Green Building Incentive Approach: The Developer Perspective

Wen Jiang1*, Lanjun Wu1
1 College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, Chengdu, P.R. China
*Corresponding author’s e-mail: xuezhongsha_wen@163.com

Abstract. Green building has become a major measure for undermining the negative impact of construction industry on global environment and climate change. Government has announced series financial incentives including tax and construction fee discount to promote the adoption of green building. However, the contractor as a critical role in the process of going green has not been rewarded for the extra effort required. This study proposed an effective incentive mechanism for the contractor through game theory approach. The optimal incentive intensity and the optimal green level are obtained. Results show that incentive mechanism can successfully lower total cost for the developer and increases the profit for the contractor. Moreover, it facilitates the sustainable development on construction industry by increasing the green building level to higher ground.

1. Introduction

The greenhouse effect is regarded as the most significant challenge to the relationship between humanity and nature. The construction industry occupies the first position as the largest contribution of pollution and greenhouse gas emissions. It has been reported in the United Nation Environment Programme that the construction sector consumed about 40% of total energy and accounts for up to 30% greenhouse emissions [1].

Green building has been widely received by government around the world as a critical strategy to reduce or eliminate the negative impact of construction activities on the environment and climate change [2]. Typical example of innovation technology implemented on green building includes green roof technology, solar water heater, high-efficiency HVAC systems, and prefabrication concrete technology [3]. Adopting green building offers a range of significant benefits including lower operation cost, increased comfort, health, productivity, and increased market value[4]. Previous studies found that green building saved about 20% energy consumption on average compared to the baseline [5, 6].

The literature related to this study primarily focused on financial incentives on the green building. Gou et al. assessed developers’ market readiness to green construction including ideas on green construction and understanding of current green building policies, and indicated that expedited permits and density bonus are thought to be major incentives [7]. Tinker et al. investigated a green building program in the US during 1998 to 2002, and found that almost half the builders constructed just single green building. Construction contractors participated the program concurred that the program successfully benefits the owner but the additional work required for participation provided little financial reward for builders [8]. Various financial incentives such as direct grants, tax incentives, rebates and discounted development application fees have been proved to be an effective method of promoting green building [9]. However, lacking of mechanism to determine the optimal level of incentives has been...
thought as a vital issue [10]. Qian et al. proposed a game model aimed at promoting green building market while minimizing the transaction costs for going green [11]. Yang and Zhou analyzed main factors restricting the development of green buildings in China, and proposed a model that calculates the optimal degree of the government incentive intensity to ensure the Pareto optimal of the society [12]. Wu et al. investigated a cooperative incentive mechanism while considering the cooperative relationship between owners and contractors in sustainable construction projects [13]. Zhang analyzed the decisions of green building participators, enterprise, consumer and government, through the evolution game theory approach [14]. The literature above considered green building incentives from various perspectives including government, consumer, and construction developer. The construction contractor plays a significant role in the process of green building construction. Yet, no research has been carried out to compensate or reward the addition effort that the contractor has put into.

To address the gap in the literature, this study attempts to promote the adoption of green building from a new perspective of the contractor. A general contractor participates the project in an early stage, and solely responsible for most activities, from engineering, procurement to construction. Then, hand over the final construction to the construction developer. Similar to existed green building incentives, the developer introduces an incentive mechanism based contract to encourage the contractor achieving high green building standard. The decision opportunity of the green building level switches to the contractor. A trade-off is faced with the contractor, high green level can cost expensive, and gain the reward bonus. Alternatively, a low green level can be economic saving but give the reward up. Thus, the following key questions are addressed in this study:

1. What is the optimal incentive intensity setting for the developer to promote green building level and achieve lower operational cost?
2. What is the optimal green level for the contractor to decide under the incentive mechanism?

To answer these two questions, this study models a Stackelberg game between the contractor and developer. The optimal decision of both participates is obtained and the impact of incentive mechanism on the optimal cost and profit is analyzed. Further, the influence of two key factors, cost efficiency and energy efficiency, on the optimal decision and optimal cost and profit is examined.

The rest of this paper is organized as follow. The model description and assumptions are presented in Section 2. The optimal decision for contractor and developer are obtained in Section 3. A comparison of optimal cost and profit with incentive mechanism between without incentive is carried out in Section 4. Sensitive analysis of optimal decision is discussed in Section 5. A numerical example of the optimal cost and profit is presented in Section 6. Section 7 is the conclusion and some further working directions.

### 2. Model description

This study considers a Stackelberg game between a construction developer and an engineering procurement construction contractor. Assume that the construction developer is the Stackelberg leader, and the contractor is the Stackelberg follower.

First, the developer sets a bonus to encourage the contractor to construct green building with high certification level. Later, the contractor decides the green building certification level he will achieve in the finishing of the construction process. Throughout this paper, we use the parameters and variables as the following notations in Table 1.

| Notation | Description |
|----------|-------------|
| $t$      | The bonus intensity of construction developer |
| $g$      | The green building certification level of contractor |
| $g_0$    | The initial green building level of the developer required |
| $C_o$    | Basic operation cost of building per unit area |
| $C_b$    | Basic construction cost per unit area |
| $C_c$    | Construction investment of developer per unit area |
The increment cost of the contractor per unit area

Increment cost coefficient of green building level

Coefficient of Energy efficiency, \( \varepsilon \in (0,1) \)

In addition, to make the model more practical, the parameters must satisfy certain conditions for the model to make sense, so we assume:

1. The bonus is a linear function related to bonus intensity and green building level, that is \( B(t) = t(g - g_0) \).

2. The increment cost function of the contractor is a strictly monotonic increasing of \( g \), then \( C_g = \frac{1}{2} \eta_1 (g - g_0)^2 \). This represents the increasing marginal cost for the contractor while innovating green building technology and promoting green level higher than \( g_0 \).

3. Operation cost consists of energy consumption only, other costs are neglected. Green technology such as high-efficiency windows, green roof, solar shading devices can lower power and water consumption. The cost saving of green building is related to green building level, that is \( \theta = 1 - \varepsilon(g - g_0) \).

The total cost of construction developer is in equation (1).

\[
\min_t C(t) = \min_t (\theta C_o + C_t) = \min_t [(1 - \varepsilon(g - g_0))C_o + C_b + t(g - g_0)]
\]

Where \( C_t = C_b + B \), construction investment consists of basic costs and bonus.

The profit of the contractor is in equation (2).

\[
\max_g P(g) = \max_g (C_c - C_g) = \max_g [C_b + t(g - g_0) - \frac{1}{2} \eta_1 (g - g_0)^2]
\]

3. The optimal decision of bonus intensity and green level

For the optimal bonus intensity of the developer \( t^* \) and optimal green level of the contractor \( g^* \) under incentive mechanism, the following proposition is obtained.

**Proposition 1.** With incentive mechanism, the optimal bonus intensity of the developer satisfies \( t^* = \frac{eC_o + \eta_1 g_0}{2} \) and optimal green level of the contractor is \( g^* = \frac{eC_o}{2\eta_1} + g_0 \).

**Proof.**

The first deviation of contractor\( \frac{dp(g)}{dg} = t - \eta_1(g - g_0) \). The second deviation is \( \frac{d^2p(g)}{dg^2} = -\eta_1 < 0 \).

The profit function of contractor \( P(g) \) is concave in \( g \). From \( \frac{dp(g)}{dg} = 0 \), the best response of the contractor is a function of \( t \), \( g(t) = \frac{t}{\eta_1} + g_0 \).

Submit \( g = g(t) \) into equation (1). Then, the first deviation of \( C(t) \) is \( \frac{dC(t)}{dt} = \frac{2t - eC_o}{\eta_1} \). The second deviation \( \frac{d^2C(t)}{dt^2} = \frac{2}{\eta_1} > 0 \). Then, the total cost is a concave function of \( t \). Let \( \frac{dC(t)}{dt} = 0 \), the optimal bonus intensity can be obtained \( t^* = \frac{eC_o}{2} \). The optimal decision of the contractor is obtained as \( g^* = \frac{eC_o}{2\eta_1} + g_0 \).

This proposition means that in a bonus incentive mechanism, the optimal green effort of contractor along with optimal bonus intensity and optimal green building level are existent and unique. From observation, \( g^* > g_0 \) represent that optimal green level is consistently greater than initial green level.

4. Comparison of incentive mechanism

This part of the study attempt to analyse the impact of incentive mechanism compares to without incentive. The following proposition is obtained.

**Proposition 2.** \( P(g^*) > P_n^* \), \( C(t^*) < C_n^* \), \( P(g^*) - P_n^* = -\frac{1}{2} (C(t^*) - C_n^*) \).
Proof.
As for the situation that without incentive mechanism, the cost function of the developer is stated as 
\[ C_n = (1 - \varepsilon (g - g_0)) C_0 + C_b \] and the profit function of contractor is formulated as 
\[ P_n(g) = \max_g \left[ C_0 - \frac{1}{2} \eta_1 (g - g_0)^2 \right]. \] Without the decision of bonus setting, the only variable faced is green building level of the contractor. The solution is similar to the one with incentive mechanism,
\[ \gamma_0 = \frac{\eta_1 (g - g_0)}{\gamma_1}, \quad \gamma_1 = C_0 + C_b. \] The maximal profit of the contractor is \[ P_n^* = C_0. \]

This proposition shows that the total cost of developer decreases with incentive mechanism, and the profit of contractor also increase with that. The increased profit contractor is half of the decreased cost of developer.

4.1. The boundary of incentive bonus
This part of the study focuses on the impact of different settings of bonus intensity. The following proposition is obtained.

Proposition 3. When \( t > \varepsilon C_0 \), \( C(t) - C_n^* > 0 \). When \( \varepsilon C_0 > t > 0 \), \( P(g) - P_n^* > 0 \) and \( C(t) - C_n^* < 0 \).

Proof.
Let the difference of cost equals to \( C_\delta = C(t) - C_n^* = -\varepsilon (g - g_0) C_0 + t (g - g_0) \). Denote the difference of profit as \( P_\delta = P(g) - P_n^* = t (g - g_0) - \frac{1}{2} \eta_1 (g - g_0)^2 \). Solve \( P_\delta = 0 \), we can obtain that \( g_1 = g_0, g_2 = g_0 + \frac{2t}{\eta_1} \). Submit \( g_2 \) into \( C_\delta \), then \( C_\delta = \frac{2t(t - \varepsilon C_0)}{\eta_1} \), solve the equation of \( C_\delta = 0 \).

This proposition shows that if the bonus intensity higher than \( \varepsilon C_0 \), then the cost of the developer is higher than that without incentive mechanism. If the bonus intensity between 0 and \( \varepsilon C_0 \), then the cost of developer with incentive is lower than that without incentive mechanism, and the profit of contractor remain higher than without insensitive. That is, the lower boundary \( t = 0 \) ensures that profit of contractor remain higher than without insensitive. The higher boundary \( \tilde{t} = \varepsilon C_0 \) guarantees that cost of the developer consistently lower than the one without incentive.

5. Sensitive analysis
In order to achieve better understanding of the impact from other parameters, resource utilization ability and maturity of green building technology etc., on the optimal decision strategies. A well-experienced contractor can be capable of smaller cost efficiency. Also, matured green building technology can lead to higher energy efficiency. This part applies sensitivity analysis on the parameter \( \eta_1, \varepsilon \). The following proposition is obtained.

Proposition 4. \( t^* \) is increasing in \( \varepsilon \) and \( \eta_1 \). \( g^* \) is increasing in \( \varepsilon \) and decreasing in \( \eta_1 \).

Proof.
From Proposition 1, this study came to knowledge that \( t^* = \frac{\varepsilon C_0 + \eta_1 g_0}{2} \) and \( g^* = \frac{\varepsilon C_0}{2\eta_1} + g_0 \). The deviation of \( \frac{dt^*}{\varepsilon} = \frac{C_0}{2} > 0, \frac{dg^*}{\varepsilon} = \frac{C_0}{2\eta_1} > 0, \frac{dt^*}{\eta_1} = \frac{g_0}{2} > 0, \frac{dg^*}{\eta_1} = -\frac{\varepsilon C_0}{2\eta_1^2} < 0 \). Thus, \( t^* \) is increasing in both \( \varepsilon \) and \( \eta_1 \). \( g^* \) is also increasing in \( \varepsilon \) and decreasing in \( \eta_1 \). This completes the proof.

This proportion indicates that the optimal decision of developer and contractor are affected by energy. As the cost efficiency of contractor increases, the developer increases the bonus setting. On the contrary, the contractor decrease the green building level to ensure its own profit is maximized. The optimal bonus
intensity of the developer and green building level of the contractor increases with the increasing of energy efficiency.

6. Numerical example
A numerical example is provided to demonstrate the feasibility of the mathematical models and analyses the impact of cost efficiency \( \eta_1 \) and energy efficiency \( \varepsilon \) on the cost and profit. This study specifies \( C_0 = 400, \ C_d = 1000, \ g_0 = 0, \text{ and } \varepsilon = 0.2 \) while investigating the impact of \( \eta_1, \ \eta_1 = 50 \) when investigate the effect of \( \varepsilon \).

Figure 1 (a) depicts that as the cost efficiency increasing, the cost of developer increases and the profit of contractor decreases. The changing becomes less significant as the cost efficiency increases. It’s critical for the contractor commits to enhance its own management level, and equally vital to the developer to select an excellent contractor.

Figure 1 (b) illustrates that optimal cost decreases and optimal profit increases as energy efficiency of green building increases. The initial cost and profit are equal to those without incentive mechanism, which are 1400 and 1000. The developer achieves lower cost and the contractor gains greater profit compares to the initial results.

![Figure 1 Impact of cost efficiency (a) and energy efficiency (b) on optimal cost and profit](image)

7. Conclusion and discussion
This study attempts to promote the adoption of green building by setting incentive for the contractor. Through a Stackelberg game theory method, the optimal bonus intensity for the contractor and the optimal green level for the contractor are obtained. The primary findings are that the incentive mechanism not only successfully lowers total cost for the developer and increases the profit for the contractor, but also raises the green level of the construction. Also, under the proposed linear incentive, the improvement of the developer is twice as much as the contractor. Results of sensitive analysis and numerical example indicate that increasing of cost efficiency for the contractor will undermine the benefit of both the developer and the contractor, and increasing of energy efficiency will benefit both participants.

Similar to existed researches, this study carried has its own limitations. A Stackelberg game between a contractor and a developer is considered in this study. However, the construction industry is characterized of multiple participates, including general contractor and certain subcontractors. The market advantages of green building, price premium and demand preference, are not considered in this paper. The study can provide better management insights and decision support if these variations are considered.

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