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Assessing the impacts of preferential procurement on low-carbon building

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A R T I C L E I N F O

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A B S T R A C T

The significance of global warming is shaping building procurement, with much of the effort aimed at reducing greenhouse gas emissions through a preferential bidding mechanism. However, only a limited number of studies have quantitatively estimated the potential impact of bid preference on the emission reduction from building construction. The aim of this paper is to improve our understanding of how bid discounts change owners' procurement costs and the magnitudes of emission mitigation. A two-stage optimization model is designed to help the owner determine the discount rate that would automatically control the emission of the awarded contract within a desired level. The goal is for bidders to regard emission reduction efforts as an investment, with returns coming in the form of an increased chance of winning the bid. Our results imply that for the building retrofit project studied herein, a discount rate of 0.6 is suggested for every percentage of emission reduction. This discount level reduces greenhouse gas emissions by 28.2% while raising procurement costs by 3.7% relative to a non-preference mechanism. The increased procurement costs can be partially compensated under existing cap-and-trade scheme. The results show that the choice of discount significantly alters bidders' efforts on emission mitigation, and emission control cost can be minimized with the proposed optimization algorithm.

1. Introduction

The construction of residential and commercial buildings emits nearly 41 million metric tons (MT) of greenhouse gases (GHG) per year, making it the largest construction-related emission contributor in the United States (Truitt, 2009). An increasingly interest has been stirred to reduce GHG emissions using contract award criteria in building procurement (Bratt et al., 2013; Rietbergen and Blok, 2013). The award criteria are often built upon basic environmental requirements (European Commission, 2011; Local Governments for Sustainability, 2007; United Nations Development Programme, 2008; Varnäs et al., 2009). Those requirements originally targeted on controlling harmful substances and began to touch on GHG issues (Hamza and Greenwood, 2009; Tarantini et al., 2011). Different from harmful substances, GHG regulation requires more flexibility due to the variety of emission sources and the high cost of technology upgrades (Sterner, 2002). As a regulatory surplus, preferential bidding is widely seen as one of the most effective potential mechanisms available to governments to drive the GHG mitigation efforts of contractors (Correia et al., 2013).

Preferential mechanisms are extensively used in public procurement auctions (Colucci et al., 2012; Marion, 2007; Mougeot and Naegelen, 2005). One commonly used mechanism, a bid discount, improves the bids of favored companies by a predetermined rate when determining the winner but uses the actual amount of the winner's bid in the contract (Krasnokutskaya, 2007). The goal of most preferential mechanisms is to facilitate the integration of favored participants into the marketplace. Typical applications include granting a certain bid discount to small companies that are considered disadvantaged due to entry barriers.

Beginning in 2009, a few European regulation bodies initiated instruments for sustainable procurement that took GHG emission performance into consideration (Alvarez and Rubio, 2015; HM-Goverment, 2009; HNS-SDU, 2010; MoD, 2010). The CO_2 Performance Ladder (CO_2PL) is one of the most widely used procurement tools in European countries, which rewards concrete improvement in the GHG performance of companies in the form of a nominal discount on the tender price (ProRail, 2009). The CO_2PL uses the capability maturity model. The model has been categorized into

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five levels, numbered from 1 to 5. The discount on the tender price ranges from 1% to 10%. The higher the level of certification, the greater the discount awarded by the company. CO_2PL has been performed by 190 companies in the Netherlands and could achieve a GHG emission reduction of 0.8–1.5% per year (Rietbergen and Blok, 2013). However, this emission reduction potential is strongly affected by economic activity, as the companies participating in the scheme have set varying levels of ambition. This paper seeks to continue this conversation within the field of low-carbon procurement. Such a growth in significance will require a new understanding of carbon management in terms of procurement mechanism designs.

The key insight of this paper is that an optimal choice of the discount level can provide incentives to companies to reduce GHG emissions while keeping procurement costs under control. An owner potentially has strong flexibility in the design of the discount level for favored parties. This paper shows that the choice of discount significantly alters a company's incentives to participate in emission savings as well as the bid it submits. While it continues to be possible to use a preferential mechanism to regulate GHG emissions from projects, both the cost-minimizing and emission-minimizing level of the contract may change when discount effects are taken into account. The empirical determination of discount levels for currently accepted procurement instruments may yield unsatisfactory emission reductions, increased procurement costs or both.

The main objective of this study is to improve our understanding of the effects of a bid discount on procurement costs and the magnitudes of emission reductions. A model has been developed to simulate the bidders' behaviors in the presence of alternative bid discounts. The owner's decision of what discount to offer is based on his knowledge about bidders' behaviors and reflects a willingness to achieve an optimal cost-emission allocation. To establish an emission benchmark against which reductions can be quantified, a GHG emission estimation method is described that enables the emission inventory to be directly linked to the quantity takeoff of a building project. A cradle-to-gate assessment principle is followed, which takes into account the entire supply chain, from raw material extraction up to the point at which it is delivered to the customer. The model uncovers the underlying effects of a bid discount on the bidders' emission reduction efforts and can be valuable for state and local agencies that want to optimize sustainable procurement instruments and improve the carbon footprints of engineering practices.

2. Existing studies on emission estimation and proposed method

As Ochoa and Erdmenger (2003) and Erdmenger et al. (2001) have emphasized, the power of low-carbon procurement has been restrained by an immature method for carbon accounting. A number of studies have investigated the estimation of GHG emissions from building construction (Hong et al., 2014; Mattinen et al., 2014; Tsai et al., 2011; Yan et al., 2010). For instance, the Athena Impact Calculator is known to play an important role in analyzing the life-cycle environmental impact of building assembly following the CSI MasterFormat coding system (Athena, 2012). This calculator supports detailed emission analysis for envelope configurations but excludes some primary emission components, such as site construction, thermal and moisture protection and electrical systems. In addition to the Athena Impact Calculator, a wide range of other tools can assist in building assembly, such as the Building Carbon Calculator (CSBR, 2011) and the CO_2 Emissions Estimator Tool (WARP, 2006). These tools have been developed using databases from different countries, follow different estimation boundaries and basic assumptions and focus on different components of building construction. Despite their complementary functions, the wisdom of applying multiple tools in a single building project may be questioned due to inconsistent methodologies. Also important for effective estimation is the supporting information for emissions from product alternatives. The Building for Environmental Economic Sustainability (BEES), developed by the National Institute of Standards and Technology (NIST), develops a database that contains emission and cost information for approximately 230 building products classified under a Uniformat coding system (NIST, 2007). This product information serves as an important reference when making trade-offs between cost and emission levels for products with equivalent functions. Efforts are still needed to establish an estimation method that is applicable to all of building assemblies and compatible with existing emission databases as needed. This would help owners to determine emission baseline for an advertised project and measure emissions for all of the submitted bids with alternative construction plans.

Quantity takeoff often assists the estimation of the GHG emissions from materials and equipment and formulates an emission inventory as part of the bid. Building information modeling (BIM) contains a standardized set of formats that can be used to organize construction information, e.g., CSI MasterFormat and Uniformat (Volk et al., 2014). For a given project specification, BIM can produce the quantity takeoff automatically based on the calculation criteria set by the estimator. It has the ability to further take off the quantities when estimating assemblies and items, with a breakdown of construction material, equipment and subcontractor costs. This function provides the ability to decompose a single bid item into multiple separate emission sources. For the case in which multiple options are available for a given system, BIM allows a specifier to qualify building products side by side and determine which meets the criteria necessary to select it. This function enables weighing the emission performance and cost benefit of each product and determining the most effective option for the bid.

The emission sources of building construction encompass all of the lifecycle stages, from raw material acquisition to product installation, complying with the cradle-to-gate assessment principle (WRI, 2008). The GHG impact of constructing a building should be calculated by adding up the following emission sources:

- The production of each construction material and ancillary material;
- The transportation of materials from the factory gate to the construction site;
- Carbon stock changes in biomass, dead organic matter and mineral soils during site preparation e.g., clearing, grubbing and earthwork;
- All forms of energy consumed by equipment on the construction site, including relevant transport activities.

Each emission source is estimated using an independent assessment method and database, which can be found in our previous study (Liu et al., 2014). The boundary excludes the activities of operation and maintenance as well as GHG emissions associated with the production of capital goods having lifetimes longer than 1 year and the transportation of employees to and from their normal place of work.

An example of placing a beam is used to illustrate the process of estimating emissions from assembled tasks based on BIM outputs. The quantity of a beam job is reported in linear feet (L.F.) for a typical quantity takeoff using the MasterFormat coding system. The GHG estimation requires the emission factor in units of $kgCO_2e$ per L.F. for material production, transportation and equipment usage. The material emission factor for the beam (using steel) is estimated