Assessing the Impacts of Preferential Procurement on Low-Carbon Building

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Background

- Building - the largest CO$_2$ emission contributor in construction
- Preferential bidding
  - Used in public procurement
  - Emission saving incentives
  - Integration of favored participants
Current practices

CO₂ Performance Ladder (Netherlands)

Aspects:
A = Insights
B = Reduction ambition
C = transparency
D = participation in CO₂ initiatives

Ref. ProRail, 2009
Knowledge gap

Incorporation of environmental performance in contract award criteria

• Characterized as “basic environmental requirements”
• Limited attention to climate change issues
• Restrained by immature method for carbon accounting

Ref. Hamza and Greenwood, 2009; Tarantini et al., 2011; Varnas et al., 2009; Ochoa, 2003 and Erdmenger, 2001
Research needs

New understanding of carbon management in terms of procurement mechanism designs

This study aims to:

- Investigate the effects of bid discount on emission reduction
- Optimize the choice of discount level for public agency
- Improve the quantification of building emissions
Optimization problem description

- $N$ potential contractors interested in a building project
- A mix of design and performance specification
- Bid is comprised of both cost and emission information
- Bid is discounted based on emission savings
- The winner is paid the full amount of his bid
Determine the discount rate that automatically controls the emission of the awarded contract within a desired level.
Modelling bidder’s behavior

- First-price sealed-bid auction
- Bidders follow the same bidding strategy, $\beta(\cdot)$, mapping project cost, $c_i$, onto a bid $b_i$, $\beta(\cdot)$: $[c, \bar{c}] \rightarrow [b, \bar{b}]$.

Bayesian-Nash equilibrium

$$b_i(c_i) = c_i \cdot \left(\frac{n\delta_i + 1}{n\delta_i}\right)$$

in which
- $b_i$ represents the bid for bidder $i$ before the discount
- $\delta_i$ represents the bid discount for bidder $i$

Ref. Ausubel, 2003
Modelling owner’s behavior

- Scoring technique
- An optimal value of $\hat{r}$ that achieves an optimal cost-emission allocation

Social welfare function

$$\max_r PS(r) = \left( \frac{c_0 - c_k}{c_0} + \frac{e_0 - e_k}{e_0} \right)$$

s.t.

$$c_k = \bar{b}_k \cdot (1 + \delta_k)$$

$$\bar{b}_k = \min \{ \bar{b}_i \}_{i=1, \ldots, N}$$

$$e_k = \sum_{m, k} g_{m, k} q_{m, k} + \sum_{c} \sum_{n} \varphi_{c, n, k} g_{c, n, k} q_{c, n, k}$$

Cost saving

Emission saving
Case study

- A building retrofit project conducted in Virginia
- Work includes:

**Design Specification**
- Division 4 Masonry
- Division 5 Metals
- Division 8 Openings
- Division 23 Heating and ventilation
- Division 26 Electrical

**Performance Specification**
- Division 3 Concrete
- Division 6 Wood
- Division 7 Thermal and moisture
- Division 9 Finishes
- Division 32 Exterior improvements

Bidders have the flexibility to choose design alternatives
Basic assumptions

- Owner determined the emission benchmark and the baseline procurement costs for the “performance-based” divisions

- Bidders’ costs and emissions for the “design-based” divisions are the same

- Individual bidders cannot obtain access to all of the design alternatives
<table>
<thead>
<tr>
<th>Building product alternatives for bidders</th>
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</thead>
<tbody>
<tr>
<td><strong>1. Framing</strong></td>
</tr>
<tr>
<td>1.1 Generic wood framing-treated*</td>
</tr>
<tr>
<td>1.2 Generic wood framing-untreated</td>
</tr>
<tr>
<td><strong>2. Ceiling insulation</strong></td>
</tr>
<tr>
<td>2.1 Generic Blown Mineral Wool R-38*</td>
</tr>
<tr>
<td>2.2 Generic Blown Cellulose R-38</td>
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<tr>
<td>2.3 Generic Blown Fiberglass R-38</td>
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<tr>
<td><strong>3. Interior wall finishes</strong></td>
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<tr>
<td>3.1 Generic consolidated</td>
</tr>
<tr>
<td>3.2 Generic reprocessed latex paint</td>
</tr>
<tr>
<td>3.3 Generic virgin latex*</td>
</tr>
<tr>
<td><strong>4. Interior partitions</strong></td>
</tr>
<tr>
<td>4.1 P&amp;M Altree panels*</td>
</tr>
<tr>
<td>4.2 Trespa Athlon panels</td>
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<tr>
<td><strong>5. Concrete pad</strong></td>
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<tr>
<td>5.1 Generic 15% Fly Ash Cement*</td>
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<td>5.2 Generic 20% Slag Cement</td>
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<td>5.3 Generic 35% Slag Cement</td>
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<td>5.4 Lafarge Portland Type I Cement</td>
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<tr>
<td>5.5 Lafarge NewCem Slag Cement (20%)</td>
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<tr>
<td>5.6 Lafarge NewCem Slag Cement (35%)</td>
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</tbody>
</table>
Build owner’s decision model

Define model
\( r_0 \) - discount coefficient
\( e_0 \) - baseline emission level

For \( i = 1, \ldots, N \) of bidders
Set \( r_0 = 0.1 \)
Solve bidder’s decision model

Choose the awarded bid
\( \overline{b}_k = \min \{ \overline{b}_i \}_{i=1, \ldots, N} \)

CHECKING & UPDATING MODEL

For \( i = 1, \ldots, N \) of bidders
Compare \( PS(r_n) \) with \( PS(r_{n+1}) \)

If \( PS(r_n) < PS(r_{n+1}) \)
Yes
\( r = r_0 + 0.1 \)
Record as \( r_n \) a local optimality

No
If \( \delta > 25\% \)
Yes
Compare \( PSs \) for recorded locally optimal values of \( r \) and choose the largest one

End (globally optimal \( r \) found)

Social welfare function
Given a 0.6 discount rate, the emissions from the awarded contract can be reduced by 28.2%, while the procurement costs increase by 3.7%.
$r = 0.6$ is the highest among all of the feasible $r$ values that enable the owner to achieve a maximum social welfare function.
Conclusion

• The model provides a generally applicable tool that enables owners to tailor the bid discount to any building project

• For the building retrofit project studied herein, a discount rate of 0.6 can be offered to reduce CO₂ emissions by 28.2% but increases procurement costs by 3.7% relative to no intervention

• The framework for predicting behavioral patterns and making decisions is pertinent to other types of projects in which preferential policies are used
Thanks for your attention!
Welcome any comments and suggestions!

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