphalt cement price for the month in which the project was let to contract, the contractor will be paid an amount calculated in accordance with the following formula:

\[ \text{PA} = \frac{\text{APM} - \text{APL}}{\text{APL}} \times \text{TMT} \times \text{APL} \]  

(1)

Where:
PA = Price Adjustment.
APM = the “Monthly Asphalt Cement Price (Georgia Base Asphalt Price)” for the month the hot mix asphalt/bituminous tack/bituminous surface treatment is placed.
APL = the “Monthly Asphalt Cement Price (Georgia Base Asphalt Price)” for the month which the project was let.
TMT = Total Monthly Tonnage of asphalt cement computed by the Engineer based on the Hot Mix Asphaltic Concrete of the various types per ton.

If the asphalt cement price for the current month is less than the asphalt cement price for the month in which the project was let to contract, the Department will deduct an amount calculated in accordance with the previous formula too.

Moreover, there is a cap of 60% above the APM/APL for any price adjustment. GDOT determines the monthly asphalt cement price index based on the average of prices from around 15 different suppliers after removing the minimum and the maximum prices.
The criteria for eligibility of the projects have been changed in August 2009 and August 2011. Based on the latest version of the PAC provision in the state of Georgia, all transportation projects with more than 365 calendar days from the contract letting date to the specified completion date are eligible for the PAC program.

**RESEARCH METHODOLOGY**

In this paper, the effectiveness of PAC on submitted bid prices is investigated using regression analysis. Multivariate regression analysis and analysis of variance (ANOVA) were conducted to evaluate the effect of several factors, such as project size, project duration, number of bidders, asphalt cement price, and availability of price adjustment clauses on unit price bids submitted by highway contractors for hot mix asphalt concrete. The investigation in this research consists of following steps:

1. Collecting the data set consisting of detailed information about submitted bid prices for one of the major asphalt line items in transportation projects.
2. Identifying possibly effective factors on submitted bid prices for hot mix asphalt concrete.
3. Drawing scatter plot for each explanatory variable versus response variable to detect any possible relation between explanatory variables and response variable visually.
4. Calculating the correlation factors between each pair of explanatory variables.
5. Identifying unusual observations and outliers and then correcting or removing them.
6. Finding the best subset of the explanatory variables to model the response variable using backward procedure.
7. Evaluating the model and checking the basic assumption of regression models to validate the model.
8. Interpreting the results to evaluate the impact of offering PAC

**DATA SET**

The data set consists of detailed information of 1520 highway construction projects consisting of one of the most common asphalt line items from January 1998 to July 2013. The description of the item is “Recycled Asphalt Concrete 19 mm, GP 1 or 2, Include Bitumen.”

**Variables**

In any regression model there is a response variable at the left of the linear equation and some explanatory variables at the right side. Since the main goal of offering PAC is to reduce the submitted bid prices by eliminating risk contingencies, the response variable is submitted bid prices for the asphalt line item. The unit of this variable is dollars per ton.
An extensive literature review was conducted to identify possibly effective factors on submitted bid prices for the asphalt mixture line item. Twelve explanatory variables for the initial regression model were determined as follows:

1- **Duration of the project**: Duration of a project might be an important effective factor to determine the bid price. Considering the volatility of the material price, cost uncertainty and consequently risks may be higher for longer projects. The unit of the duration is days.

2- **Quantity**: Quantity of the line item can be an important factor to attract different size of contractors. Larger projects can be more attractive for big contractors and they may submit lower price for them. At the same time, large quantities may lead to higher risks. Scatter plots and correlation coefficients indicate that using natural logarithm of quantity instead of row value of quantity lead to more accurate model.

3- **Total Price of the contract**: Total proposal bid price or contract amount may show the project size. Contractors may have various strategies to determine price for different line items based on the project size. Similar to the quantity variable, natural logarithm of total contract price provide higher accuracy than its row value.

4- **Relative value of the line item**: This variable shows the relative dollar value of the line item compared to the total bid price of the project by dividing the total price of each item on the total bid price.

5- **Number of the bidders for each project**: Number of bidders can be an indicator of competition. Level of competition may have significant effect on the submitted bid prices. Usually higher competition leads to lower prices.

6- **Asphalt price index**: Since liquid asphalt is the most expensive and volatile material in an asphalt mixture, its price should be consider in the model.

7- **Changing rate of the asphalt cement price index**: Changing rate of the asphalt cement price index can show the expectation of future prices. Thus, it might be important beside the price index.

8- **Location**: Considering the availability of resources, distance to the asphalt plant and weather conditions, location of a project may affect the bid price. Koo et al (2010) used site location of a project as a predictor variable for project cost and duration. Georgia State DOT has divided the state to seven different areas. In this research, for each area a binary variable has been defined. Value 1 for the binary variable indicates that the project was located in that area.

9- **Eligibility for PAC**: This is a binary variable which indicates whether a project is eligible for PAC or not. As mentioned before, GDOT has been offering PAC for asphalt cement since September 2005. The criteria for eligibility of the projects have been changed in August 2009 and August 2011. This variable considers a project eligible for PAC if the project was eligible based on the valid provision on its bid date.

In addition to changes in offering PAC in 2005, 2009, and 2011, the bid prices might have been affected by some other regulatory and macroeconomic factors such as market condition, level of economic prosperity or depression, and employment
rate. To capture the effect from these unexplained variables, three binary variables for letting date have been introduced to the model.

11-Letting from September 2005 to August 2009 (Period 05 to 09): This variable is one for all projects with letting date between September 2005 and August 2009 and zero for other projects outside this period.

12-Letting from August 2009 to August 2011 (Period 09 to 11): This variable is one for all projects with letting date between August 2009 and August 2011 and zero for other projects outside this period.

13- Letting after August 2011 (Period after 11): This variable is one for all projects with letting date after August 2011 and zero for other projects outside this period.

REGRESSION ANALYSIS

Unusual Observations

In any data set, some unusual observations or outliers may exist and affect the results of the regression analysis significantly. Various methods were created to identify unusual data points. In this research, an unusual observation is defined as observation with large standardized residuals or large leverage values (Neter et al. 1996). The standardized residual equals the value of a residual divided by an estimate of its standard deviation. In general, a data point can be considered unusual if the absolute value of the standardized residual is greater than 2. Furthermore, an observation might be considered unusual if the leverage value is more than 3 times the number of model coefficients divided by the number of observations (Neter et al. 1996). Unusual data points may result from the natural variation in the process or mistake in data recording. The results of this process to identify the outliers indicated that most of the unusual observations are for projects with a very small quantity of asphalt mixture. Since the unusual data points may have a strong influence on the results, an appropriate strategy to handle such observations should be selected. 88 observations have been identified as outliers. Thus, the remaining 1432 observations are used to develop the regression model.

Finding the Best Subset

Finding the best subset is the main procedure in a multivariable regression analysis that aims to determine which explanatory variables should be included in the regression model. Various procedures and criterion can be used to find the best combination of the explanatory variables to model the response variable. In this research, a backward elimination process with a 5% significance level is used.

A backward process starts with all explanatory variables, testing the significance of each explanatory variable and deleting the variable with the highest p-value more than the significance level (if any) to improve the accuracy of the model. This process is repeated until no further improvement is possible. Table 1 shows the results.
Table 1. Results of Regression Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Statistic</th>
<th>P-Value</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>6.751</td>
<td>1.77</td>
<td>0.077</td>
<td></td>
</tr>
<tr>
<td>Duration of the project</td>
<td>-0.002504</td>
<td>-2.06</td>
<td>0.040</td>
<td>2.692</td>
</tr>
<tr>
<td>Ln Quantity of the Item</td>
<td>-7.3723</td>
<td>-30.87</td>
<td>0.000</td>
<td>4.132</td>
</tr>
<tr>
<td>Ln Total Bid Price of the Project</td>
<td>5.8811</td>
<td>16.87</td>
<td>0.000</td>
<td>5.538</td>
</tr>
<tr>
<td>AC Index in the Bid Date</td>
<td>0.045672</td>
<td>14.79</td>
<td>0.000</td>
<td>6.609</td>
</tr>
<tr>
<td>Changing Rate of the AC index</td>
<td>0.04346</td>
<td>3.48</td>
<td>0.001</td>
<td>1.179</td>
</tr>
<tr>
<td>Number of Bidders</td>
<td>-0.6897</td>
<td>-6.82</td>
<td>0.000</td>
<td>1.368</td>
</tr>
<tr>
<td>Relative value of the Line Item</td>
<td>22.411</td>
<td>9.84</td>
<td>0.000</td>
<td>2.194</td>
</tr>
<tr>
<td>Location: Region 1</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Location: Region 2</td>
<td>1.4319</td>
<td>2.53</td>
<td>0.011</td>
<td>1.123</td>
</tr>
<tr>
<td>Location: Region 3</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Location: Region 4</td>
<td>2.5794</td>
<td>4.31</td>
<td>0.000</td>
<td>1.312</td>
</tr>
<tr>
<td>Location: Region 5</td>
<td>4.8704</td>
<td>7.86</td>
<td>0.000</td>
<td>1.133</td>
</tr>
<tr>
<td>Location: Region 6</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Location: Region 7</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Period 05 to 09</td>
<td>18.6139</td>
<td>26.67</td>
<td>0.000</td>
<td>2.585</td>
</tr>
<tr>
<td>Period 09 to 11</td>
<td>9.273</td>
<td>8.36</td>
<td>0.000</td>
<td>2.837</td>
</tr>
<tr>
<td>Period after 11</td>
<td>9.641</td>
<td>6.94</td>
<td>0.000</td>
<td>5.720</td>
</tr>
</tbody>
</table>

S = 7.23355
R-Sq = 83.8%
R-Sq(adj) = 83.7%

Evaluation of the Models

Multivariate regression models are evaluated by investigation on the null hypothesis indicating that all coefficients of explanatory variables equal to zero. If the null hypothesis is not rejected, it is concluded that none of the explanatory variables used in the model has explanatory power (Webster 2013). The results of Analysis of Variance (ANOVA) test for the regression model reject the null hypothesis. Thus, the model has significant explanatory power.

Residual Analysis

A regression analysis is based on several assumptions. One of the basic assumptions is that the error terms are random with a mean value of zero. Thus, the residual plot should not show any patterns. Another important assumption is that the error terms have a constant variance around the mean value of the response variable. The third vital assumption requires that the error terms are normally distributed (Webster 2013). Figure 2 depicts the residual plots for the regression model. This figure shows no violation of the aforementioned assumptions.

Multicollinearity Diagnosis

Multicollinearity means two or more explanatory variables in a multivariate regression model are highly correlated. If this phenomenon occurs significantly,
regression analysis may give misleading results. Variance Inflation Factor (VIF) is commonly used to diagnose the multicollinearity. In general, a VIF of 10 or larger indicates a problem based on multicollinearity (Webster 2013). VIF index was calculated for each explanatory variable. The results indicate that in this research the regression model for bid prices does not have any problem caused by multicollinearity.

Figure 2. Residual Plots for Regression Model

### Interpretation of the results

Since none of the basic assumptions are violated and multicollinearity phenomenon did not occur significantly, the multivariate regression model is valid. Very high adjusted R squared value (Table 1) indicates that the linear regression model is capable of explaining the variation in the response variable. The results of the model specify that eligibility for PAC is not a statistically significant (with a significance level of 5%) explanatory variable to explain the variation of the bid prices.

Regarding the other explanatory variables, asphalt cement price index in the bid date is significant with a positive coefficient indicating higher expected bid prices when the price index increases while other variables are held constant. Furthermore, the mean change in the bid prices is expected to be negative for an increase in the number of bidders or quantity. In contrary, total bid prices and the relative dollar value of the line item are significant with positive coefficients indicating higher expected bid prices when the total bid price or relative dollar value of the item increases and other variables are held constant.

Finally, relative value of all asphalt mixture items is not statistically significant in the model. Also, changing rate of the asphalt cement price index, duration, and location of the projects do not show any consistent patterns.

### Conclusion and Future Works

Empirical study using multivariate regression analysis presented in this paper indicates that the variations of the submitted bid prices for one of the most common
asphalt line items can be explained appropriately by a linear combination of several variables, such as asphalt cement price index, quantity, total bid price, and number of bidders. However, eligibility for PAC is not a statistically significant explanatory variable in the regression model. The results of this study can help state DOTs to examine the financial implications of offering the PAC program for asphalt cement in transportation projects.

One of the most critical limitations of the regression analysis is the fact that this method is unable to establish cause and effect relationships (Webster 2013). A regression model can explain changes in the response variable but cannot explain why the response variable changed. A high correlation between two variables does not mean change in one of them leads to change in another one certainly. Thus, more investigations using causal methods can contribute to this research significantly.

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