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Green Performance Bond: Managing Greenhouse Gas (GHG) Emissions in Construction Projects

Xinyi Song[1], Tao Wang[2], Tianyi Nie,[3] & Xuan Guo[4]

Abstract

With growing concern about global warming and climate change, the construction industry, as a major contributor to greenhouse gas (GHG) emissions, has begun to realize its essential role in improving the environment by reducing emissions through the life cycle of buildings and infrastructures. While a considerable amount of prior research has been devoted to assess the environmental impacts of sustainable design alternatives and post-construction operations, there is an increased awareness of, and demand for managing greenhouse gas (GHG) emissions during the building process. One approach suggested by previous researchers is to adopt an innovative competitive bidding system called A+B+C which includes the estimated environmental cost incurred during the construction phase as one of the evaluation criteria in addition to cost and schedule. The main problem with this practice, however, is that there are no enforcement mechanisms to evaluate and guarantee the actual performance of GHG emissions control, as compared to project schedule and quality. As a result, it may induce contractor's opportunistic bidding behavior which could lead to many issues such as abnormal low bids and poor environmental performance. To address this problem, this research proposed a framework which adds another dimension to the traditional project management structure and investigates the possibility of applying a green performance bond to insure against the risk of discrepancy between the actual and expected GHG emissions during construction. Drawing an analogy from the construction performance bond, a conceptual model is presented to illustrate how to utilize this innovative surety product, along with the A+B+C bidding method, to manage embodied carbon in the building process. The result shows that from the owner's perspective, it is a way to encourage contractors to improve their environmental performance through financial means.

Keywords: Green Performance; Construction Projects; Bond; Greenhouse Gas; Emissions

[1] Assistant Professor, School of Building Construction, Georgia Institute of Technology, 280 Ferst Dr., Atlanta, GA, 30308, USA.E-mail: xinyi.song@coa.gatech.edu, Phone: 404-894-7102

[2]Lecturer, School of Management Science and Engineering, Central University of Finance and Economics, No.39, South College Road, Haidian District,Beijing, 100081, China. E-mail: wangtaothu@163.com, Phone: 0086-13811180036

[3] Research Assistant, School of Management Science and Engineering, Central University of Finance and Economics, Beijing, 100081, China. E-mail:13240334462@163.com, Phone: 0086-13240334462

[4] Research Assistant, School of Management Science and Engineering, Central University of Finance and Economics, Beijing, 100081, China. E-mail:719676520@qq.com, Phone: 0086-13269350321

1. Introduction

Burdened with a stressed budget and tight schedule, most development in the construction industry in the past decades was mainly guided by short-term economic considerations (Singh 2007). However, the imperative is a strong focus to deal with the pressing issues of sustainability such as carbon footprint at each stage of a building's life cycle. While it is difficult to determine the extent of climate change driven by the Greenhouse Gas (GHG) effect, there is little scientific debate on the fact that the global concentration of carbon dioxide in the atmosphere has far exceeded its natural range (EIA 2004), presenting itself as one of the most significant risks that could lead to serious social and economic consequences (Epstein 2000, McMichael et al. 2003, IPCC 2007, ISO 2007). Since 1997, various efforts have been made to catalyze upon global action to curb GHG emissions and promote sustainability (Cui and Zhu 2011).

In response to other industries that strive to improve their environmental performance, the construction community has recently begun to realize its leadership role in promoting environmental stewardship. While a considerable amount of prior research has been devoted to assess the environmental impacts of sustainable design alternatives and post-construction operations (Vale and Vale 1996, Guggemos and Horvath 2006, Peschiera et al. 2010), there is an increased awareness of, and demand for managing greenhouse gas (GHG) emissions during the construction phase. According to the EPA (2009b), the construction industry produced approximately 1.7% of the total U.S. GHG emissions in 2002, placing itself as the third highest GHG emitting sector. Although a single construction activity does not produce as much GHGs as the operations of other industries such as chemical or steel manufacturing, the sheer number of construction projects results in a significant amount of aggregate emissions (EPA 2009b). Further projections illustrate that among seven industrial sectors, the construction industry is predicted to have the highest average annual rate of increase in GHG emissions from 2011 through 2030 (EPA 2009c).

Although there exits great reduction potential in material selection, waste recycling, onsite equipment operation and the adoption of innovative construction methods, the problem with current practices in managing GHG emissions during the construction phase is that existing government regulations and standards for construction emissions are limited to hazardous air pollutants (HAPs), such as CO, NO_x, PM, volatile organic compound (VOC) and SO_2, with no focus on GHGs (Peña–Mora et al 2009), despite the fact that GHGs are also defined as a pollutant under the Clean Air Act, ruled by the U.S. Supreme Court in 2008 (EPA 2009a). As a result, although the government is providing incentives for carbon reduction, there are no enforcement mechanisms to evaluate and guarantee the actual performance of GHG emissions if the contractors consider the reduction measurements to be economically unattractive. On the other hand, even if contractors strive to follow the pre-determined emissions goal, there always exists the risk of "over-emissions" resulting from inefficient construction methods, field rework, and improperly sized equipment, among others. To deal with this unwanted situation, there is a broad agreement that the key policy is to put a price on GHG emissions (CBO 2008).

One example is the popular cap-and-trade policy in Europe and Asia, where each firm in the system is assigned an overall quota, or cap, on the total amount of CO_2 they are allowed to emit. Firms that "over-emit" must purchase an extra quota from those organizations that emit less than their allowance, so as to keep the total amount of emissions in the system to a certain limit (Tietenberg 2003). However, despite the vigorous debate of introducing the cap-and-trade program into the US, there is currently no system in existence. Hence, there is a need to explore other feasible methods on managing GHG emissions during the construction phase.

1. Green Contracting Through Alternative Bidding Methods

Kunzlik (2003) first introduced green contracting which considers the environmental factors into public procurement. Cui and Zhu (2011) further defined green contracting as any strategic consideration in construction contracts which provides economic, ecological, or social benefits to the public. It has been recognized as an innovative strategy to tackle climate change and decrease GHG emissions of construction activities, especially in highway projects (Cui and Zhu 2011). The most common green contracting strategies practiced by public agencies include contract specifications, contract allowances, and bidding preference (ICF 2005, Cui and Zhu 2011). Contract specifications mandates contractors to either use EPA certified construction equipment, replace or upgrade existing engines, use alternative fuelor install diesel emission retrofit devices that achieves pollutant reduction by capturing and/or destroying hazardous particles from diesel engine exhaust(Cui and Zhu 2011, Ahn et al 2012).

While contract specifications is the primary form of green contracting in current practice(Cui and Zhu 2011), the problem, however, is that it may exclude small to mid-sized companies from bidding for green projects because of the relatively expensive upfront investment on equipment upgrade. Thus this approach is not considered socially optimal (ICF 2005). The second strategy is contract allowances. It allows the owner to partially or fully reimburse the contractor's initial investment on green technologies thus provide incentives for the utilization of greener construction equipment. Similar to contract specifications, contract allowances also imposes financial stress on potential bidders.

Finally, applying alternative bidding methods is another green contracting strategy that can create incentives for contractors to identify and quantify construction GHG emissions during the pre-construction phase thus offers an opportunity to implement greener construction practices (Ahn et al 2012). Generally, alternative bidding methods are devised by public owners to overcome the weaknesses in the traditional single-criterion competitive bidding system which tends to award the contract to the lowest cost bidder. This method not only embeds more than one evaluation criterion in the process of contractor selection, but also considers potential rewards and penalties for different project performance (Ellis et al. 2007). Common alternative bidding methods include A+B, incentive/disincentive (I/D), no excuse bonus, and lane rental (TRB 1995, Carr 1994, Herbsman, 1995). Take the A+B method for example. It allows each bidder to bid on the number of days in which the work can be accomplished (the B element), in addition to the construction cost (the A element) (Ellis et al. 2007).

The owner then select the contractor based on the best A+B value instead of awarding the contract to the lowest cost bidder. By utilizing alternative bidding methods, the owners seek to improve project performance by simultaneously minimizing the time and cost of highway construction (El-Rayes2001). Drawing on the successful experience of the A+B method in highway projects (MnDOT 2006; Ellis et al. 2007; Anderson and Damnjanovic 2008), other researchers such as Ahn et al. (2012) suggested an innovative competitive bidding system called A+C method that requires each contractor to bid on not only the total construction cost, the A component, but also the C component, which represents the environmental cost caused by their estimated construction emissions and energy use. The lowest total combined bid, calculated by the following formula (Ahn et al. 2012), will determine the awarding contractor.

$$\text{Bid award cost} = A + C \times \text{weight}$$

Where A is the construction cost and C the estimated environmental cost. C is defined as (Vogtländer et al. 2001):

$$C\ (\text{environmental cost}) = \Sigma\ (\text{emission estimate} \times \text{eco-cost of emission})$$

$$+\Sigma\ (\text{fossil fuel use} \times \text{eco-cost of material depletion})$$

Many techniques have been developed to perform construction emission simulation for emission estimate, such as the special purpose simulation modeling (SPS) (Hajjar and Abou Rizk 1998), discrete-event simulation model (Ahn et al 2010), and interactive simulation during the pre-planning phase (Tang 2012). Eco-cost is a concept introduced by Vogtländer et al. (2001) as the environmental cost of GHG emission generated by construction activities. The weight of the C component is determined by the owner's preference for a green contractor. The purpose of the A+C method is to incorporate environmental impact of construction activities as one of the evaluation criteria in addition to cost and schedule, and use reinforced incentive/disincentive provisions to secure the expected GHG emission performance by contractors.Compared to the other two green contracting strategies, alternative bidding method does not necessarily require upfront investment on equipment purchase or remodeling, but rather encourage all kinds of approaches to reduce GHG emission during the construction phase such as more efficient equipment operation or better supply chain management. Thus it provides a fair level for contractors with different financial capabilities to compete.

2. Problem Statement

As discussed earlier, alternative bidding method can be applied to reduce GHG emission during the construction phase thus promote sustainable construction. However, one challenge is how to guarantee the satisfactory environmental performance by the awarding contractor by managing the risk of discrepancy between the actual and expected GHG emissions during construction.

In another word, how to discourage contractor's opportunistic bidding behaviour on the environmental factor. Ho and Liu (2004) defined opportunistic bidding as *"a contractor's intentional ignorance of possible risks involved that may significantly increase costs or decrease profitability, such as the use of the most optimistic cost estimation for the bid price"*. In A+C bidding, this behaviour can emerge as the inconsistencies between a contractor's GHG emission mitigation plan in the bid and the contractor's actual equipment, staff, and management capability. For example, consider the following illustrative bid tabulation using the A+C bidding method in Table 1.

Table 1: Illustrative bid tabulation using the A+C bidding

Bidder	Construction cost (A) ($)	Bid gap with the lowest ($)	GHG Mitigation plan	Eco-cost ($)	Weighted environmental cost (C) ($)	Total combined bid (A+C) ($)	Bid gap with the lowest ($)
1	11,435,224	36,802	DOC	1,099,733	879,787	**12,315,011**	0
2	11,415,759	17,337	Hybrid Equip. (most likely)	1,175,869	940,695	12,356,454	41,443
3	11,430,070	31,648	SCR+DOC	1,116,652	893,322	12,323,392	8,381
4	**11,398,422**	0	B20	1,166,201	932,960	12,331,382	16,372
2'	**11,415,759**	17,337	Hybrid Equip. (optimistic)	1,123,903	899,123	**12,314,882**	(129)

There are a total of 4 bidders in the final round. Without GHG mitigation plan, contractor 4 is the lowest bid. However the owner decides to adopt the A+C bidding mechanism and include environmental performance as one of the evaluation criteria. Contractor 1's mitigation plan is to use diesel oxidation catalysts (DOC) which reduces the total eco-costs by 0.9% through controlling diesel emissions from construction equipment. Contractor 2 plans to replace the current equipment with hybrid equipment, which in the optimistic scenario reduces the total eco-costs by 7%. However, based on past experience, contractor 2 seldom achieves the optimal equipment operational efficiency. As a result, a most likely savings on eco-cost is by 2.7%.

Contractor 3 has promised to use a selective catalyst reduction (SCR) in addition to diesel oxidation catalysts (DOC) which together reduce the total eco-costs by 7.6%. Contractor 4's mitigation plan includes substitution of biodiesel fuels for petroleum diesel which reduces the total eco-costs by 3.5%. The weight of environmental impact is set at 0.8 by the owner. Adding the mitigation plans, as presented in Table 1, will lead to awarding the project to contractor 1 with the lowest total A+C bid of $12,315,011.

However, if contractor 2 intentionally ignores the risk of “over-emission” resulting from inefficient operation and submits the optimistic estimates of reducing eco-cost by 7%, he or she will be selected for a total bid of $12,314,882 (as shown in the last row of 2’).

The above example shows that even with green contracting method, without a guarantee mechanism, it creates an opportunity for bidders to submit unrealistic GHG mitigation plan whether intentionally or unintentionally just to increase their competitiveness. As a result, there is no way to know if the selected contractor has indeed produced improvement on GHG emission control during the construction phase. Thus, a better solution for this problem is to include a supervisory, preventive mechanism during the bidding process which discourages contractors’ opportunistic behavior and reduces the risk of not achieving the predetermined GHG emission goal.

3. Methodology: Insurance Vs. Surety ship

Surety ship and insurance are two effective risk management mechanisms for construction projects. Song and Peña-Mora (2012) suggested adopting an emission liability insurance to manage GHG emissions by drawing an analogy from the construction professional liability insurance. Professional liability insurance protects policyholders from any financial loss caused by error or omission on the policyholder’s part (Mhyr and Markham 2003). By requiring a mandatory insurance policy on GHG emission, the awarding contractor is charged a premium by the insurance company, and in return, the insurance company compensates the owner for any environmental damage cost determined in the contract should the contractor fail to meet the pre-determined emissions goal. (Song and Peña-Mora 2012).

Analogous to auto insurance, in which the insurance company charges a higher premium to drivers with a higher likelihood of incurring accidents or rejects to insure drivers with bad records, the GHG emission insurance creates a penalty mechanism that penalizes bidders’ opportunistic bidding behavior by charging higher premium on policyholders with poor performance record. It could serve as a selection tool in the bidding process that screens out contractors with undesired environmental performance by a high emissions liability premium. However, there exists some applicability issues associated with the implementation of GHG liability insurance. The following section introduces and compares surety ship and insurance, and the authors investigate the possibility of applying Green Performance Bond in construction projects to handle the risks of over-emission and associated challenges in the implementation of green contracting methods.

4.1 Insurance

Insurance is essentially a two-party indemnity agreement between the insurer (the insurance company) and the insured (the policyholder) (Myhr and Markman 2003). In risk management, insurance products serve as a risk transferring technique that provides a means to pay for losses that occur to the insured (Myhr and Markman 2003).

Taking health insurance as an example, the insurance company will compensate customers for their medical expenses, wholly or partially, in return for the payment of a specified premium. In insurance theory, the expected future losses can be calculated according to the law of large numbers based on statistic data. The premium is determined by actuaries to cover expected losses and the insurance company's underwriting expenses and targeted profit(Russell 2000). Finally, it is worth noting that losses are usually not recoverable under the insurance mechanism, meaning that the insurance company does not expect to be repaid by the policyholder who incurs financial loss. Common construction insurance products currently on the market can be divided into two categories: property insurance and liability insurance (Bunni 2003).Property insurance provides protection to the works and any material, equipment and machinery connected with it, while liability insurance provide protection to the insured party against specific legal liabilities to which he/she may become exposed as a result of activities culminating in bodily injury and/or property damage (Bunni 2003).

4.2 Surety ship

Unlike insurance, surety bonds are mostly a three-party guarantee agreement between the oblige, the principal, and the surety company. There are seven families of surety bonds: contract bonds, fidelity bonds, license and permit bonds, judicial (court) bonds, public official bonds, fiduciary bonds and miscellaneous and federal bonds (Lunt 2010). Construction bonds, under the first category, involve three parties: the surety company, the owner (oblige) and the contractor (principal). Common construction bonds include bid bond, performance bond, payment bond, and maintenance bond (Russell 2000). A bid bond is issued as part of a bidding process by the surety company to the owner, to guarantee that the winning bidder will undertake the contract under the terms at which they bid. If the winner walks away, the surety company will perform the contract instead or pay the difference between the winner and the second lowest bid.

A payment bond guarantees that the subcontractors and material suppliers on the project will be paid by the contractor as according to the terms specified in the contract and the owner will not face any risks in this regard. A maintenance bond is adopted to guarantee that the awarding contractor will provide facility repair and upkeep for a specified period of time. A performance bond guarantees the faithful performance of the contractor in accordance with the provisions of the contract. Should the contractor fails to meet his/her contractual obligations, the owner may call on the surety company to step in and complete the project, correct project deficiencies or compensate any financial losses resulted from the contractor's default (Dagostino and Feigenbaum 1999).

Under the Miller Act of 1932 and Little Miller Act, all construction contracts funded by the federal government and states must be backed by performance and payment bonds. The surety company then reclaim its loss from any resources left to the principal according to the indemnity agreement. As such, in surety ship, losses are considered recoverable and the principal retains the risk of failure [5](Lunt 2010).

[5]Unfortunately, actual experience shows few such recoveries(Bunni 2003).

To determine the premium, surety underwriters assess the risk by looking at the principal's past record and current status. For example, based on the interviews with several surety companies, the premium for construction performance bond could have a wide range of variance between 1%- 5% of the contract value. However, unlike insurance premium that is designed to cover expected losses, surety premium is majorly a service charge for the use of the surety company's financial backing and guarantee. The extent of the surety's liability is determined by the penal sum of the bond which is the dollar value of the bond(Bunni 2003).In most construction projects, the penal sum of the bond is the value of the contract price. In surety ship, because surety agents view their underwriting as a form of credit instead of "spreading the risk", their focus is on prequalification and selection to help weed out unqualified candidates.

4.3 Insurance vs. Surety ship

First of all, managing GHG emission during the construction phase needs the involvement and concerted effort of all major parties (owner, contractor and, insurance or Surety Company) throughout the construction project. Insurance is an indemnity agreement between the contractor and the insurance company while the owner plays a less active role in this mechanism. On the other hand, surety ship is a three-party guaranty agreement. Specifically, the surety company has this opportunity to establish a bilateral relationship with the contractor before the bidding process because of the general prequalification as a part of underwriting process. The surety company also has access to historical record regarding the contractor's capability in different aspects that contractors rarely release or truthfully report to the project owners despite the most rigorous prequalification processes. Consequently, the surety company may be able to not only help the owner evaluate the contractor's mitigation plan before the project but also offer technical, financial, or managerial assistance to the contractor before and during the project (SIO 2009).

Second, proper risk allocation among project participants are needed in order to minimize the risk of over-emission. As discussed before, insurance is a loss funding mechanism designed to compensate the insured against unforeseen adversities. In emissions liability insurance (Song and Peña-Mora 2012), the contractor's loss, which is the penalty charged by the owner, will be compensated by the insurance company; the contractor transfers the risk of financial penalty due to over-emission to the insurance company. However, environmental damages have irreversible social impact and cannot be easily compensated by monetary value.

Moreover, the nature of insurance's transferring mechanism creates potential moral and morale hazards, both describing the different behaviours of the insured when protected from risk and when fully exposed to risk. (Pritchett et al. 1996). In insurance analysis, the term "moral hazards" refers to a condition that "increases the likelihood that a person will intentionally cause or exaggerate a loss" (Myhr and Markham 2003). Morale hazards are "attitudes of carelessness and lack of concern that increase the chance of a loss occurring or increase the size of losses that do occur" (Pritchett et al. 1996). The difference is that the former is considered malicious, while the latter is mainly due to indifference.

Either way the protection offered by insurance policy could potentially decrease project participants' motivation to achieve contractually agreed level of GHG emissions. In contrast with insurance, surety ship is a loss avoidance mechanism designed to prequalify individuals based on their credit strength and construction expertise, thus to prevent the risk of over-emission. The surety company selects green contractors that are reliable to meet the environmental requirements. Both in short term and long term surety ship provides preventive measures which are more favourable to the owner than compensatory ones. On the other hand, the contractor will thrive to minimize any environmental damages because he/she retains the risk of over-emission and its consequences.

The last reason which justifies the use of surety ship mechanism is the dilemma of ratemaking. Generally, there are two types of scientific uncertainty (Costanza and Cornwell 1992). Statistical uncertainty is a random event with a known probability but an unknown future outcome, also known as risk with certainty. While true uncertainty is an event with an unknown probability because of a lack of knowledge at a deeper level or limited information (Costanza and Cornwell 1992). In general, insurance premium can be determined based on large number of similar exposure units (Pritchett et al. 1996)..For example, the likelihood of a policyholder incurring car accidents is calculable for insurance company because of large quantities of statistical data.

On the other hand, Costanza and Cornwell (1992) believe that most important environmental problems are influenced by true uncertainty, not statistical uncertainty. When dealing with true uncertainty, it is not feasible to calculate insurance premium via actuarial methods such as pure premium method or loss ratio methods. In the case of GHG emissions, uncertainty over the level of emissions is considered as "true uncertainty" instead of "statistical uncertainty" because there is few historic data regarding the emission performance of construction projects that can be used as a basis for determining insurance premium. However, the ratemaking process for surety bonds is mainly based on the cost of service with the expectation of zero non-performance risk. Since surety underwriters take a judgment based approach to determine the premium, it is possible to overcome this challenge of true uncertainty. As a result, the practicality of the ratemaking process indicates surety ship as a better approach than insurance in GHG emission management.

4. Green Performance Bond Framework

Following the above discussion, the authors propose a risk management approach which adds another dimension to the traditional triangle project management structure and investigates the possibility of applying green performance bond in managing GHG emissions in construction projects. As illustrated in Figure 1, contractors suffer economic consequences if they fail to follow the planned schedule, budget and quality described in the contract. For example, the owner requires a performance bond from the contractor as protection from financial loss should the contractor fail to fulfill the contract; a liquidated damage clause would protect the owners from construction delays by charging the contractor a certain sum of money for every day he/she goes over the scheduled completion date (Eggleston 2009).

Analogously, required green performance bond will compensate the owner in the event of the contractor failing to meet the emissions goal, as promised in the contract.

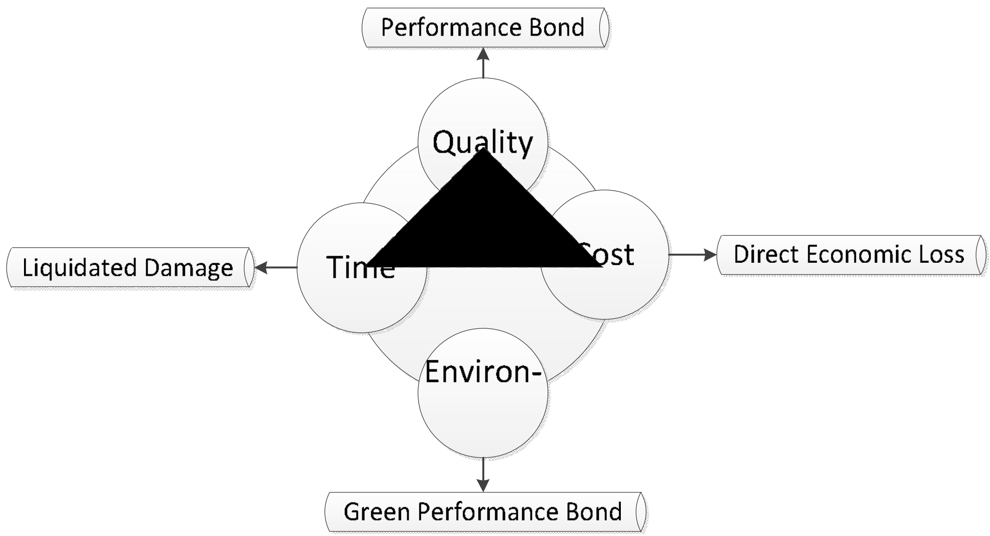

Figure 1: Project Management Structure with Environmental Performance Dimension

Figure 2 shows the mechanism of Green performance bond implementation. There are two phases in the framework: pre-construction and construction.

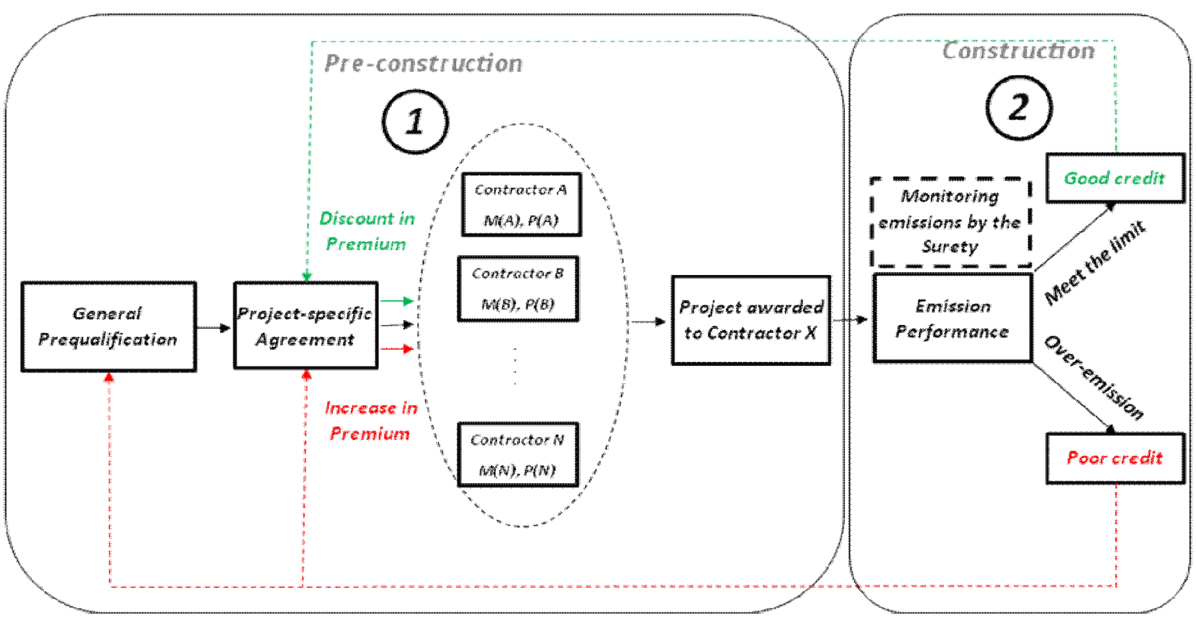

Figure 2: The proposed framework with the concept of green performance bond

In the first phases, the owner sends out a RFP with an estimated benchmark for GHG emissions, and requires a mandatory green performance bond from the awarding contractor in addition to the common construction performance bond. Potential bidders need to first pass the general prequalification process to bid on a green work. The bidders are evaluated for their financial, technical, and managerial capabilities to perform environmental obligations as well as past performance on GHG emission control during the construction phase. Then, the contractor must demonstrate his/her plan for mitigating risks *M (N)* associated with GHG emissions based on specific project

Characteristics, for example, to show that the proposed technology is a proven one for a certain type of project. The owner then evaluates the bids with a weight on environmental cost and selects the awarding contractor. Before entering the construction phase, the awarding contractor is required to submit the green performance bond that financially backs the quality of his/her GHG emission control along with the performance bond. Once construction begins, the surety company and the owner monitor and track the actual emissions using portable emissions measurement system (PEMS) which are attached to the tailpipe of construction equipment collecting and recording the emission information on the construction site throughout the construction phases (Peña–Mora et al 2011), and provide any necessary technical and managerial assistance to the contractor to optimize the environmental performance of the construction processes.

At the end of the project, if the contractor meets the GHG emission limit, the surety company offers future premium discounts for the contractor's future green work. Otherwise, poor environment performance can bring immediate consequence (severe financial penalty charged by the owner) and future consequence (increase in premium by the surety company). The owner may use non-linear functions for determining the environmental damage costs as the penalty for over-emissions. The more it exceeds the contractual emission limit, the more severe the penalty become. Because the premium of the green performance bond *P(N)*is included in the bid as part of the cost estimates, the contractor's actual environmental performance could make him/her more or less favorable in future competitions, and opportunistic bidding behavior could be effectively discouraged by limiting bidders' financial incentive to promise a mitigation plan beyond their capability.

Similar to performance bond, the green performance bond rates can be determined by judgment-based approaches, meaning the ratemaking process rely heavily on the experience and knowledge of an actuary (Myhr and Markman 2003), take into consideration of the contractor's previous works, equipment, staff, credit, financial history, characteristics of the project, and jurisdiction. The applicability of the submitted mitigation plan for the project is a major element in the process of determining the premium, as showed in Figure 3. From the surety company's perspective, premium has three components (Russell 2000): first, operating expenses such as salaries, commissions, rent, utilities, potage, communications, consultants, supplies, taxes, etc. second, loss cost, which is associated with investigating and settling losses, and third, the profit factor.

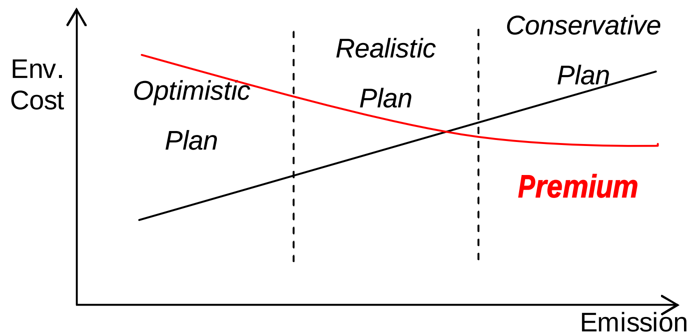

Figure 3: Degree of Practicability of the Mitigation Plan and Premium

5. Conclusions

Just as the surety industry once asserted its leadership and expertise in tackling major construction quality risks, the prospect for its involvement in managing GHG emissions as a financial tool during the building process stands as an immense opportunity for promoting sustainability in construction projects. In 2010, The World Bank (Reichelt 2010) proposed the concept of "green bonds" which demonstrated that the capital markets can be a source of funding for climate-related initiatives. In the highly competitive construction industry, surety bonds serve as the evidence of the contractor's competence and capability and perform well as the basis for a competitive, properly functioning bidding system (Russell 2000). This paper introduces the concept of developing an innovative surety product – the green performance bond into construction projects.

From the owner's perspective, the objective is to encourage construction contractors to improve their environmental performance in public projects through a financial means, and increase the likelihood of awarding the contract to competent and environmentally responsible contractors. Although the framework presented in the paper is still in the conceptual development phase, it appears that there are both risk management and risk financing benefits potentially available to owners if such a process can be devised. In addition, the increasingly competitive market motivates risk-management companies to push for product and service innovations that differentiate them from fellow competitors and offer new ways to meet customers' demands (Mills 2003).

For example, Fireman's Fund's Green Guard Program replaces standard materials and systems with green alternatives after a loss. AIG's Sustain-A-Build Program enables AIG environmental customers to receive discounts of up to 10% on premiums for new pollution legal liability policies. These two programs are both pilot programs entering the fledgling construction sustainability risk management market (Ayers 2008). Most recently, the District of Columbia Green Building Act of 2006 required the use of a surety product that does not currently exist in the marketplace (Seifert 2008). This act mandates public and private projects to meet the U. S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED).

Though this legislative activity to involve the surety industry was not successful because of reasons such vague language and assumptions by the drafters; failing to define the parties to the bond; inappropriate risk allocation and poor determination of liability or certification Seifert (2008), it shows a new governmental trend towards benefiting from the surety potentials when promoting sustainability in construction projects.

For future studies, an in-depth analysis of the proposed framework from all parties' perspective is still recommended. The rich literature around performance bond (Kangari and Bakheet 2001, Bayraktar and Hastak 2010, Awad and Fayek 2012) will be examined to develop a decision support system for prequalification and pricing premium of the green performance bond. Furthermore, the authors will look into other possible applications such as cap and trade, general contractor's pollution liability, and so on, under a broader framework of construction sustainability risk management.

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References

Ayers, K.W. (2008). " The Role of Insurance in Sustainability Risk Management." *Joint Meeting – SOA, CAS, CIA, Quebec City* - June 18, 2008

Awad, A. and Fayek, A. R. (2012) "A decision supports system for contractor prequalification for surety bonding." *Automation in Construction*, 21: 89–98, doi:10.1016/j.autcon.2011.05.017

Bayraktar, M.E. and Hastak, M. (2010) "Scoring approach to construction bond underwriting." *Journal of Construction Engineering and Management* 136 (9) 957–967, doi: 10.1061/(ASCE)CO.1943-7862.0000217

Bunni, N.G. (2003). Risk and Insurance in Construction (Second Edition). New York: Spon Press, ISBN: 0419213805.

Bushnell, S. (2010). "Applied Solutions: Green Insurance." *Fireman's Fund Insurance Company*. November 11, 2010.

Anderson, S. D., and Damnjanovic, I.D. (2008). "Selection and evaluation of alternative 16 contracting methods to accelerate project completion." *NCHRP Synthesis* 379, 17 Transportation Research Board, Washington, D.C.

Carr, P. (1994). "Reducing highway congestion: creative approach to highway contracting."Rep., Legislative Commission on Critical Transp. Changes, Assembly State of New York, Albany, N.Y.

Congressional Budget Office (CBO) (2008). " Policy Options for Reducing CO2 Emissions. " *The Congress of the United States*. Available via < http://www.cbo.gov/ftpdocs/89xx/doc8934/02-12-Carbon.pdf> [accessed September 28, 2014]

Cui, Q. and Zhu, X. (2011). “Green contracting in highway construction: state of the practice.” Transportation Research Record: *Journal of the Transportation Research Board*, 2228, pp. 11–18, doi:10.3141/2228-02

Dagostino, F. R. and Feigenbaum, L. (1999). *Estimating in building construction*. Pearson Education Asian Limited.

Eggleston , B. (2009). *Liquidated Damages and Extensions of Time: In Construction Contracts*. Wiley-Blackwell. UK.

Ellis, R., Pyeon, J. H., Herbsman, Z., Minchin, E., and Molenaer, K. (2007). Evaluation of 17 alternative contracting techniques on FDOT construction projects, *Florida Department of 18 Transportation*, Tallahassee, Florida.

El-Rayes, K. (2001). ”Optimum Planning of Highway Construction under A + B Bidding Method.” J. Constr. Eng. Manage., 127(4), 261–269, doi:10.1061/(ASCE)0733-9364(2001)127:4(261)

Energy Information Administration (EIA) (2004). " Greenhouse Gases, Climate Change, and Energy." *U.S. EPA*. Available via < http://www.eia.gov/oiaf/1605/ggccebro/chapter1.html > [accessed September 28, 2014]

Environmental Protection Agency (EPA) (2009a). " Regulating Greenhouse Gas Emissions under the Clean Air Act ." *Sector Strategies Division, U.S. EPA*, Washington D.C. Available via < http://www.epa.gov/sectors/pdf/construction-sector-report.pdf > [accessed September 28, 2014]

Environmental Protection Agency (EPA) (2009b). "Potential For Reducing Greenhouse Gas Emissions In The Construction Sector." 40 CFR Chapter I, U.S. EPA, Washington D.C. Available via < http://www.epa.gov/climatechange/emissions/downloads/ANPRPreamble.pdf > [accessed September 28, 2014]

Environmental Protection Agency (EPA) (2009b). "Basic Information," Climate Change. Available via < http://www.epa.gov/climatechange/basicinfo.html > [accessed September 28, 2014]

Epstein, P.R. (2000). " Is Global Warming Harmful to Health?" *Scientific American*. August 2000:36-43.

Executive Order [EO] No. 13514, 3 C.F.R. 248 (2009) “Federal Leadership in Environmental, Energy, and Economic Performance” < http://www.epa.gov/oaintrnt/documents/fleetguidance_13514.pdf > [accessed July 20, 2014]

Guggemos, A.A. and Horvath, A. (2006). "Decision-support tool for assessing the environmental effects of constructing commercial buildings." *Journal of Architecture Engineering* 2006, 12, 187-195, doi:10.1061/(ASCE)1076-0431(2006)12:4(187)

Herbsman, Z. (1995). ”A+B Bidding Method—Hidden Success Story for Highway Construction.” J. Constr. Eng. Manage., 121(4), 430–437, doi: 10.1061/(ASCE)0733-9364(1995)121:4(430)

ICF Consulting (2005). Emission Reduction Incentives for Off-Road Diesel Equipment Used in the Port and Construction Sectors. *US Environmental Protection Agency*.

Insurance Services Office (ISO) (2007). "Property Claim Services" Available via < http://www.iso.com/press_releases/2007/01_16_07.html > [accessed September 28, 2014]

Intergovernmental Panel on Climate Change (IPCC) (2007). "Climate Change 2007." *The Fourth Assessment Report. United Nations*. Available via < http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf> [accessed June 30, 2014]

Kangari, R. and Bakheet, M. (2001) “Construction surety bonding.” *Journal of Construction Engineering and Management* 127 (3) 232–238, doi:10.1061/(ASCE)0733-9364(2001)127:3(232)

Kunzlik, P. (2003). “Making the market work for the environment: Acceptance of 'green' contract award criteria in public procurement”. Journal of Environmental Law, 15 (2), pp. 175-201. doi:10.1093/jel/15.2.175

Lunt, E. (2010). *Surety bonds: nature, functions, underwriting requirements*. Gale, Making of Modern Law.

McMichael, A.J., Campbell-Lendrum, D.H., Corvalan, C.F., Ebi, K.L., Githelo, A., Scheraga, J.D., and Woodward, A. (2003). "Climate Change and Human Health - Risks and Responses." *World Health Organization*. ISBN-10: 924156248X

Minnesota Department of Transportation (MnDOT). (2006). “Innovative contracting in 10 Minnesota: 2000–2005.” *Office of Construction and Innovative Contracting*, MnDOT. 11 <http://www.dot.state.mn.us/const/tools/innovativecontract.html> (Apr 10, 2014).

Mhyr ,A. E. and Markham J. J. (2003). *Insurance Operations, Regulation, and Statutory Accounting. American Inst. Chartered Property Casualty Underwriters* (AICPCU)/Insurance Institute of America, Pennsylvania. Second Edition.

Mills, E. (2003). "The Insurance and Risk Management Industries: New Players in the Delivery of Energy-Efficient Products and Services." *Energy Policy* 31:1257-1272. doi:10.1016/S0301-4215(02)00186-6

Minnesota Department of Transportation (MnDOT). (2006). “Innovative contracting in Minnesota: 2000–2005.” *Office of Construction and Innovative Contracting*, MnDOT. <http://www.dot.state.mn.us/const/tools/innovativecontract.html> (June 26, 2014).

Peña–Mora F., Ahn C., Golparvar-Fard M., Hajibabai L., Shiftehfar S., An S., Aziz Z. and Song S.H. (2009). “A Framework for managing emissions during construction.” *Proc., Int. Conference and Workshop on Sustainable GreenBuilding Design And Construction*, National Science Foundation.

Peschiera, G., Taylor, J., and Siegel, J. (2010). "Response-Relapse Patterns of Building Occupant Electricity Consumption Following Exposure to Personal, Contextualized and Occupant Peer Network Utilization Data." *Energy and Buildings*, 42(8): 1329-1336.doi:10.1016/j.enbuild.2010.03.001

Pritchett, S. T., Schmit, J. T., Doerpinghaus, H. I., and Athearn, J. L.(1996). *Risk management and insurance*: (7th edition). West Publishing Company, Minneapolis.

Reichelt, H. (2010). "Green bonds: a model to mobilise private capital to fund climate change mitigation and adaptation projects." The Euro money Environmental Finance Handbook. The World Bank. Washington, D.C.

Russell, J. S. (2000). *Surety Bonds for Construction Contracts*, ASCE Press, Reston, VA.

Singh, T.P. (2007). " Sustainable Construction." *Sustainability Tomorrow*. CIIITC Centre for Excellence in Sustainable Development. July 2007

Surety Information Office (2009) < http://www.sio.org >

Tietenberg, T. (2003). "The Tradable-Permits Approach to Protecting the Commons: Lessons for Climate Change". *Oxford Review of Economic Policy* 19 (3): 400–419. doi:10.1093/oxrep/19.3.400. Retrieved 2010-08-25.

Transportation Research Board. (1991). “Innovative contracting practices.”Transp. Res. Circular No. 386, Nat. Res. Council, Washington, D.C.

United Nations Environment Programme (UNEP) (2009). "The Global State Of Sustainable Insurance: Understanding and Integrating Environmental, Social And Governance Factors In Insurance." *UNEP FI Insurance Working Group and its Academic Working Group*. Available via < http://www.unep.org/pdf/Global_state_of_sustainable_insurance.pdf> [accessed June 30, 2014]

Vale, B. and Vale R. (1996). *Green architecture: design for a sustainable future*. Thames and Hudson, 1996.

Vogtländer, J.G., Brezet, H.C., and Hendriks, Ch.F. (2001). "The Virtual Eco-costs '99, a single LCA-based indicator for sustainability and the Eco-costs / Value Ratio (EVR) model for economic allocation," *Int. J. LCA*, 6 (3), 157-166. doi: 10.1007/BF02978734