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Prioritization of Price Volatility Management Strategies in Construction Projects

Alireza Joukar[1,] Isabelina Nahmens[2] and Craig Harvey[3]

Abstract: The existence of material price volatility in construction projects puts forward substantial risks for all parties involved. Depending on the parties involved in the project, type of contracts, and state of the market various risk management strategies are practiced by contracting parties to manage project risks related to price volatility. Unfortunately, in many cases companies fail to select an adequate approach to better manage volatilities of material prices due to the lack of a decision support system to aid in the selection of an appropriate strategy based on the project characteristics. The aim of this study is to identify critical project factors and align them to documented strategies to manage price volatility based on an extensive literature review and industry interviews. This study found Integrated Project Delivery (IPD) as the ideal strategy with respect to project duration; quantitative risk management methods with respect to the cost; and Price Adjustment Clauses (PAC) with respect to the risk allocation, as the top price volatility management strategies.

Keywords: Risk Management, Project Cost, Price Volatility, AHP

I. Introduction

In the past decade, the construction industry has undertaken unprecedented price volatility, which has severely impacted the industry. It has caused Construction companies' bankruptcies, disputes, cost and time overruns (Rows, 2009). The construction Financial Management Association in a recent study has reported approximately 70% of general contractors have mentioned fluctuations in material prices as the main project risk (2012). The construction industry, particularly highway construction is an energy intensive economic sector. Therefore, even in a stable construction material market, the dynamics of other market elements such as oil prices cause unexpected fluctuations in the material market. For instance, about a 4 % increase in the price of asphalt cement is usually considered within normal range; however, over the past decade industry has experienced very often price jumps as high as 60% (Zhou, 2014).

Although a number of strategies have been used by the construction industry to deal with material price volatility, still the impacts of various project factors such as project risk, project cost, and project duration are not clear for parties involved in the contract (i.e. owner, contractor). Due to limited knowledge, in many cases companies fail to select an adequate approach to better manage volatilities of material prices. Therefore, it is imperative for the industry to have access to a systematic approach that will allow for decision-making at a broader level while it includes all the possible price volatility management strategies and relevant project criteria (such as total project duration or total number of claims).

In this study, a selection model based on Analytic Hierarchy Process (AHP) is used to consider both price volatility management strategies and project criteria concurrently. The AHP methodology applies objective mathematical model in order to formalize the knowledge of an expert panel. This study intends to provide a decision making support system, as well as a practical guideline to help various parties to make consistent, logical decisions. The objective of this study is twofold: 1) document current strategies and criteria used by contractors and owners to manage material price volatilities, based on an extensive literature review and industry experts' interviews; 2) prioritize price volatility management strategies with respect to a number of criteria, using AHP as a selection tool. Lessons learned from this study are discussed and used to propose practical guidelines to deal with price volatility.

II. Management Strategies for Price Volatility

The lack of a plan to manage the risk of material price volatility, typically leads to price speculations or exaggerated premiums that contractors add to the bid prices to cover their risks. Furthermore, it could be the source of other problems, like cost escalation, schedule delays, disputes and material shortages (Skolnik 2011). This section discusses the most common strategies that are currently used in the construction industry or have been

1 Senior Quantitative Expert (Ph.D.), A2F Consulting, Bethesda, MD. ajoukar@a2f-c.com
2 Associate Professor, Department of Mechanical and Industrial Engineering, Louisiana State University, nahmens@lsu.edu
3 Professor, Department of Mechanical and Industrial Engineering, Louisiana State University, harvey@lsu.edu

Korea Institute of Construction Engineering and Management

proposed in previous studies as viable options in order to deal with this issue.

A. Price Adjustment Clauses (PAC):

Price adjustment clauses (PAC) are usually provided for specific items in construction projects contracts (e.g. fuel price in highway projects contracts, steel price for commercial construction projects). The specification of the clauses usually varies depending on the amount of material required, total duration of the contract or type of the material. By including PAC in the contract, the owner promises an adjustment to or from the contracting parties contingent on the direction of the price change either inclusively or exclusively (Brown and Randolph 2011; Kosmopoulou and Zhou 2014). The inclusive PAC allows for the entire price difference while the exclusive PAC allows only for the partial price adjustment.

Many PACs require floor (trigger) and ceiling value (cap). Adversaries of this strategy claim that these kinds of price adjustments define new extra role of insurer for the owners and provides protection and support to less productive firms (Kosmopoulou and Zhou 2014). They also emphasize the role of a trigger value as a tool in support of owners. There have been a few systematic studies on how motivations and bidding behavior of contracting parties are influenced due to these price adjustment policies or how this strategy influences projects with respect to other projects' factors such as cost and duration (Brown and Randolph 2011; Kosmopoulou and Zhou 2014).

Historically, highway construction sector has been the first sector to notice the importance of minimizing the effects of price volatilities (Pierce et al. 2012), mainly due to intensive use of fuel in this industry. However, the requirement for price adjustment clauses in 80s and 90s had been very strict, and it has been limited to specific projects under certain conditions. Eckert and Eger III (2005) highlighted that using PAC helps smaller contractors to compete against larger companies and enables them to submit their bids. They also noted that using PAC may reduce legal fees due to litigation arising from severe price changes in a project. This view is also supported by Kosmopoulou and Zhou (2014). Using a six-year data set provided by the Oklahoma Department of Transportation, they evaluated the price adjustment clauses for the specific fuel based items and its potential effects on bidding behaviors of contractors. They concluded that the bidding became more competitive after the implementation of the PAC policies, as well as decreasing the risk of price uncertainties for contractors. However, they emphasized the trigger value as the most critical factor in the success of this policy. Similarly, Zhou (2011) notes that in the absence of such clauses most likely contractors inflate their bid prices to the point that it might cost owners even more than the actual cost escalation amount. Since the true direction of price changes is not determined, it might pose owners who do not adopt this strategy to an even higher risk.

The results of a study by the National Cooperative Highway Research Program (2012) indicated that using similar clauses are moderately positive. The report revealed that, while this mechanism could be effective for certain materials (i.e. asphalt and fuel); it cannot provide a reliable way for dealing with price volatilities for other construction materials like steel and concrete; mainly because of the large number of such products are manufactured. Application of aggregate indices like Constructing Cost Index (CCI), Building Construction Index (BCI) or multiple price indices could help to manage this problem (Pierce et al. 2012). The report also lists some benefits of PAC including "positive effect on bid prices, number of bidders, market stability and supply chain". Nevertheless, the study points out that there is not enough evidence showing that contractors tend to withdraw their bids in absence of PAC. Furthermore, the report recommended the use of PAC for only projects that last longer than six months. Interestingly the study did not recommend the use of a trigger value in the use of PAC. Whereas other studies' focus is on the trigger value as a critical element of such clauses (Pierce et al. 2012; Zhou and Damnjanovic 2011).

B. Alternative Project Delivery Methods:

In regard to alternative project delivery methods with respect to price volatility in highway construction projects, Lean Project Delivery (LPD) and Project Fast Track methods have been explored in previous studies (Smith et al. 2011; Weidman et al. 2011). LPD emerged in 2000 from abstract and applied information (Ballard 2008). It encourages all the parties involved in the construction project to behave as a team for the success of the project and it involves tactics that construct on the relational principles (Forbes and Ahmed 2010). According to the Lean Construction Institute, LPD decreases the risk in projects of long duration, high uncertainty and complexity. If an unexpected price spike occurs down the road, for the sake of the project, parties are willing to share the consequences instead of trying to shift it entirely toward each other. Furthermore, IPD (Integrated Project Delivery) methods enhance the communication among the project players, which helps to control the amount of fluctuation in certain situations. The IPD is one type of relational contract. According to Forbes and Ahmed (2010), IPD is a relational contracting approach that aligns project objectives with the interests of key participants. It creates an organization able to apply the principles and practices of the LPD system.

Smith et al. (2011) and Weidman et al. (2010) in separate studies interviewed commercial and residential contractors in the state of Utah regarding the effectiveness of the Integrated Project Delivery (IPD) which is a subset of LPD in managing material price volatility. The results suggest that contractors overall have positive attitude toward using IPD as a systematic way to deal with variety of risks including material price volatility in construction projects. However, the majority of participants mentioned that LPD is a new concept to the construction industry, and it requires cultural changes for its successful implementation. Using LPD, several studies have addressed different factors including: many different aspects of projects (Ballard and Howell 2003); scheduling and total duration of construction projects (Khanzode et al. 2005); numbers of disputes throughout a project (Lichtig 2006); logistic and supply chain of a construction project (Thomas et al. 2004); total cost of a project (Ballard 2008); and safety and productivity (Nahmens and Ikuma 2009). Although none of these studies addressed the specific case of price volatility and potential impact of LPD on long-term projects. However, a major theme emerged from reviewing the current literature on LPD. LPD can act as an independent strategy of managing material price volatility, as well as a promising platform on which other price volatility management strategies could be conducted with lower risk and essentially with higher influence.

Project fast tracking is another delivery method that reduces the possibility of price fluctuations by minimizing project duration (Allen and Iano, 2013). In fast track, construction of the project starts while the design phase of the project still is in progress. This method can be utilized in manufacturing built construction to achieve the ultimate pace (Kasim et al. 2005). Similar to IPD, project fast tracking requires high communication and collaboration of the parties involved in the project for the successful implementation.

C. Price Cap Contract

Typically, contractors buy a certain amount of materials every year. Price cap agreements provide the contractors with the opportunity to place a cap on the price of construction materials (Ng et al., 2004). The price cap option allows contractors to minimize their inventory cost, as well as the risk of price volatility, while it helps suppliers to retain their market share and smooth their production schedule (Weidman et al. 2011). Price cap contract for material procurement essentially is similar to "call option" in financial markets. A call option is a financial contract between two parties in which the buyer of the "call option" has the "right but not the obligation to buy an agreed quantity of a particular commodity or financial instrument from the seller. On the other hand, seller is obligated to sell the commodity or financial instrument to the buyer if the buyer decides. The buyer pays the fee for this premium" (O'Sullivan and Sheffrin 2007). Apparently, this option stresses on long run agreements between buyer and seller and relationships become significantly vital.

Ng et al. (2004) compared the cost of long-term contract with a price cap to spot purchases in the construction material market. They attempted to quantify the savings that contractors can achieve by entering into a long-term material contract with a price cap rather than making spot purchases. They concluded using this approach that while suppliers benefit from steady demand and long term contracts, it secures contractors from the price volatilities and reduce the contingency value of the contract. Similarly, Weidman et al. (2011) suggested price cap contract as one of the approaches that commercial construction industry can utilize to manage price fluctuations. However, the result of their study did not demonstrate the broad adoption of this strategy in commercial construction market. Dong and Chiara (2010) in their study, highlighted the role of price cap contracts and real options as a risk management device for risk mitigation in infrastructure projects.

D. Contingency

Contingency in cost estimation entails items such as minor price fluctuations or changes within the scope (Upp 2010), and it is generally determined either by expert judgment or stochastic methods. Recently due to increase of price volatility, many contractors rely on a contingency plan to deal with volatile prices, particularly for contracts without PAC (Zhou 2011). It is discussed that in fixed price contracts, contractors include large contingencies in their initial estimate in order to cover changes in prices and hedge against the risk exposures. On the other hand, it is also argued that if contractors overestimate the contingency amount, the prices of fixed price contracts could go above those contracts with adjustment clauses. Farid and Boyer (1985) introduced the Fair and Reasonable Markup (FaRM) pricing model in fixed contracts, in particular in commercial projects. FaRM is the smallest fee that fulfills the required rate of return based upon minimum acceptable price for the contract. The study noted that the FaRM pricing model could provide contracts with a substitute method for subjective estimation of contingencies. However, this approach has not gained in popularity in commercial construction (Smith et al. 2011).

In order to eliminate the subjectivity from the contingency calculation, using quantitative methods such as Monte Carlo simulation, regression analysis, time series techniques and Artificial Neural Network have been proposed (sources). Nevertheless, in practice this number is most likely subjectively determined based on past experience. Some shortcomings of using contingency to deal with material price volatility are: 1) full reliance of this method on estimator, 2) double counting risk, in particular in projects with various subcontractors, any of them include contingencies and premiums in their calculation, and 3) not providing any confidence interval for the results (Chapman 2001; Smith et al. 2011; and Zou et al. 2009).

E. Risk Management Methods

Risk Management methods refer to utilizing either quantitative or qualitative techniques in order to assess and measure the risk that is associated with the material price fluctuations in highway construction projects. Examples of quantitative methods include forecasting and modeling future trends of the market and cost indexes using statistical modeling. Both modern methods, such as time series analysis, Neural Networks and conventional ones, like Multiple Regression analysis and Monte Carlo simulation have been widely used (Ashouri and Lu 2010; Hwang 2009; Joukar and Nahmens 2015; Wilmot and Cheng 2003; Xu and Moon 2013).

Qualitative techniques of risk management, however, remain mostly subjective to experts' opinions, as well as using confidence indexes that have been developed by the construction news agencies and associations such as

Associated Builders and Contractors and Engineering News Records.

Risk management methods not only provide cost estimators with more accurate estimates of the probable cost of the projects, but it also helps them in making other critical decisions. Decisions include managing price volatility such as estimation of contingency amount, need for stockpiling materials in advance, selection of the desired method of project delivery, inclusion of any particular clause in the contract language and etc (Mehdizadeh 2012; Touran and Lopez 2006). It is worth mentioning that although risk management methods cover a broad range of both quantitative and qualitative methods, the primary attention of this paper under this category is toward the common quantitative methods applied in practice and theory as there is a well-established literature on quantitative measures and applications of risk management (Ashouri and Lu 2010; Hwang 2009; Joukar and Nahmens 2015; Wilmot and Cheng 2003; Xu and Moon 2013).

F. Other practices

In addition to strategies previously mentioned for managing material price volatility, there are a few other simple, yet effective alternatives that can be found in previous studies. Pierce et al. (2012) noted that many highway agencies break the projects into smaller pieces or into smaller phases in order to limit the time and scope of the project and minimize the risks of price uncertainties and material shortages; particularly, in more complex projects. Another strategy documented in the literature is considering alternative designs with respect to material prices and availability for minimizing the effects of price spikes (Skolnik 2011).

Early material procurement method is another way of dealing with price volatilities. With these method materials are purchased upon approval of the project or at least those materials that are most susceptible to price fluctuations are purchased. In this scenario contractors attempt to either separate the volatile price material from the rest of the job and they place the order within the hour of signing the contract (Koushki et al. 2005; Moore 2008). The major concern with this method is the potential for dispute between the owner and the contractor over where to store the materials or the cost of warehouse space for stockpiling of materials. However, typically owners are willing to come up with some policies to pay for contractors to stockpile the materials as a way to manage the risk of price volatilities (Smith et al. 2011). The second issue related to this strategy is the risk of theft and overall risk of material management.

III. ANALYTIC HIERARCHY PROCESS (AHP) APPLICATIONS IN THE CONSTRUCTION INDUSTRY

Various methods of dealing with material price volatility have been proposed or practiced over the past few years (Weidman et al. 2011). Nevertheless, each of which has upsides and downsides with respect to different criteria or projects' factors. For instance, although PAC has gained recent popularity, the downside is that the entire risk is transferred to the owner, and in projects with long duration this could be significant. Moreover, these types of clauses usually cannot be applied to any contract or any material. On the other hand, the method is accurate and potentially minimizes the number of disputes over the course of a construction project. In this case or many similar decision-making situations, the final decision is dependent on the assessment of a number of alternatives (solutions) with respect to a number of tangible or intangible criteria. This decision-making problem is referred to as Multi Attribute Decision Making problem (MADM). Analytic Hierarchy Process (AHP) is a method that provides a systematic approach for making the best-informed decision in such complex problems. Since AHP introduction (Saaty 1977), it has been widely used by many researchers in different areas like manufacturing, construction, computer science, data science, engineering, and management (Al-Harbi 2001; Anderson et al. 2010; Dey 2010; Hsu and Pan 2009). This section provides a brief review on previous application of AHP in process of decision making in the construction industry.

Mustafa and Al-Bahar (1991) conducted one of the first studies using AHP in the field of project risk management. The study underlined the potential benefit of AHP in the construction industry, where presence of various qualitative factors makes it hard for the construction entities to make systematic and formalized decisions. In another study, Al-Harbi (2001) addressed the problem of selecting the best contractor among bidders. The study also highlights the ability of performing sensitivity analysis within the AHP method. Shapira and Goldenberg (2005) established an AHP model for construction equipment selection. Their study first points out that previous methods in selecting an appropriate construction equipment could not address all influential factors properly due to lack of considering soft factors.

An et al., (2007) used the AHP methodology along with Case Based Reasoning (CBR) model in order to include experience in all processes of cost estimating for construction projects, particularly in determining the important weights of criteria in the CBR model. The study noted that AHP is a reliable tool for measuring experience. Similarly, Dey (2010) by integration of AHP and risk map developed a framework for risk management of projects. In a very recent study, Li and Zou (2012) applied fuzzy AHP in a unique case of public private partnership infrastructure projects like motorways, bridges, tunnels and railways for risk identification and assessment with respect to project life cycle.

Surprisingly, just during the past two years AHP has drawn increased attention of researchers and practitioners in the construction industry. Aminbakhsh et al. (2013) used AHP in ranking of safety risks in construction projects. Janackovic et al. (2013) applied fuzzy AHP for ranking the indicators of occupational safety throughout a case study in road construction companies and supported the results of Aminbakhsh et al. (2013). Liu et al. (2011) and

Hosseinijou et al. (2014) used a combination of AHP and fuzzy theory in order to create an evaluation system of concrete pavement and material selection. Zhang-yin and Sheng-hui (2013) as well as Whang and Kim (2014) used AHP in the context of sustainable design management.

Collectively, these studies outline a critical role for AHP in construction management, particularly areas that require integrating soft factors and personal experience into the problem. This study, intends to introduce the application of AHP to another critical area, in which the construction industry is also struggling - material price volatility.

IV. METHODOLOGY

This study intends to provide a decision-making guideline to help various parties to make consistent, logical decisions for mitigating the risk of material price volatility. The objective of this study is twofold: 1) document current strategies and criteria used by contractors and owners to manage material price volatilities; and, 2) prioritize price volatility management strategies with respect to a number of criteria. These two objectives account for two major phases in this paper.

Phase one is completed through a comprehensive literature review, as well as semi structured interviews with a panel of experts. In fact, this phase comprises of information gathering and generation of feasible alternatives. A panel of seven transportation builders' experts was used for both phases of this study. Experts were selected carefully from the major players in highway construction projects within the state of Louisiana: contractors, Louisiana Department of Transportation Engineers and material suppliers. The industry experts were selected based on the years in the industry (minimum 10 years) and they also had to be active in the highway construction industry at the time of the interview. Also it is worthwhile to note that the reliability of results at either phase is not dependent on the quantity of sample size, but its quality (Saaty and Vargas, 2012). Two separate meetings with each member of the panel were held.

The first round of meetings is dedicated to phase 1. It primarily consisted of brainstorming and generating an exhaustive list of the alternative price volatility management strategies and project criteria in any large highway construction project, discussing all the alternative strategies and criteria that have already been found in the literature, and their advantages and disadvantages. As it was noted, criteria in this study can be considered as project performance indicators such as cost, time and duration. In the context of material price volatility, various criteria can be considered by parties to evaluate the performance of any potential strategy. Impact of a strategy on total project cost, total project duration or the performance of a strategy in terms of risk allocation, chance of dispute arising, accuracy, and institutional barriers to implement the strategy are some instances of these criteria. The second round of meetings was allocated to the AHP process which comprised phase two of this research. This study used Expert Choice 11 software for conducting AHP analysis. The following section briefly reviews AHP concepts and its methodology. However, readers could refer to Saaty (1981); Saaty (2003); Saaty and Vargas (2012) for more detailed information.

V. ANALYTIC HIERARCH PROCESS (AHP)

The AHP takes advantage of the psychological fact that, an individual is typically good and rational at pairwise comparisons. Therefore, AHP essentially offers a framework in which making simple pairwise comparisons enable decision makers to overcome the entire problem. As outlined in the Figure 1, the AHP methodology comprises three major steps.

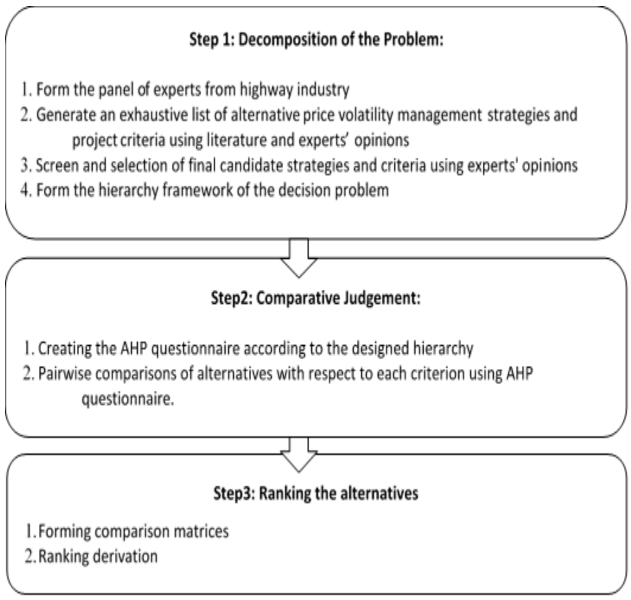

FIGURE I
Tailored AHP Methodology (reference)

Step 1 is decomposition of the problem. Outputs from phase one provided major inputs to this step. Round two meetings with the panel of experts starts with the screening process and creating the hierarchy structure of the decision problem. Out of a total of ten following identified strategies,

i. Price Adjustment Clauses
ii. Integrated Project Delivery Methods (IPD)
iii. Price Cap Contracts
iv. Quantitative Risk Management methods
v. Fast Track
vi. Information & Communication Technology
vii. Contingency & risk premium
viii. Early material procurement
ix. Break the project into smaller pieces
x. Consulting with market expert

four strategies ultimately were selected as the final candidates for AHP analysis based on their effectiveness, current popularity, future perspective of the industry, and experts' personal experience. These four strategies were: 1- Price Adjustment Clauses (PAC), 2- Integrated Project Delivery methods (IPD), 3- Price Cap Contracts, and 4- Quantitative Risk Management methods. Furthermore, three criteria of 1-project total cost, 2-risk allocation and liability sharing, and 3-project duration were selected by the panel of experts with which strategies will be compared. These project criteria were considered as the top three performance indicators in highway construction projects by the panel of experts.

Project cost refers to expense incurred by a contractor for labor, material, equipment, financing, services, utilities, etc., plus overheads and contractor's profit. Costs such as that of land, architectural design, consultant and engineer's fee are not relevant in this context. Project duration refers to the time required to complete all activities associated with the construction processes of a project. Finally, Risk allocation and liability sharing refers to the degree to which a strategy is fair in sharing the price volatility risk between various project parties involved in a construction contract; particularly between contractor and owner.

Figure 2 illustrates the hierarchy structure of the decision problem. Consequently, The AHP questionnaires was completed and pairwise comparisons were made (step 2). Step 3 (Figure 1) entailed making the final analysis and actual ranking of the alternatives with respect to each criterion.

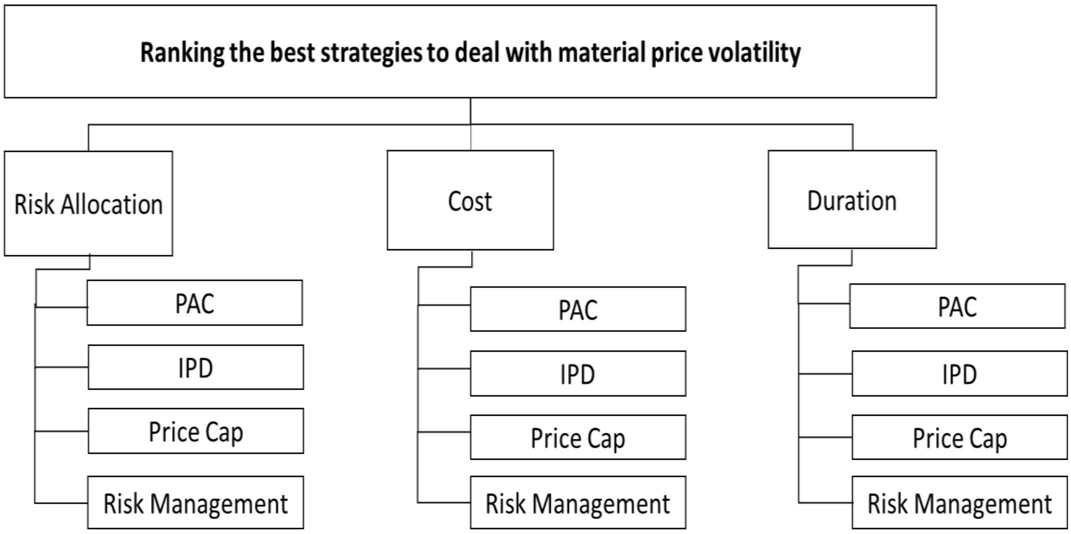

FIGURE II
Hierarchy of project criteria and risk management strategies

A. The theoretical background of AHP:

Once the hierarchy structure of the decision making problem is mapped, step 3 (Figure 1) begins. It first starts by comparing criteria in pairs, and then it continues by comparing alternatives in pairs with respect to each criterion. The pairwise comparison is done using the AHP standard numerical scale presented in Table 1. Results are recorded for each set in a separate matrix which is referred to as "decision matrix" denoted by DM (1). Since there are 3 criteria and four alternatives, a total of four decision matrices must be filled out by each expert. The term a_{ij} in DM (equation 1) expresses an expert's preference of strategy A to B according to the scale presented in Table 1. a_{ij} is reciprocal of a_{ji}.

$$DM = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \qquad (1)$$

Each entry of the matrix DM determines two major facts regarding each criterion or alternative in comparison with another one: 1- which one is more important, 2-the importance intensity of that comparison.

TABLE I
The standard numerical and verbal scale for pairwise comparisons in AHP

Value of the entry	Interpretation (verbal intensity)
1	***Equal*** importance of two alternatives
3	One alternative is ***slightly*** more important than another one
5	One alternative is more ***important*** than another one
7	One alternative is ***strongly*** more important than another one
9	One alternative is ***absolutely*** more important than another one
2, 4, 6, 8	These are intermediate scales between two adjacent judgements
Reciprocals (1/x)	A value attributed when alternative A is compared to alternative B, becomes the reciprocal when B is compared to A

After forming decision matrices, each element of the decision matrix is normalized across its column (i.e. = $\frac{\alpha_{ij}}{\sum_{k=1}^{n}\alpha_{kj}}$, n=numbers of columns which are equal to number of strategies) producing the Normalized Column Matrix (NCM), and then the average of each row for the NCM is calculated. Taking averages across NCM rows according to equation two is the most popular way to estimate the eigenvector of a decision matrix which is referred to as weight vector for criteria ($\vec{\omega}$), and local priority vector for alternatives ($\vec{\beta}$). Saaty's core theory states that the eigenvectors of the decision matrices are the priority vectors.

$$\omega_i = \frac{1}{n}\sum_{k=0}^{n}\frac{\alpha_{ij}}{\sum_{k=1}^{n}\alpha_{kj}} \qquad (2)$$

Once vector of $\vec{\boldsymbol{\omega}}$ for criteria, as well as alternatives ($\vec{\boldsymbol{\beta}}$) are calculated, the global score of each alternative which indicates the overall ranking of one strategy is obtained. This aggregation is achieved by multiplying local priority vectors by the relative weights of the respective criteria ($\vec{\boldsymbol{\omega}} * \vec{\boldsymbol{\beta}}$).

Consistency Index (CI) which is calculated according to equation 3 is a tool for handling the consistency of pairwise comparisons. Although the absolute consistency should not be expected, researchers must be able to control the inconsistency to some certain extent. The acceptable range for the CI is equal or less than 0.10 (Saaty and Vargas, 2012). If this condition is not met, revisions of the comparisons are suggested. λ_{max} is the maximum eigenvalue of matrix D.

$$\text{Consistency Index (CI)} : \frac{\lambda_{max}-n}{n-1} \qquad (3)$$

VI. Results

The first objective of the current study was to document strategies on which the construction industry could rely to manage price volatility. Through literature review and interviews with panel of experts, a total of 10 strategies were collected. Table 2 list these strategies, as well as their advantages and disadvantages.

TABLE II
List of alternative strategies and their advantages and disadvantages

Strategies	Advantages	Disadvantages
PAC	• Increase the competition among the contractors • Enable small contractors to compete. • High accuracy • Minimize the chance of arising disputes due to material price volatility	• Owner plays the role of insurer • Cannot be applied to any contract • Cannot be applied to any material • It is popular with contractors during periods of escalation but not during periods of price drops.
LPD	• Sharing the entire risk of the project among contracting parties • Positive impacts on other aspects of the project	• Requires mutual trust and cultural requirements • Not applicable to all kinds of projects
Fast Track	• Save time • Facilitate some other strategies such as early material procurement • Increases the accuracy of some other methods due to shortening the project duration	• Increase the chance of design revision and change orders • Quality concerns • Cost concerns
Price Cap	• Decrease the price uncertainty for contractors • Provide steady demand and market share for material supplier • Reduce the waste • Provide operating flexibility for buyers including minimizing inventory cost	• Requires long-term relationship between contractor and material supplier • Not suitable for complex projects with very long durations.
ICT	• Provide comprehensive tools for all aspects of construction management including cost and price volatility. • Save time • Provide information and eliminate the middle men.	• Not directly address the material price volatility. • Not adequate in the case of price spikes. • Depends on other factors such as training

Contingency	• Easy implementation • Applicable in long term projects	• Subject to personal opinions, usually estimator • It does not manage / mitigate the risk but it allocates money to it • Double counting the risk
Quantitative risk management	• High accuracy • High variety of methods and techniques • Provide confidence interval for estimation.	• Difficult implementations • Lower accuracy in long-term projects.
Qualitative risk management	• Easy implementation • Applicable in long-term projects. • Using qualitative indexes produced by prominent agencies increases accuracy and consistency of these methods.	• Subject to expert's opinions
Early material procurement	• It is cost effective	• Dispute over the warehouse rent • Safety concerns • Not feasible in more complex projects • Not feasible for some materials in highway construction such as asphalt
Breaking the project into smaller phases	• Facilitates some other strategies such as early material procurement • Increases the accuracy of other methods due to shortening the duration of the project	• Not feasible in many projects, most of the projects are best handled as a single project • Project duration concerns in public projects • Coordination and communication concerns • It cuts back on large scale savings

The second objective of this study was to prioritize price volatility management strategies with respect to the most important criteria of highway construction projects. Out of 10 strategies identified in phase 1 of this study, the panel of experts selected the top four. In addition, cost, duration, and risk allocation were selected as the top projects' criteria.

The first pairwise comparisons were made among the criteria to determine their relative importance in the overall decision making frame.

TABLE ICriteria weight vector and its CI

Criteria	Weight vector ($\vec{\omega}$)
Cost	0.435
Duration	0.236
Risk allocation	0.329
CI	0.01

Table 3 summarizes the final weights, as well as the Consistency Index (CI) obtained at this level. These weights represent marginal contributions or importance. The higher the weight, the more important the corresponding criterion. Project cost was perceived as the most significant criterion (0.435), followed by the risk allocation and liability sharing (0.329), and project duration (0.236). The CI calculated for the entire participants at this level is 0.01, which is well below the threshold of 0.10

Next, pairwise comparisons were made between the four identified strategies with respect to the three project criteria. Six pairwise comparisons for each combination. These are called local comparisons that from which eigenvectors or so-called local priority vectors are extracted. The first three columns of Table 4 summarizes the local priority vectors obtained from pairwise comparisons for each criterion $\overrightarrow{(\beta_1)}$. Also the numbers in the last row are CIs for each set which are well below 0.10.

TABLE IV
Local priority vectors for alternatives with respect to each project's criterion and global rankings

	Local priorities (eigenvectors)			Global priorities ($\vec{\omega} * \vec{\beta}$)
	Cost $\overrightarrow{(\beta_1)}$	Duration$\overrightarrow{(\beta_2)}$	Risk allocation$\overrightarrow{(\beta_3)}$	
Risk Management	0.45	0.32	0.24	0.337
PAC	0.30	0.15	0.44	0.311
IPD	0.20	0.46	0.27	0.280
Price Cap	0.05	0.07	0.05	0.078
Consistency Ratio	0.03	0.057	0.07	0.045

Final evaluation of the pairwise comparisons indicates that with respect to project cost, which was recognized as the most important criterion of our decision making model, the highest priority strategy was quantitative risk management methods (0.45), followed by the PAC (0.30), IPD (0.20) and price cap (0.05). With respect to risk allocation and liability sharing, PAC ranked number one strategy (0.44) to deal with material price volatility followed by the IPD (0.27), risk management (0.24) and price cap (0.07).

Finally, with respect to duration; experts gave their highest priority to IPD (0.46). Risk management methods was selected as the second most important alternative (0.32), followed by the PAC (0.15) and price cap (0.07).

Moreover, AHP can aggregate the local rankings across all criteria to determine the global rankings by multiplying $\vec{\omega}$ and $\vec{\beta}$. The last column of Table 4 shows the global strategies' rankings. Risk management gained the first place (0.337), PAC the second place (0.311), IPD (0.280) and Price cap (0.078) the third and fourth places respectively. Also, the overall CI is 0.045 which is within acceptable range.

A sensitivity analysis was also conducted to help with the uncertainty surrounding the decisions. In order to determine the sensitivity of the experts' responses, the criteria percentage ranking was altered slightly to observe any changes in the strategies' rankings. For instance, if we increase the percentage weight of cost by 10%, from 43.5 % to 53.5 %, no changes will occur in the ranking of the priorities. Overall, by increasing the priority percentage of the cost, no changes will occur in ranking of alternative strategies. However, if we decrease the relative weight of the cost, risk and liability sharing will replace the cost as the most important criterion of the decision making model. This change will influence the overall rankings. In the new scenario PAC will gain the highest priority among the four candidate strategy. As it was shown in Table 4, final scores for these two strategies in overall rankings have been very close. Therefore, by reducing the weight of cost, PAC immediately replaces the risk management methods as the number one strategy in dealing with material price volatility. Furthermore, if we increase the importance (weight) of the criterion of project duration which is the last one in original ranking, IPD will be the number one strategy to manage material price volatility.

VII. Conclusions and Discussions

Material price volatility has become one of the major risks in highway construction projects mostly because of its dependence on energy prices and other macroeconomic factors. This study for the first time aimed to document and rank all the strategies that have been used or proposed to manage material price volatility. According to the results, quantitative risk management methods due to their high accuracy outweigh other strategies when total cost of the project is the primary concern. Systematic quantitative risk management methods are more prevalent in the

Figure 3 consolidates the results of this study in a decision tree, which is further integrated in a decision-making guideline to help various parties to make consistent, logical decisions for mitigating the risk of material price volatility in highway construction projects.

highway projects, while Weidman et al. (2011) noted that in the residential and commercial projects subjective price speculation is a more common practice. Also, in terms of project cost, PAC showed the satisfactory performance, mainly because it helps contractors to reduce the contingency portion that is related to price volatility.

With respect to the risk allocation and liability sharing, PAC was selected as the best strategy. Although some studies had noted that Price Adjustment Clauses transfer the entire risk of price volatility to the owners (Brown and Randolph 2011; Kosmopoulou and Zhou 2014), the panel of experts in this study unanimously believed that owners have control tools such as setting trigger values and imposing ceiling values (cap) to utilize PAC in a way that each party be exposed to a fair share of risk as it pertains to price volatility. IPD was regarded as the second best strategy to address material price volatility when risk allocation is performance indicator. It was underlined that IPD covers broader range of issues and it is not applicable to all types of projects. However, in terms of the project duration, IPD was selected unanimously as the number one strategy that has significant impact on duration of the projects. Similarly, Smith et al. (2011) had noted the role of "communication" between contractors and suppliers in residential and commercial construction projects in dealing with the risk of price volatility.

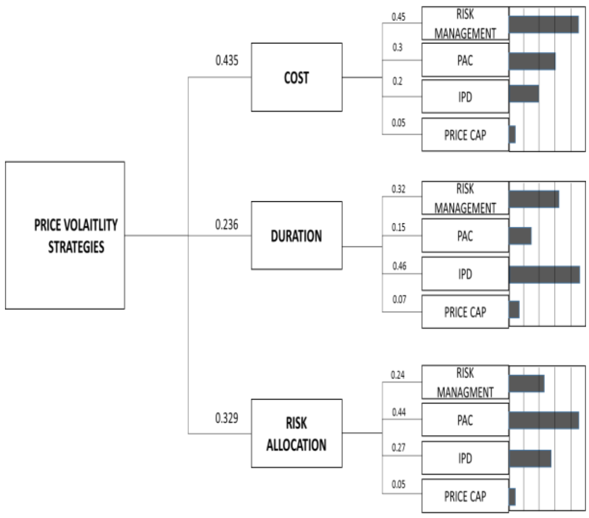

FIGURE III
Weighted decision tree with criteria, alternatives and allocated weights

The ranking produced in this paper is the starting foundation knowledge and guidance on how each of these methods of managing price volatility could be more preferable in different situations where one or two criteria may have higher relative importance. The results surely could vary in different scenarios in different projects with different priorities. Contracting parties in highway construction projects not only can directly benefit from the results of this study, but also they can utilize the AHP methodology as a platform in their own customized way in highway construction projects using strategies and criteria discussed in order to gain early insight and better understanding regarding feasible alternative strategies and project's criteria in terms of price volatility management. AHP methodology takes advantage of both subjective ideas of experts and objective rigorous mathematical modeling at the same time. Therefore, it is able to handle both simple and complicated models along with various options for post analyzing the critical elements of the decision. This paper focuses on constructing a simple, straightforward and systematic selection method for cost estimators and risk managers by including the top four risk management strategies and the top three project criteria. Adding more complexities such as increasing the numbers of criteria and sub levels for alternatives, replicating the study in other geographical regions, as well as considering other selection strategies such as Delphi methodology could be the next steps for future researchers interested in this field.

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