

GREEN PERFORMANCE CONTRACTING ON HIGHWAY CONSTRUCTION PROJECTS

Xinyuan Zhu¹, Lisa Whitten², Qingbin Cui³

ABSTRACT

With the growing awareness of sustainability and global climate change, state highway agencies are taking essential steps to reduce carbon emissions from highway infrastructure on a life cycle basis. While much is known regarding climate change mitigation and adaption strategies during highway operation, very little is understood about how climate change issues should be integrated into highway planning, delivery, and construction processes. This paper presents the current contracting practice for addressing the climate change issues. A Green Performance Contracting (GPC) framework is defined. Four levels of the GPC strategies are identified and discussed, namely, material related strategies, equipment and energy efficiency related strategies, green life-cycle strategies, and clean energy development strategies. A survey of the GPC practices of U.S. state Departments of Transportation (DOTs) is introduced, and strategies addressed by different states aligned with the four levels are also discussed. Furthermore, evaluation criteria, including attributes of greenhouse gases (GHGs) reduction efficiency, financial feasibility, technology readiness, risk and uncertainty, and community and industrial acceptance, are proposed to assist state highway agencies in better incorporating green and sustainability into their project delivery processes.

KEYWORDS:

Green Performance Contracting, Climate Change, Highway Construction

INTRODUCTION

During the last century, the global surface temperature increased 0.74 ± 0.18 C (1.33 ± 0.32 F) (IPCC, 2007b), which is due to a serious problem usually referred as Climate Change or Global Warming. In the U.S., total greenhouse gas emissions have risen by 17% from 1990 to 2007 and reached 7,150.1 Million Metric Tons of carbon dioxide-equivalent (MMTCO₂-eq) in 2007. This represents a 0.6% increase (41.5 MMTCO₂-eq) from the 2005 emission level (EPA, 2009).

Various global efforts have been made to mitigate greenhouse gas emissions and adapt to climate change resulting from global warming. In December 2009, the United States officially pledged at the Copenhagen climate summit to cut its greenhouse gases emissions from the 2005 level by 17% by 2020, 42% by 2030, and 83% by 2050. Many state and local

¹ Research Assistant, Department of Civil & Environmental Engineering, University of Maryland, College Park, MD 20742, zxyemily@umd.edu

² Undergraduate Research Assistant, Department of Civil & Environmental Engineering, University of Maryland, College Park, MD 20742, lwhitten@umd.edu

³ Assistant Professor, Department of Civil & Environmental Engineering, University of Maryland, College Park, MD 20742, cui@umd.edu

governments have adopted even more aggressive reduction targets to tackle climate change. For example, Assembly Bill 32 passed in 2006 requires the state of California to reduce greenhouse gas emissions by 25% by 2020 (CARB, 2006). Similarly, in Maryland, the Greenhouse Gas Emissions Reduction Act of 2009 sets the target at 25% below 2006 levels by 2020. (MDE, 2009) Therefore, it is a wide research and practical need for different government agencies to incorporate climate change and sustainability issues into their usual practice in order to meet the ultimate goal in the long run.

Highway construction is an inter-industry field related to both the construction and transportation sectors. Although highway construction is typically considered as being emission intensive (Truitt, 2009), it is not usually addressed as the major greenhouse gas emission source from either the construction or transportation industry. Most of the regulations and initiatives of transportation agencies are regarding emission reduction from on-road operations, and that of construction agencies are mostly considering the building industry. After all, highway construction has its unique features compared with on-road sources or buildings. However, very few studies have been focused on greenhouse gas emissions from the whole life cycle of highway infrastructure development and construction. Nor are there any comprehensive studies to explore the strategies to integrate emission reduction and sustainability into highway project planning and the delivery process.

This paper is aimed to investigate various green contracting strategies for tackling climate change in highway construction projects. The paper briefly reviews the emission sources of highway construction projects on a life cycle basis, and then defines a specific system called Green Performance Contracting (GPC) strategies for highway projects. A previous survey of 39 state Departments of Transportation is referred to regarding the current state of practice and implementation of the strategies. Furthermore, the paper identifies key evaluation criteria used to integrate green contracting strategies into the existing project management system, including greenhouse gases (GHGs) emission reduction efficiency, financial feasibility, implementation readiness, risk and uncertainty, community and industrial acceptance.

EMISSIONS FROM HIGHWAY CONSTRUCTION

FROM THE TRANSPORTATION PERSPECTIVE

The transportation sector is the second largest source of carbon dioxide in the U.S. and accounts for almost 30% of carbon emissions, which is only 5% lower than that of electricity generation. Meanwhile, it is the fastest-growing source of GHGs. The U. S. Environmental Protection Agency's (EPA) analysis for GHGs emission of end-use economic sectors indicates that the transportation sector's emissions were around 24% greater in 2003 than in 1990, which is much higher than the average U.S. GHGs emission net increase of 13 percent over the same time. (EPA, 2006)

Related to highway construction, most CO₂, methane, and N₂O emissions are from transportation fossil fuel combustion, which includes petroleum combustion (for light-duty trucks and workers' commuter cars) and diesel combustion (for heavy-duty trucks and off-road construction equipment). Other fluorinated gas emissions are from facility air conditioners and lubricants from vehicle engine combustion.

The common methods used to reduce emissions from these sources recommended by the U.S. EPA and U.S. Federal Highway Administration (FHWA) are intended to reduce either fossil fuel usage or emissions from fuel combustion. Available technologies include: increasing engine efficiency using fuel substitutions like biodiesel, installing retrofit devices to filter chemical emissions, or adding additives into fuel to reduce GHGs generation. Meanwhile, transportation infrastructure is vulnerable to predicted changes in sea levels, increasingly severe weather, and extreme high temperatures. Long-term transportation adaptation will need to be considered in the early stages of design and construction.

FROM THE CONSTRUCTION PERSPECTIVE

Although the construction sector contributes a smaller portion of the U.S. GHGs emissions than the transportation industry does, it ranks as the third-highest emission source among end-use industry sectors. According to the EPA's report, in 2002, 131 MMTCO₂-eq were produced by construction site activities, which represents about 6% of U.S. industrial GHGs emissions, or 1.7% of total U.S. emissions (EPA, 2008). Within the 131 MMT of carbon emissions by the construction industry, 76% results from fossil fuel combustion, which overlaps with the transportation sector. The remaining 24% comes from purchased electricity, which is the quantity of GHGs resulting from the generation of purchased electric power.

Specifically for highway construction projects, in order to reduce material-related GHGs emissions, common practices are to reuse or recycle available industrial materials in the landfill or pavement process. This method can reduce the GHGs emissions from the material disposal process and emissions during the manufacturing stage of virgin materials. For emissions from purchased electricity use, it is recommended to employ efficient electrical equipment, such as LEDs for lighting and signals. It is also a growing trend that renewable energy facilities prefer solar panels and wind turbines to be built on highway right-of-ways to generate energy for highway electricity use.

Another important field for highway projects to address climate change is the life-cycle construction planning. For example, more and more requests for proposals (RFP) are requiring contractors to conduct project evaluations for the environmental or community impact. Regulations, such as the Work Zone Safety and Mobility Rule (FHWA, 2004), are also put forward to minimize the GHGs emissions generated by traffic congestion because of construction projects.

GREEN PERFORMANCE CONTRACTING (GPC) STRATEGIES

In order to systematically integrate construction firms' sustainability performance into agencies' carbon emission reduction programs, transportation agencies need to develop innovative contracting strategies to address climate change issues in the highway planning, delivery, and construction processes. However, there is no universally agreed definition of going-green or of sustainability, nor is there a clear definition of green contracting in highway construction. Therefore, we define the sustainable contracting strategy as Green Performance Contracting (GPC), which involves contract provisions, contracting methods,

and delivery strategies that help reduce greenhouse gas emissions and improve adaptation to climate change.

Similar to the triple bottom line approach (Elkington, 1998) widely used in businesses, the GPC strategy of highway projects could be covering sustainability’s economic, environmental, and social aspects. In detail, the strategies could be specified at three scopes:

1. Reduce emissions and adapt to climate change
2. Benefit the environment
3. Improve the quality of public lives through a direct economic, ecological, or social benefit

A great number of contracting strategies were identified as green due to their direct or indirect contribution to emission mitigation and adaptation. Therefore, green contracting strategies were further classified into four levels in accordance with applied project phase and emission sources addressed by the strategies. Table 1 shows some examples of the strategies on each level.

Table 1: Example Green Contracting Strategies

Level	Green Contracting Strategy
I: material related strategies	Material Recycling and Reuse
	Warm Mix Asphalt
	Waste Management
II: equipment and energy efficiency	Equipment Retrofit
	Engine Replacement and Upgrade
	Idling Reduction
	Alternative Fuels
	Truck Staging Zone
	LED Lighting
	Work Zone Mobility
III: green life cycle strategies	Green Road Rating System
	Climate Impact Analyses
	Climate Adaptation Design
IV: clean energy development	Solar Highway
	Highway-based Wind Turbines

LEVEL I: MATERIAL RELATED STRATEGIES

Material Related Strategies are the most common green methods utilized in the highway construction process. Although the original incentives are mainly based on the cost saving perspective instead of the climate change concern, the effect of greenhouse gas emission reduction using the material related strategies is substantial.

Material Related Strategies mainly include:

- Material Recycling or Reusing, which takes advantage of industrial byproducts or recycled materials, such as reclaimed asphalt, recycled concrete, fly ash, etc., as substitutions

for raw materials during construction. These strategies can reduce the GHGs emission during material disposal and virgin material manufacturing.

- Material Treatment, which basically controls the GHGs emissions directly from the material treatment process and future operation phase or indirectly related to the energy use in material treatment. Typical strategies include warm/cool pavement, concrete additives, light aggregate in concrete pavements, etc.
- Material Life Cycle Management, which refers to the whole life cycle of materials as they flow through the process of selection, production, procurement, shipment, recycling/reusing, and disposal. These strategies are usually conducted with different software and tools, such as the shipment model FLEET (EPA), pavement life-cycle assessment tool PaLATE (Horvath, 2007), and material life cycle tool BEES (DOE, 2008).

LEVEL II: EQUIPMENT AND ENERGY EFFICIENCY STRATEGIES

Emission from fuel combustion is the largest GHGs emission resource of the transportation and construction industries. In order to reduce the fuel combustion emission, renewable equipment devices and efficient fuel use are two important categories for highway construction projects.

For example, contractors could be regulated or incentivized to adopt engine retrofit according to U.S. EPA (EPA, 2000) or CARB (CARB, 2002) verified technologies, using repowering and upgrading engines or better selecting their equipment. Alternatively, construction companies could also be required to use alternative fuels for their equipment, to reduce equipment idling, or to implement Work Zone Mobility management.

LEVEL III: GREEN LIFE CYCLE STRATEGIES

In businesses, Life-Cycle Management (LCM) has been developed as an approach for managing the total life cycle of products and services. It addresses a broad range of activities, starting with the initial identification of the problem, processing through the building or acquisition of a solution, and ending with the final disposition of the solution at the end of its useful life (EPA, 1989). Similarly, green life-cycle strategies for highway projects should be a framework used to target, organize, analyze, and manage project-related information and activities toward continuous sustainable improvement along the project life cycle. A particular strategy could help to:

- Analyze and understand the environmental issues of the different life-cycle stages of the project
- Identify the potential environmental, economic, and social risks, as well as the potential sustainability opportunities at each stage
- Establish proactive systems to pursue the opportunities and manage or minimize the risks

LEVEL IV: CLEAN ENERGY DEVELOPMENT STRATEGIES

A clean energy development strategy involves innovative thinking through infrastructure design, project partnerships, financing methods, construction techniques, evaluation methodologies, delivery processes, and future maintenance. For highway constructions, clean

and then transportation agencies evaluate the feasibility, environmental suitability, and expected performance before adopting the strategies (Collins & Ciesielski, 1993). Sometimes agencies will regulate a certain percentage ceiling based on their research, or they will refer to U.S. FHWA's guidelines (FHWA, 1994). Some states also have on-going efforts on standardizing the Level I strategy adoption. For example, Wisconsin DOT continues to rewrite its contract standard specifications as "performance-based specifications", facilitating the use of recycled materials to the maximum extent possible in their highway construction projects (Wisconsin DOT, 2006).

There are 12 states that have implemented at least one Level II strategy in addition to Level I strategies. Among all Level II strategies, 10 states adopted idling reduction policies, 9 utilized alternative fuels, 7 launched engine retrofit programs, and 4 established energy efficiency programs. These strategies, on the other hand, are expected to result in incremental costs in project construction and therefore need extra organizational support through agency initiatives, regulations, or even legislations. Most states DOTs established air quality programs in the early 90's to assess and address the construction-related emissions, including reactive organic gas (ROG), nitrogen oxides (NO_x), particulate matter (PM), etc. Therefore, some state DOTs (e.g. New York, Oregon, Washington) address the impact for climate change by incorporating GHGs emissions into the existing program and update their evaluation process. Some other states establish new initiatives or programs to promote the Level II strategies. Missouri DOT established its green initiative program to award green contractors. Under this program, the agency assigns a "green credit" goal for the contractor and appoints a "green credit" value for the use of various environmentally friendly practices, including alternative fuels and retrofit technologies. The California Air Resources Board (CARB) proposed a Low Carbon Fuel Standard Program (LCFS) that will reduce greenhouse gas emissions by reducing the full fuel-cycle carbon intensity of the transportation fuel pool used in California (CARB, 2005). In Vermont, besides the green initiative within the highway agency, a state climate change commission was established three years ago by the governor to both promote energy efficiency and create a "Green Standard" for pricing carbon reduction efforts.

Five states (CA, IL, NY, OR, WA) responded that they have adopted Level III strategies used in the areas of project life-cycle emission and energy analysis and green highway rating. Their strategies are entirely driven by state policies and legislations. In New York, the State Energy Plan requires the state DOT to conduct a greenhouse gas energy analysis on its transportation plans. In Washington, Executive Orders 05-01, 04-01, and 02-03 direct Washington DOT to develop Sustainability Plans that report on sustainable business practices and track progress. In Illinois, along with agency's green initiative, an office of sustainable practice was established to guide the agency's sustainable practice in the areas of planning, design, construction, maintenance, operations, and others.

Also associated with Level III strategies are the green highway rating systems. The survey identified three rating systems currently used in the U.S., namely, GreenLITES, Greenroads, and I-LAST. The Green Leadership in Transportation Environmental Sustainability (GreenLITES), endorsed by New York State DOT, requires all project Plans, Specifications & Estimates (PS&Es) submittals to be GreenLITES certified. Greenroads was developed by the University of Washington and Ch2MHILL, and has been used for

evaluating several pilot projects in Washington and Oregon. The Illinois-Livable and Sustainable Transportation (I-LAST) rating system is also voluntary in nature. The purpose, according to Illinois DOT, is to provide a list of best practices to bring sustainability to highway projects.

For the Level IV strategy, Oregon DOT developed its first solar highway project in 2008 and continues to expand the installation of solar panels in the highway right-of-way to generate power for highway lighting. Although other states have not yet addressed Level IV strategies in highway projects, many efforts are underway. The Massachusetts Turnpike Authority is currently building a wind turbine near the turnpike rest area. The Maryland SHA also installed a wind turbine in 2009 to power an agency facility. Several state DOTs (e.g. CA, IL, MI) are pursuing federal grants for renewable energy projects, including green rest areas and solar powered interchanges.

EVALUATION CRITERIA FOR ADOPTING GPC

There are many attributes transportation agencies should consider before choosing to adopt a portfolio of GPC strategies for their various highway construction projects. It would be a complicated decision process considering a strict target to meet, limited budget, lots of strategies to choose from, and various uncertainties to encounter. In this part, we will discuss the evaluation criteria:

GHGs Emission Reduction Efficiency

Agencies should evaluate different strategies' potential efficiency in the long run. The most important objective for them is to manage different strategies in an effective way so that the agency or the whole state can realize the ultimate long-term goal, such as 2020 or 2050 GHGs emission reduction. Some of the strategies can immediately be adopted and require less investment, while their effectiveness in reducing the overall GHGs emissions could be limited. On the other hand, some more expensive strategies may need a longer time to be implemented, but they may be far more effective in reducing the GHGs emissions. Additionally, some strategies like wind turbines or solar panels would be more efficient depending on the environment where they are used.

Financial Feasibility

Agencies also need to consider the strategies' feasibility from a financial perspective. The financial feasibility basically encompasses the total cost of developing and implementing the strategy, as well as the availability of some external financial resources. The total cost may vary from installing small equipment to building series of infrastructures, or from replacing small amount of materials to building and delivering the whole project. Some strategies can also engender a large amount of succeeding operation or maintenance costs. Meanwhile, there are a lot of federal/state-level or market-based initiatives or programs proposed to encourage certain strategies in the form of grants, funding, or credit awards. These resources are essential for adopting some large scale or expensive strategies, as they usually can dramatically reduce the total cost.

Implementation Readiness

Agencies should fully consider the implementation readiness before they decide on certain strategies. The first aspect is the agency-based organizational readiness, which involves how prepared the agency is to incorporate some new strategies into their original work. Possible changes could include establishing a specific innovative contracting team, launching new programs and initiatives, or rewriting official documents. Another aspect is the technology readiness, dealing with whether or not the strategy is proven to be functional or if further developments, such as R&D or Pilot Studies, are required. Some technologies are mature enough and commercially used, while some may still be in the laboratory phase, and hence, may require further development. Strategies using advanced technologies are anticipated to have more uncertainty along with the learning curve in the practical implementation process.

Risk and Uncertainty

Risk is another factor states should consider when choosing appropriate strategies. This aspect includes issues such as reliability, safety, and uncertainties in the development of the strategies. Some strategies may be too complex, causing them to frequently fail, while others may not be entirely safe and need to be better developed. One more item that this risk aspect may include is the issue of future uncertainties. Policies, markets, and technologies could be totally different in the next five or ten years statewide, nationwide, or even worldwide.

Community and Industrial Acceptance

Last but not least, community and industrial acceptance should be fully considered for the development and operation of the strategy. Construction companies should be willing to work with agencies while going green. Meanwhile, many of the strategies may directly influence the community life. The public's feedback should be paid enough attention to. Public education about sustainability or green concepts will also be an important byproduct.

CONCLUSIONS

In this paper, we defined a Green Performance Contracting (GPC) framework for addressing the climate change issues in highway construction projects. Four levels of the GPC strategies are identified and discussed, namely, material related strategies, equipment and energy efficiency related strategies, green life-cycle strategies, and clean energy development strategies. State practices are discussed for each level of the GPC, according to a survey conducted for U.S. state DOTs. Furthermore, we proposed a series of evaluation criteria to assist state highway agencies in better incorporating green strategies and sustainability into their project delivery processes, including attributes of GHGs reduction efficiency, financial feasibility, implementation readiness, risk and uncertainty, and community and industrial acceptance. We will try to develop an evaluation matrix or toolkit based on the criteria in future work.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support provided by the Maryland State Highway Administration. Special thanks go to Kirk McClelland, Lisa Choplin, Allison Hardt, and Hua Xiang for their help and advice on the survey design and research direction. Their time and efforts are acknowledged and greatly appreciated.

REFERENCES

- CARB. (2006). *Assembly Bill 32: Global Warming Solutions Act*.
- CARB. (2005). *Regulations to Achieve Greenhouse Gas Emission Reductions, Low Carbon Fuel Standard*. Retrieved from <http://www.arb.ca.gov/regact/2009/lcfs09/lcfscombofinal.pdf>
- CARB. (2002). *Verified diesel emission control strategies*. Retrieved from <http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm>
- Collins, R., & Ciesielski, S. (1993). *Recycling and Use of Waste Materials and Byproducts in Highway Construction*.
- Cui, Q., & Zhu, X. (2010). *Green contracting in highway construction: State of practice*. Working paper.
- DOE. (2008). *Material Life Cycle Tool BEES*. Retrieved from http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=176/pagename=alpha_list
- Elkington, J. (1998). *Cannibals with Forks: the Triple Bottom Line of 21st Century Business*.
- EPA. (1989). Retrieved from OSWER Life Cycle Management Guidance: <http://www.epa.gov/oswer/oswerlcm.htm>
- EPA. (2006). *Greenhouse Gas Emissions from the U.S. Transportation Sector, 1990–2003*. US Environmental Protection Agency.
- EPA. (2009). *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2007*. US Environmental Protection Agency.
- EPA. (2008). *Quantifying Greenhouse Gas Emissions from Key Industrial Sectors in the United States*. U.S. Environmental Protection Agency.
- EPA. (n.d.). *Transportation Tools*. Retrieved from http://www.epa.gov/climatechange/wycd/tools_transportation.html
- EPA. (2000). *Verified technologies for engine retrofit programs*. Retrieved from <http://www.epa.gov/dieselretrofit/verif-list.htm>
- FHWA. (2004). *Rules and Regulations: Work Zone Safety and Mobility*. Federal Highway Administration.
- FHWA. (1994). *The Use of Recycled Materials in Highway Construction*. Retrieved from <http://www.fhwa.dot.gov/publications/publicroads/94fall/p94au32.cfm>
- Horvath, A. (2007). *Pavement Life-cycle Assessment Tool for Environmental and Economic Effects*. Retrieved from <http://www.ce.berkeley.edu/~horvath/palate.html>
- IPCC. (2007b). *Climate Change 2007: The Physical Science Basis*. Intergovernmental Panel on Climate Change.
- MDE. (2009). *GREENHOUSE GAS REDUCTION ACT OF 2009 BILL SUMMARY*. Maryland Department of Environment.
- Truitt, P. (2009). *Potential of Reducing Greenhouse Gas Emissions in the Construction Sector*. US Environmental Protection Agency, February 2009, Washington DC.
- Wisconsin DOT. (2006). *Beneficial Use of Industrial Materials and Recycling in Wisconsin DOT Projects*. Retrieved from <http://www.epa.gov/osw/conserves/rrr/imr/pdfs/wiscon1.pdf>