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# Pricing and incentive strategy for construction supply chain w ith carbon emission sensitive heterogeneous demand and gove rnment subsidies

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# Pricing and incentive strategy for construction supply chain with carbon emission sensitive heterogeneous demand and government subsidies

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**Abstract**: Based on consumers' purchase intention, this paper obtains the utility function of carbon emission sensitive heterogeneous consumers and establishes a two-level supply chain model composed of the owner and the contractor under the government subsidy. Based on the principle of maximizing the profits of each member of the supply chain, the optimal pricing, incentive intensity and emission reduction effort level of the owners and contractors are obtained. On this basis, the influences of government subsidies, customer composition ratio and carbon sensitivity on the owner's optimal decision are analyzed. The results show that, with the increase of government subsidies for the contractor emission reduction costs, the proportion of carbon emission-sensitive consumers and the carbon sensitivity of consumers will increase, and the market demand will be increased, which will not only improve the profits of owners and contractors, but also the contractors' emission reduction efforts. It can provide decision-making reference for enterprise product pricing, emission reduction and government subsidies.

## 1. Introduction

Nowadays, global warming is attracting more and more attention. It has gradually become the focus topic of the international community, and poses severe challenges to the survival and development of mankind. The problem of carbon emissions has become a major problem faced by governments and society. Under the pressure of tremendous climate change, all countries are looking for a low carbon, low pollution and sustainable low-carbon economic development mode.

In recent years, with the development of low-carbon economy and the improvement of consumers' low-carbon awareness, Price is no longer the only factor affecting customers' purchasing decisions, and carbon emissions play an increasingly significant role in customers' purchasing behavior. Such low-carbon preference behavior of consumers will also increase the enthusiasm of enterprises to develop low-carbon products. However, the low-carbon construction needs higher technical requirements and more cost input, which makes the construction supply chain enterprises flinch. In order to maximize social benefits, the government formulates subsidy policies to guide developers to reduce building carbon emissions and promote low-carbon buildings throughout the society [1]. The government's guidance on low carbon consumption, market demand has changed from traditional price-sensitive to carbon emission-sensitive heterogeneity. Traditional price sensitive customers tend to focus on price rather than product carbon emissions. With the improvement of customers' awareness of environmental protection, some customers not only pay attention to the price of products, but also pay attention to the carbon emission of products, that is, environmentally friendly customers. When environment friendly customers and traditional price sensitive customers coexist, carbon emission sensitive heterogeneous demands are formed. Corporate profit level is not only related to the sales price, but also related to the proportion of carbon emission sensitive customers and carbon emission sensitivity. In order to cope with the carbon emission sensitive heterogeneous demand of customers, the owner and the contractor sign a fixed total price plus emission reduction incentive contract, prompting the contractor to pay more carbon emission reduction efforts [2]. When the proportion of environmentally friendly is higher, the owners will increase the incentives to encourage the contractors to make more reduce emissions efforts, and the sales price can be appropriately increased to obtain more benefits. On the contrary, when the proportion of traditional price sensitive is higher, the owner will reduce the incentive strength, and at the same time, the market demand will be improved by lowering the sales price. Therefore, the owner faces two decisions: one is how to determine the selling price; the other is how to maximize the profit of the owner to award the contractor the emission reduction incentive.

Rest of the paper is organized as follows. Related literature is presented in Section 2. The model description and assumption are presented in Section 3. In Section 4, we established the decision-making model under centralized financing. Sensitive analysis is presented in Section 5. Finally, section 6 concludes this paper and presents area for future investigation.

## 2. Literature review

### *2.1 Research on bonus incentive mechanism of construction supply chain*

The literature related to this study primarily focus on financial incentives on the low-carbon building. Babich et al. studied the design of supplier incentive contract under asymmetric demand information, and the results showed that the contract could realize the arbitrary distribution of profits between suppliers and retailers. [3]. Hosseinian and Carmichael established the optimal bonus incentive model between owners and contractors based on different risk preferences, and extended to multi-objective (duration, cost and safety) bonus incentive model in non-cooperative situations [4]. Kerkhove and Vanhoucke developed a decision system consisting of three modules: incentive contract design, multi-objective trade-off and performance evaluation, based on multi-objective trade-offs of cost, duration, safety and effort [5]. Onuoha IJ et al. using structural equation modelling methods to identify and simulate the incentive factors that affect the decision-making of developers and investors to invest in green commercial real estate [6]. The above literatures have laid a good foundation for the construction of incentive contract model for emission reduction. However, there are few researches on the application of incentive mechanism to contractor emission reduction input. Therefore, this paper aims to address this research gap by focusing on the incentive mechanism of the contractor.

### *2.2 Operation decision of enterprises under government subsidy*

Hong et al. Analyzed the effect of government subsidies on the promotion of electric vehicles [7]. Chang et al. Established a system dynamics model to study the emission reduction effect of Taiwan's subsidy to solar water heater products [8]. Based on government subsidies, she et al. Studied the impact of government intervention on the green supply chain. The results showed that the government financial subsidies can effectively guarantee green manufacturers to obtain reasonable profits [9]. Liu et al. studied the incentive policy of green building development in Beijing. It adopted different Subsidy Methods for low carbon building supply end and low carbon building consumption terminal to promote the development of low carbon construction market [10]. Liu et al. pointed out the importance of the design of incentive mechanism for low-carbon buildings, used the game model to study the government subsidies to developers and consumers, and finally put forward policy suggestions [11]. Liu et al. believe that low-carbon buildings play a positive role in energy conservation, environmental protection, construction of ecological city and other aspects, but they will be hindered by high incremental cost and long payback period in the implementation process, which requires government subsidies to ensure the development of low-carbon buildings[12]. Yue et al. proposed that in order to achieve the goal of green building of low-income housing, we must adopt appropriate incentive policies and focus on the government's financial subsidies to the owners [13].

The above literatures studied the bonus incentive mechanism of construction supply chain and the operational decisions of supply chain enterprises under government subsidies. However, very little research has been done regarding emission reduction and pricing decisions of construction supply chain under government subsidies. Therefore, this paper aims to address this research gap by focusing on government subsidy and owner incentive mechanism

This paper studies the secondary construction supply chain composed of the owner and the contractor. In order to encourage the contractor to invest more costs to reduce emissions and reduce the carbon emission of products to a greater extent, not only the government subsidizes the cost of contractors' investment in carbon emission reduction, but also the owner sign a fixed total price plus bonus contract with contractors to encourage the contractor to pay more efforts in emission reduction. A decision-making is faced with the contractor， increase a high level of emission reduction efforts, obtain government subsidies and emission reduction incentives. Alternatively, Low level of emission reduction efforts can save costs, the questions of interest in this paper are as follows:

(1) What is the optimal incentive coefficient for the owner to encourage the contractor to reduce emissions?

(2) what is the optimal emission reduction for the contractor Under the incentive mechanism?

(3) What is the optimal sale price of the owner?

To answer these questions, we use Hotelling model to establish the consumer utility function in this paper, the optimal decision of both participates is obtained. Further, the influence of government subsidies, the proportion of carbon sensitive consumers and the sensitivity of consumers on optimal decision is examined.

## 3. Model description and assumption

This paper considers a two-level supply chain composed of the owner, the contractor and carbon emission sensitive heterogeneous consumers. With the deepening of the concept of low-carbon development and the improvement of people's living standards and environmental awareness, in order to encourage contractors to reduce emissions, the government gives contractors a certain amount of emission reduction cost subsidies to reduce the carbon emission reduction of unit products to a greater extent. The owner determines the sale price and the emission reduction award paid to the contractor, who is responsible for producing the low-carbon products and determining the carbon emission reduction effort level of the products. Consumers determine their demand for products based on their sensitivity to price and low carbon products.

In order to analyze and describe the problem more clearly, we use the parameters and variables as the following notations in Table 1.

Table 1 Notations

| Notation | Description |
|---|---|
| $D$ | The market demand |
| $p$ | The selling price of the product |
| $\eta$ | customer sensitivity to the product $\eta \in (0,1)$ |
| $\mu$ | Carbon emission reduction incentive coefficient $\mu > 0$ |
| $\xi$ | Cost coefficient of carbon emission reduction $\xi > 0$ |
| $\alpha$ | The proportion of carbon emission sensitive customers in the market |
| $e_0$ | Initial carbon emissions per unit product |
| $e_1$ | Actual carbon emissions per unit product |
| $c_1$ | Fixed total price |
| $c_2$ | Fixed construction cost |
| $v$ | customer valuation of the product |
| $t$ | Government subsidy coefficient for contractor's carbon emission reduction cost |

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 market consisting of carbon emission sensitive customers and price sensitive customers, whose total number is standardized as 1. Under the guidance of the government to the low carbon market, the market demand has changed from the traditional price sensitive to the carbon emission sensitive heterogeneity. The proportion of carbon emission sensitive is $\alpha$, and the proportion of price sensitive is $1-\alpha$. Customers decide whether to buy products according to their utility. Products for customers in valuation $v$ obey [0, 1] uniform distribution, customers only buy one product at most. When a price sensitive customer's estimate of the product is higher than the sales price of the product, the product will be purchased; otherwise, they will leave the market. Carbon emission sensitive weigh price against low-carbon utility to decide whether to buy a product.

(2) This paper refers to Hotelling model to construct customer utility function [14]. The utility functions of carbon emission sensitive to purchase products is $U_e = v - p + \eta(e_0 - e_1)$, the utility functions of price sensitive customers to purchase products is $U_u = v - p$. $v$ is the customer's valuation of the product,$e_0 - e_1$ is the contractor's emission reduction effort level, $\eta(e_0 - e_1)$ is the customer's low carbon utility.

(3) The contractor receives the emission reduction incentive paid by the owner as $\mu(e_0 - e_1)$, $\mu > 0$. The higher the level of emission reduction efforts, the greater the incentives the owner will award to the contractor. The contractor's carbon emission reduction cost function is $\frac{1}{2}\xi(e_0 - e_1)^2$, $\xi > 0$. According to the contractor's emission reduction effort level, the owner needs to make the decision on the contractor's emission reduction incentive level with its own profit maximization.

(4) The contractor's fixed total price and fixed construction cost remain unchanged before and after emission reduction, which are $c_1$,$c_2$ and $c_1 > c_2 > 0$, respectively.

## 4. The model

In order to meet the market demand, the owner and the contractor signed the contract of fixed price plus bonus to encourage the contractor to make more emission reduction efforts. The owner takes the profit maximization as the goal to decide the emission reduction incentive for the contractor. Under the incentive of government emission reduction cost subsidy and owner emission reduction bonus, the contractor takes profit maximization as the goal to determine the emission reduction effort level of the product. We consider the impact of price sensitivity and emission sensitivity on demand, when a price sensitive customer's estimate of the product is higher than the sales price of the product, the product will be purchased; otherwise, they will leave the market. Carbon emission sensitive weigh price and low-carbon utility to decide whether to buy a product. Firstly, two customer demand functions are obtained under the carbon emission sensitive heterogeneous demand. Secondly, the owner's emission reduction incentive and sales pricing model are established. The owner's optimal emission reduction incentive and sales price are obtained. Finally, the influence of government subsidy, customer composition ratio and emission sensitivity on the owner's optimal decision making and maximum expected profit is discussed.

For products in the market, carbon emission sensitive customers need to meet the requirements of $U_e = v - p + \eta(e_0 - e_1) > 0$,get to $0 < p - \eta(e_0 - e_1) < v < 1$, the number of carbon emission sensitive is $d_e = \alpha\int_{p-\eta(e_0-e_1)}^{1} f(v)dv = \alpha[1 - p + \eta(e_0 - e_1)]$.Price sensitive customers need to meet the requirements of $U_u = v - p > 0$,get to $0 < p < v < 1$, the number of carbon emission sensitive is $d_u = (1-\alpha)\int_p^1 f(v)dv = (1-\alpha)(1-p)$.So, the market demand is $D(\alpha,\eta) = d_e + d_u = \alpha[1 - p + \eta(e_0 - e_1)] + (1-\alpha)(1-p)$, simplify the above formula to get $D(\alpha,\eta) = 1 - p + \alpha\eta(e_0 - e_1)$. Based on the above model assumptions and variable settings, the owner's profit, denoted by $\pi_m(p,\mu)$, is

$$\pi_m(p,\mu) = pD(\alpha,\eta) - c_1 - \mu(e_0 - e_1), \text{ that is } \pi_m(p,\mu) = p[1 - p + \alpha\eta(e_0 - e_1)] - c_1 - \mu(e_0 - e_1) \quad (1)$$

The first term is total revenue. The second term is the contractor's fixed total price. The last term is the contractor's emission reduction incentive. Then the decision model for the developer's profit maximization is $max\pi_m(p,\mu)$.

The contractor's profit, denoted by $\pi_r(e_1)$, is

$$\pi_r(e_1) = c_1 + \mu(e_0 - e_1) - c_2 - \frac{1}{2}(\xi - t)(e_0 - e_1)^2 \quad (2)$$

The first term is fixed total price of the contractor. The second term is the contractor's emission reduction incentive. The third term is fixed construction cost. The last two items are divided into contractor's emission reduction cost and government subsidies for the cost of reducing emissions to contractors. Then the decision model for the contractor's profit maximization is $max\pi_r(e_1)$.

**Proposition 1** When $4\,(\xi - t) - \eta > 0$, then $p^* = \frac{2(\xi-t)}{4\,(\xi-t)-(\alpha\eta)^2}$ ,$\mu^* = \frac{\alpha\eta\,(\xi-t)}{4\,(\xi-t)-(\alpha\eta)^2}$ and $e_1{}^* = e_0 - \frac{\alpha\eta}{4\,(\xi-t)-(\alpha\eta)^2}$.

Proof: The first deviation of $\pi_r(e_1)$ is $\frac{d\pi_r(e_1)}{de_1} = -\mu + (\xi - t)(e_0 - e_1)$.The second deviation of contractor is $\frac{d^2\pi_r(e_1)}{de_1{}^2} = -\,(\xi - t) < 0$,The profit function of contractor $\pi_r(e_1)$ is a concave function of $e_1$. Set$\frac{d\pi_r(e_1)}{de_1} = 0$ to get $e_1(\mu) = e_0 - \frac{\mu}{(\xi-t)}$. Then, replace $e_1(\mu)$ to formula (1), the second-order partial derivative of $\frac{\partial^2\pi_m(p,\mu)}{\partial p^2} = -2 < 0$,the second-order partial derivative of $\frac{\partial^2\pi_m(p,\mu)}{\partial\mu^2} = -\frac{2}{(\xi-t)} < 0$，we can obtain that hessian matrix is $H^N = \begin{vmatrix} -2 & \frac{\alpha\eta}{(\xi-t)} \\ \frac{\alpha\eta}{(\xi-t)} & -\frac{2}{(\xi-t)} \end{vmatrix} = \frac{4\,(\xi-t)-(\alpha\eta)^2}{(\xi-t)^2}$ (3),When $4\,(\xi - t) - \eta > 0$ is satisfied, $H^N > 0$,and$-\,2 < 0$,thus, the hessian matrix is negative definite. $\pi_m(p,\mu)$ is a joint concave function of $p$ and $\mu$.Let$\frac{\partial\pi_m(p,\mu)}{\partial p} = 0$ and $\frac{\partial\pi_m(p,\mu)}{\partial\mu} = 0$, we get the optimal price $p^* = \frac{2(\xi-t)}{4\,(\xi-t)-(\alpha\eta)^2}$, optimal emission reduction reward $\mu^* = \frac{\alpha\eta\,(\xi-t)}{4(\xi-t)-(\alpha\eta)^2}$. Finally, replace $\mu^*$ to $e_1(\mu)$, we can obtain $e_1{}^* = e_0 - \frac{\alpha\eta}{4\,(\xi-t)-(\alpha\eta)^2}$. This completes the proof.

The proposition means that considering the customer composition ratio, emission sensitivity and government subsidies, the optimal price ($p^*$) and emission reduction reward ($\mu^*$) of the owner and optimal emission reduction effort level ($e_1{}^*$) of the contractor are in existent and unique.

Bring $e_1^*$,$\mu^*$ and $p^*$ into equation (1), that the maximum profit of the owner is

$$\pi_m(p^*,\mu^*) = \frac{(\xi-t)}{4\,(\xi-t)-(\alpha\eta)^2} - c_1 \qquad (3)$$

Bring $e_1^*$ and $\mu^*$ into equation (2), that the maximum profit of the contractor is

$$\pi_r(e_1^*) = \frac{(\alpha\eta)^2\,(\xi-t)}{2[4\,(\xi-t)-(\alpha\eta)^2]^2} + c_1 - c_2 \quad (4)$$

## 5. Sensitive analysis

In order to achieve better understanding of the impact from other parameter, including the customer composition ratio, emission sensitivity and the government's subsidy to the contractor's emission reduction cost, on the optimal decision strategies, this part applies sensitivity analysis on the parameter $\alpha$ , $\eta$ and $t$.

The following propositions are obtained.

**Proposition 2** (1) $\frac{dp}{d\alpha} > 0$, $\frac{dp}{d\eta} > 0$, $\frac{dp}{dt} > 0$, $p^*$is increasing in $\alpha$ , $\eta$ and $t$.

(2) $\frac{d\mu}{d\alpha} > 0$, $\frac{d\mu}{d\eta} > 0$, $\frac{d\mu}{dt} > 0$, $\mu^*$is increasing in $\alpha$, $\eta$ and $t$.

(3) $\frac{de_1}{d\alpha} < 0$, $\frac{de_1}{d\eta} < 0$, $\frac{de_1}{dt} < 0$, $e_1{}^*$ is decreasing in $\alpha$, $\eta$ and $t$.

(4) $\frac{d\pi_m(p^*,\mu^*)}{d\alpha} > 0$, $\frac{d\pi_m(p^*,\mu^*)}{d\eta} > 0$, $\frac{d\pi_m(p^*,\mu^*)}{dt} > 0$ , $\pi_m(p^*,\mu^*)$ is increasing in $\alpha$, $\eta$ and $t$.

(5) $\frac{d\pi_r(e_1^*)}{d\alpha} > 0$, $\frac{d\pi_r(e_1^*)}{d\alpha} > 0$ , $\frac{d\pi_r(e_1^*)}{dt} > 0$, $\pi_r(e_1^*)$is increasing in $\alpha$, $\eta$ and $t$.

Proof: From proposition 1, we have $p^* = \frac{2(\xi-t)}{4(\xi-t)-(\alpha\eta)^2}$, $\mu^* = \frac{\alpha\eta(\xi-t)}{4(\xi-t)-(\alpha\eta)^2}$, $e_1{}^* = e_0 - \frac{\alpha\eta}{4(\xi-t)-(\alpha\eta)^2}$, $\pi_m(p^*,\mu^*) = \frac{(\xi-t)}{4(\xi-t)-(\alpha\eta)^2} - c_1$ and $\pi_r(e_1^*) = \frac{(\alpha\eta)^2(\xi-t)}{2[4(\xi-t)-(\alpha\eta)^2]^2} + c_1 - c_2$ .Then $\frac{dp^*}{d\alpha} = \frac{4\eta^2\alpha(\xi-t)}{[4(\xi-t)-(\alpha\eta)^2]^2} > 0$, $\frac{dp^*}{d\eta} = \frac{4\alpha^2\eta(\xi-t)}{[4(\xi-t)-(\alpha\eta)^2]^2} > 0$, $\frac{dp^*}{dt} = \frac{2(\alpha\eta)^2}{[4(\xi-t)-(\alpha\eta)^2]^2} > 0$,$\frac{d\mu^*}{d\alpha} = \frac{\eta(\xi-t)[4(\xi-t)+(\alpha\eta)^2]}{[4(\xi-t)-(\alpha\eta)^2]^2} > 0$, $\frac{d\mu^*}{d\eta} = \frac{\alpha(\xi-t)[4\xi+(\alpha\eta)^2]}{[4(\xi-t)-(\alpha\eta)^2]^2} > 0$, $\frac{d\mu}{dt} = \frac{(\alpha\eta)^3}{[4(\xi-t)-(\alpha\eta)^2]^2} > 0$. Thus, $p^*$ is increasing in $\alpha$, $\eta$ and $t$. $\mu^*$ is increasing in $\alpha$, $\eta$ and $t$. Then $\frac{de_1{}^*}{d\alpha} = -\frac{\eta[4(\xi-t)+(\alpha\eta)^2]}{[4(\xi-t)-(\alpha\eta)^2]^2} < 0$, $\frac{de_1{}^*}{d\eta} = -\frac{\alpha[4\xi+(\alpha\eta)^2]}{[4\xi-(\alpha\eta)^2]^2} < 0$, $\frac{de_1{}^*}{dt} = -\frac{4\alpha\eta}{[4(\xi-t)-(\alpha\eta)^2]^2} < 0$. thus, $e_1{}^*$ is decreasing in in $\alpha$, $\eta$ and $t$. Then $\frac{d\pi_m(p^*,\mu^*)}{d\alpha} = \frac{2\eta^2\alpha(\xi-t)}{[4(\xi-t)-(\alpha\eta)^2]^2} > 0$, $\frac{d\pi_m(p^*,\mu^*)}{d\eta} = \frac{2\alpha^2\eta(\xi-t)}{[4(\xi-t)-(\alpha\eta)^2]^2} > 0$, $\frac{d\pi_m(p^*,\mu^*)}{dt} = \frac{(\alpha\eta)^2}{[4\xi-(\alpha\eta)^2]^2} > 0$, $\frac{d\pi_r(e_1^*)}{d\alpha} = \frac{\eta^2\alpha(\xi-t)[4\xi+(\alpha\eta)^2]}{[4(\xi-t)-(\alpha\eta)^2]^3} > 0$, $\frac{d\pi_r(e_1^*)}{d\eta} = \frac{\alpha^2\eta\xi[4(\xi-t)+(\alpha\eta)^2]}{[4(\xi-t)-(\alpha\eta)^2]^3} > 0$, $\frac{d\pi_r(e_1^*)}{dt} = \frac{(\alpha\eta)^2[4(\xi-t)+(\alpha\eta)^2]}{2[4(\xi-t)-(\alpha\eta)^2]^3} > 0$. Thus, $\pi_m(p^*,\mu^*)$ and $\pi_r(e_1^*)$ are increasing in $\alpha$, $\eta$ and $t$. This completes the proof.

This proposition means that with the increase of the government's subsidy to the contractor's emission reduction cost($t$), the higher the proportion of carbon emission sensitive consumers ($\alpha$) and the sensitivity of consumers to products($\eta$), the more consumers are encouraged to buy low-carbon products and increase the market demand, so the owner can improve the product price and obtain more profits. On the other hand, in order to urge the contractor to increase carbon emission reduction efforts, the owner pays more carbon emission reduction incentives to the contractor, so as to reduce the actual carbon emissions of products, and the contractor will obtain more profits.

## 6. Conclusion and future research

The purpose of this study is to promote the development of low carbon buildings through incentive construction contractors. In this paper, we build a two-level supply chain composed of the owner and the contractor under the government subsidy. We consider the situation that consumers are carbon emission sensitive heterogeneity, it constructs the pricing and emission reduction model of supply chain enterprises, and the optimal pricing and incentive strategies of owners and the level of emission reduction efforts of contractors is studied. The study finds that under the government subsidy and incentive mechanism, the Contractor's efforts to reduce emissions have improved, and the profit of the owner and the contractor increased. The results of sensitivity analysis show that the proportion of carbon emission sensitive consumers, carbon sensitivity and government subsidies are the key factors for owners to make optimal decisions. The higher the government's subsidy to the contractor's emission reduction cost, the proportion of carbon emission sensitive consumers and the sensitivity of consumers to products, the more profit the owner and the contractor will get.

Similar to many other previous studies, this research has some limitations which open avenues for future research. For example, This paper only considers the owner and the contractor of the two- level supply chain , It can be can extend the model by considering subcontractors and other participants. Moreover, in future studies, the influence of different government subsidies on the optimal decision of enterprises can be considered. It will be useful and a more challenging research if these factors are considered.

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## References

[1] Anna. Game Analysis of Economic Incentive Policies for Green Building Demand End. Ecological Economy, 2012 (2): 107-110.

[2] Chan A P C, Chan W M, Fan C N, etc. Achieving Partnering Success through An Incentive Agreement: Lessons Learned from An Underground Railway Extension Project in Hong Kong. Journal of Management in Engineering, 2008, 24(3): 128–137.
[3] Babich V, Li H, Ritchken P, Contracting with asymmetric demand information in supply chains． European Journal of 0pemtional Research, 2012, 217(2)：333-341．
[4] Hosseinian S M, Carmichael D G. Optimal Incentive Contract with Risk-Neutral Contractor. Journal of Construction Engineering and Management, 2013, 139(8): 899–909.
[5] Kerkhove L P, Vanhoucke M. A Parallel Multi-Objective Scatter Search for Optimising Incentive Contract Design in Projects. European Journal of Operational Research, 2017, 261(3): 1066–1084.
[6] Onuoha, I.J, Aliagha, G U, Rahman, M S A. Modelling the effects of green building incentives and green building skills on supply factors affecting green commercial property investment. Renewable and Sustainable Energy Reviews,2018,90:814–823.
[7] Hong J, Koo Y, Jeong G, Lee J. Ex-ante Evaluation of Profitability and Government's Subsidy Policy on Vehicle-to-Grid System. Energy Policy,2012, 42:95-104．
[8] Chang P L, Ho S P, Hsu C W. Dynamic Simulation of Government Subsidy Policy Effects on Solar Water Heaters Installation in Taiwan[J]. Renewable and Sustainable Energy Reviews, 2013, 20:385-396.
[9] She J，Chen Y J. Impact of Government Financial Intervention on Competition among Green Supply Chains. International Journal of Production Economics, 2012, 138(1): 201－213．
[10] Liu Y Ming. Research on the Incentive Policies for the Development of Green Buildings in Beijing. Journal of Beijing Jiao tong University, 2012 (02): 52-57)
[11] Liu G, Li X. Research on Incentive Mechanism Design and Incentive Dynamics of Green Building Based on Game Theory. Science and Technology Management Research, 2014 (4)．.
[12] Liu G, Kan Q Z. Research on the Construction and Development of Green Building Industry Chain Based on Circular Economy. Ecological Economy (Academic Edition), 2014 (1): 254-257
[13] Yue H J, Han Z H. A Brief Introduction to the Implementation of Green Building Incentive Policy in the Construction of Indemnificatory Housing [J]. Ju She, 2018 (19)
[14] Hotelling H. Stablility in Competition. Economic Journal,1929,39(153):41-57.