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A simulation-based decision model for designing contract period in building energy performance contracting

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ABSTRACT

This paper presents a simulation-based decision model for contract period determination in Energy Performance Contracting (EPC). The model attempts to assist the Energy Service Companies (ESCOs) on how long the contract period should be to balance the bidding competitiveness and the potential revenue loss. The uncertainties within the energy efficiency investment and the energy cost savings as return are addressed by stochastic processes, taking the maintenance and savings performance variations and the energy price fluctuations into account. Considering both the contract period and the energy cost savings guarantee, a framework is proposed to identify the profit sharing in EPC for both the owners and the ESCOs. An optimization model is derived accordingly, and the balanced length of the contract period is then reached. Finally, a campus case is presented to verify the applicability of the proposed model. The method can be used by industry practitioners as a decision support tool for contract period design, and is worth popularizing in other performance-based projects.

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1. Introduction

Performance-based contracting, which buys performance through an integrated acquisition and logistics process delivering improved capability to a range of products and services, is growing in popularity around the world. Industrial sectors, such as commercial shipping, public transport, health services, and energy generation, adopt the performance-based contracting frameworks commonly. Following the general performance-based contracting mode, Energy Performance Contracting (EPC) emerged in North America in the 1970s after the first oil crisis [1], and shows a remarkable growth trend in recent years [2,3]. EPC utilizes the future energy savings revenues to repay the initial energy efficiency investment. During the contract period, the Energy Service Companies (ESCOs) get shared profits from the regular savings of utility bills, and the facility owners upgrade the aging and inefficient assets without capital investment [4].

Since EPC has encouraged the ESCO to develop more desirable energy efficient solutions, the well-designed provisions, such as the contract period, would go a step further to unite the owner and the ESCO for a shared profit goal [5]. Within the contract period, the ESCO takes care of the operation and maintenance (O&M) activities for the energy conservation measures and, at the same time, holds the major part of the energy cost savings as return. After the contract period, the ESCO leaves and both the O&M cost and the savings revenue would be held by the owner. Due to the complexity in dynamic project environments, the length of the contract period has a significant impact on the risks allocation and benefits sharing. The energy cost savings produced by the energy project must be sufficient to cover all project related costs over the contract period from both the owner's and the ESCO's perspectives. Thus, the length of the contract period determined is critical for both the owners and the ESCOs concerning the EPC success.

However, tradeoffs exist in the contract period decision-making of EPC. In general, the ESCOs prefer to sign a contract with a longer contracting term as more profit can be made over time. But the owners are likely to shorten the contract period to a reasonable length, so as to guarantee their project rights and interests after the well-equipped facility transferred. Also, the ESCOs need to make competitive offer concerning the shorter contract period to win the bidding. How to determine the contracting term becomes a critical issue in the negotiations between the owners and the ESCOs. Besides, there are other limits. According to the Energy Policy Act [6], the whole contract period of EPC shall not exceed 20 years to allow longer payback periods for retrofits, including windows, heating

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system replacements, wall insulation, site-based generation, advanced energy savings technologies, and other retrofits. States and local authorities have also issued legislation on the EPC duration. For instance, the maximum energy performance contract period for New Jersey is 10 years, North Carolina, 12 years, Maryland, 15 years, and Florida, 20 years. Therefore, the contract period in EPC should be neither too long nor too short according to the estimation.

Owing to the absence of a universally accepted standard, how to determine the length of the contract period on a win–win basis has not been agreed upon in the EPC market. To a large extent, the future O&M cost, the unknown energy conservation measure performance, and the fluctuated energy price, are considered as the main uncertainties that affect the project success in EPC. As a result, mismatches between the estimated and the observed project performance commonly arise in industrial practice [5]. In this paper, the uncertainties within the energy performance during the contract period of EPC are modeled in two separate stochastic processes, namely the annual energy savings amount and the energy price. A framework concerning the shared energy savings revenues is proposed, and the owners' and the ESCOs' profits are then derived respectively during the contract period. An optimization model for the contract period design in EPC is structured to address the potential risks on a win–win basis. A simulation-based decision approach with quantitative analysis is then developed to determine how long the contract period should be in order to balance the profit expectations for both the owners and the ESCOs.

This paper is organized as follows: the related studies on the determination of the contract length are reviewed in Section 2. Section 3 models the uncertainties in energy savings performance on a simulation basis, with the energy efficiency investment, the energy savings instability and the energy price fluctuation taken into account. In Section 4, a decision model with quantitative analysis is developed to determine how long the contract period should exactly be. In Section 5, a campus case is used to verify the applicability of the proposed approach for the contract period determination. Finally, the conclusions are drawn in Section 6.

2. Literature review

In recent years, performance-based contracting frameworks have become more and more popular in social welfare programs [7], public health [8], public-private partnership (PPP) [9,10], and energy sectors [11]. As an alternative financing mechanism authorized by the United States Congress, EPC is classified as one of the performance-based contracting forms which focuses on developing strategic performance metrics and directly relating contracting payment through incentivized, long-term contracts with specific and measurable levels of operational performance [12]. Thus, EPC is intended to accelerate the investment in cost-effective energy conservation measures of existing buildings [13]. As a typical EPC, the ESCOs provide turnkey services including investigating, designing, financing, and renovating those aging and inefficient assets with multiple energy conservation measures [14]. During the contract period, the ESCOs guarantee that the improvements could generate sufficient energy cost savings to pay for the project investment. After the contract period, the remaining cost savings are attributed to the owners. Based on the performance guarantees offered by the ESCOs, technical risks are transferred from the owners to the ESCOs. The ESCO's remuneration is based on the demonstrated energy performance. Essentially, the ESCOs will not receive payment unless the project delivers the energy cost savings as expected.

In general, many challenges and problems have been encountered which affect satisfied performance achievement due to the uncertainties and unforeseen risks over a long contract period, typically more than 10 years. According to Ghosh et al. [15], the ambiguity regarding realization of estimated savings was ranked as one of the highest market barriers for the adoption of EPC in the private building sector. How to determine the contracting term becomes a critical issue in the negotiations between the owners and the ESCOs, which might affect the promotion and development of the EPC in the energy saving market [13]. Due to the limited previous research, identifying the decision-making process of the contract length in other performance-based contracting gives some references. According to Zhang and AbouRizk [16], a contract period is defined as the time span which includes a construction period and an operation period, during which the contractor has the right to commercially operate the facility or service, before it is transferred back to the owner or government [17]. The contract period is vital to the success, since it directly affects the interests and risks of both the involved parties. A reasonable length of the contract period can help to alleviate the financial risk for both the contractor and the owner, so that they could reach their expected investment returns within the operation period. Yu and Lam [18] indicated that the determination of the contract length is a complex problem, due to the nature of the problem, such as subjectivity, non-linearity, and multi-criteria. For simplicity, the contract period is preset to a fixed length in some early cases, particularly in government-invested projects. For instance, the first eight Design-Build-Finance-Operate (DBFO) roads in the United Kingdom [19] and the five Build-Operate-Transfer (BOT) tunnel projects in Hong Kong [20] all had a 30-year government-preset contract period, even though the physical length, design capacity, traffic demand, construction time and construction costs, are quite different for each project [21]. However, the traditional practice of fixing the concession in advance does not generally lead to an efficient solution due to the potential financial, economic, and social problems without sufficient justification [22]. Failures or the renegotiation of concession contracts frequently occurred over the operational period in the above projects.

To solve this problem, scholars adopted various research methods, such as the net present value (NPV), the payback period [23], the NPV-at-risk method [24], NPV-based concession models, bargaining-game theory, and simulation techniques [18]. As one of the commonly used investment evaluation methods, the NPV-at-risk method [24] is formed by the combination of the weighted average cost of capital and dual risk-return methods. Compared with the traditional NPV method, the NPV-at-risk method requires the probability distributions of variables, whereas those are hard to evaluate in reality. Hence, this method is useful in assisting relatively simple decision-making in the investment evaluation for privately financed infrastructure projects. Actually, the uncertain factors are most likely to alter the project performance and future cash flow within the contract period [25]. To address the inevitable uncertainties, the simulation modeling approach provides a powerful tool for stochastic modeling process and risk allocation in uncertain environments [26,27]. Simulation is the imitation of the operation of a real-world process or system over time, and can be used to measure and evaluate construction and economic uncertainties and risks [28]. In the past 10 years, the simulation techniques have extended from computer science to decision-making and optimization in construction fields [29,30]. Shen and Wu [31] proposed a Monte Carlo simulation approach for the concession period determination of a BOT project, with the stimulated values of risk factors considered, such as NPV, capital investment, toll price, and discount rate. Ng et al. [32] also developed a simulation model to assist the public partner to determine the optimal contract period, with the uncertain parameters, such as the cost, operation revenue, and income. Zhang [18] proposed a win–