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A model to control environmental performance of project execution process based on greenhouse gas emissions using earned value management

Abdollah Abdi [a], Sharareh Taghipour [a,*], Homayoun Khamooshi [b]

[a] *Department of Mechanical and Industrial Engineering, Ryerson University, Toronto, ON M5B 2K3, Canada*
[b] *Department of Decision Sciences, School of Business, George Washington University, Funger Hall, Suite 415, 2201 G St. NW, Washington, DC 20052, United States*

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Abstract

In response to recent climate change, which is believed to be attributed to the release of greenhouse gas (GHG) emissions, many countries are placing CO2 abatement programs such as carbon tax and cap-and-trade. Projects do have a significant share in GHGs and therefore their environmental performance, like their schedule and cost performance, should be monitored and controlled. Although many large projects would pass an environmental assessment in the project evaluation phase, the issue of environmental performance monitoring during the project execution phase has not been addressed in project management methodologies. The objective of this paper is to develop a model to estimate project GHG emissions, and to measure project GHG performance using the developed metrics, which can be used at any point in time over the life of a project. A comprehensive study is conducted to collect information on GHG emission factors of various project activity data (such as material use, energy and fuel consumption, transportation, etc.), and a user form interface is developed to calculate the total GHG of an activity. Also, a breakdown structure is proposed which supports managing all the project GHG accounts. The monitoring and control model is formulated based on the logic used in earned value management (EVM) methodology. The proposed model is then implemented to a work package of a real construction project. The results present the project initial GHG plan and show that the model is able to calculate project GHG variance by the reporting date and predict project final GHG based on a project GHG performance index. The method presented in this paper is general and can be applied to any type of projects in an organization that aims to reduce its carbon footprint. The same structure can be applied to monitor and control any other environmental impact associated with project execution process.

Keywords: Greenhouse gas (GHG) emissions; Project control; Earned value management (EVM)

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) reports, recent climate changes, one of the most important issues of our day, can largely be attributed to the release of greenhouse gas (GHG) emissions into the atmosphere through human activities, resulting sever impacts on people and ecosystems (IPCC, 2014a). In response to global climate change and increased GHG emissions, many countries have introduced regulatory policy schemes of carbon reduction. Such schemes have been in place especially following the agreement at the 21st Conference of the Parties in Paris to the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations Framework Convention on Climate Change, 2015).

Projects, with a significant role in global economy as much as one third (Turner, 2014) have a significant contribution to

* Corresponding author.
E-mail addresses: abdollah.abdi@ryerson.ca (A. Abdi), sharareh@ryerson.ca (S. Taghipour), hkh@gwu.edu (H. Khamooshi).

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global climate change and GHGs. This is the case specifically in construction projects which are the primary contributor of global GHG emissions (Hong et al., 2016). Moreover, because of the growing competitive pressure and tendency to apply modern management techniques, organizations are being more and more projectized or project oriented (Hazır, 2015). Despite this fact, common practices in project performance measurement use project conventional triple constraints (i.e. quality, time and cost), neglecting its investment effectiveness and organizational benefits (Zwikael and Smyrk, 2012). To integrate and incorporate the impact of GHGs emission in project execution and control, and to address national and international concern on the climate change, sustainability and reducing environmental impacts, GHGs emission can be considered as a cost for almost any types of project. Furthermore, carbon pricing using either a carbon tax or cap-and-trade program can motivate organizations to model project's environmental impacts in their estimations and performance measures. Carbon tax and cap-and-trade programs are two sides of the same coin. The former sets the price of CO_2 emissions and lets the market determine the quantity of reduction in emissions. The latter, sets the permits as the quantity of emission reductions and allows the market to determine the price. Moreover, most of countries have set emission mitigation targets for the future decades which implies that the issue of GHG control will be of much more importance to every sector including construction. According to Canada's 2016 Greenhouse Gas Emissions Reference Case (Environment and Climate Change Canada, 2017), Canada's annual emission target is 523 megatons of carbon dioxide equivalent in 2030, which is 239 megatons less than historical emissions recorded for the year 2014 (Environmental Canada, 2017). Therefore, it is essential for future project managers to have a monitoring system for their project environmental impact performance or GHG management, and hence it is not far-fetched to see a '*Project GHG Management*' chapter in Project Management Institute's (PMI) standard "Project Management Body of Knowledge, PMBOK" (PMI, 2013).

The common practice for project performance measurement is earned value management (EVM) technique and its extensions. A comprehensive study by Willems and Vanhoucke (2015) shows that EVM-based models have been mostly developed for time or cost control. Many studies have been published to represent the basic concepts of EVM (e.g. Anbari, 2003; Fleming and Koppelman, 2010; PMI, 2013) and its more complicated, advanced extensions (e.g. Khamooshi and Golafshani, 2014; Kerkhove and Vanhoucke, 2017; Willems and Vanhoucke, 2015). It is believed that the traditional EVM technique is one of the most straightforward and widely used methods for monitoring and controlling project cost and schedule. For this reason, the EVM concepts have been used in this paper to propose a model to control environmental performance of a project during its execution process.

Recently, several studies have been conducted to estimate and report the total amount of GHG emissions contributed to construction phase of a project (Hong et al., 2016; Yeo et al., 2016; Wang et al., 2015; Sandanayake et al., 2016; Chou and Yeh, 2015; Hong et al., 2015). The issue of GHG emission control during project execution, however, has been seldom addressed in the literature. Kim et al. (2015) developed a method to evaluate CO_2, cost and schedule of building construction projects, using the cost and schedule performance indices (CPI and SPR). However, this method uses cost and schedule based criteria to monitor project overall performance and fails to decouple the environmental performance from cost and schedule profiles. Therefore, this model does not reflect the project current environmental variance also its final GHG emission.

The objective of this paper is to develop a model for estimation and control of GHG and some metrics to measure project GHGs emission performance at any point in time over the life of a project. The performance indices and forecasting formula are developed based upon the logic behind EVM methodology. In order to apply the proposed model in projects, a comprehensive study is conducted to collect information on GHG emission factors of various project activity data (such as material use, energy and fuel consumption, transportation). The proposed model is implemented in a work package of a real construction project.

The remainder of the paper is organized as follows: Section 2 presents information on greenhouse gas emissions, an overview of EVM methodology, and review of relevant publications. The proposed model and metrics for project GHG performance measurement are explained in Section 3. Section 4 discusses the results of applying the model in a construction project. Finally, conclusions and future works are given in Section 5.

2. Literature review

2.1. Greenhouse gas (GHG) emissions

The world will be dealing with a bigger challenge of GHG emissions reduction over the next decades. The latest report of the IPCC (IPCC, 2014b) indicates that although a large number of mitigation policies have been implemented so far, the growth of carbon emissions has increased over the last decade. Observations from very many of new mitigation scenarios show that to control temperature escalation within the 21st century, it is necessary to change business-as-usual. Moreover, the IPCC's scenarios-known as representative concentration pathways (RCPs)-promote efficiency improvements and behavioral changes to reduce energy demand in transport, buildings and industrial sectors and thereby provide more flexibility and diverse opportunities for reducing carbon intensity in energy supply sector.

Previous research makes it evident that a large amount of GHG emissions are being released from construction projects all around the world. For example, Noland and Hanson (2015) reported 2671.5 metric tons of CO_2-eq for a pavement rehabilitation project in the US, state of New Jersy. Fernández-Sánchez et al. (2015) calculated 390 k tons of CO_2-eq for a highway project in Ciudad Real, Spain. About 273.5 k tons of CO_2-eq was reported by Chou and Yek for a wholesale building project in Taiwan. In China, after performing a comprehensive study on different types of highway project, Wang et al. (2015) stated that there is an average CO_2-eq of 5229, 35,547, and 42,302 kg per meter for road, bridge, and tunnel construction, respectively.

It is possible to identify the most effective reduction strategies by accounting for emissions. Not only can this lead to energy and