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Study on Added-Value Sharing Ratio of Large EPC Hydropower Project Based on Target Cost Contract: A Perspective from China

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Abstract: Engineering, procurement, and construction (EPC) has been applied in China's hydropower projects for its value-added advantages compared with traditional project delivery systems in theory. However, the actual performance of large EPC hydropower projects has been challenged by the complexity of the stakeholders' interest demands and conflicts. The increasing use of target cost contracts (TCC) in the construction industry has provided a pain/gain share mechanism for the owners to incentivize contractors to complete projects within cost budgets. The added-value sharing ratio is the core element of TCC, and it predetermines how much proportion of savings the contractor can get paid if the actual cost is below the target cost, and how much proportion of overspend the contractor has to pay if the actual cost is higher than the target cost. In this paper, we consider the added-value sharing ratio under the framework of TCC based on the principal-agent theory, and look at how the added-value sharing ratio is influenced by various factors and how it affects the owner and the contractor in large EPC hydropower projects. Determination of the added-value sharing ratio in both discrete and continuous conditions are discussed, respectively. It is found that the added-value sharing ratio is relatively explicit in the discrete case, while the optimal added-value sharing model in the continuous case is more complex, which can be used to analyze the relationship between the added-value sharing ratio and the key influencing factors. Our research conclusions can provide both theoretical guidance and practical suggestions to contract design in the implementation of EPC hydropower projects, to some extent.

Keywords: hydropower project; EPC; target cost contract; added value; sharing ratio

1. Introduction

Society's energy consumption worldwide has increased by up to 600% over the last century. This increase has been a direct result of population growth since the industrial revolution, in which energy has been provided mainly by fossil fuels [1]. Renewable energy sources can replace fossil fuels for electricity generation to a certain extent, contributing to the reduction of CO_2 emission worldwide [2]. Among all of the different types of renewable energy, the hydropower plant stands out for its feasibility. The most important hydropower plants are located in countries such as China, the United States, Brazil, and Canada [1]. According to data from the National Bureau of Statistics of China, the operation revenue of hydropower engineering in China in 2016 was 2,320,331,000 yuan (RMB), with a 58.98% increase over 2015 [3]. At present, the development and utilization of hydropower resources in China has just exceeded 50%, and it still has great potential for development [4]. At the same time, many experts in the hydropower industry predict that there will be a new round of rapid growth in China's hydropower industry under the "Belt and Road" initiative. The international industry also predicts that by 2050, the installed capacity of hydropower globally will double from the current 1 billion kilowatts to 2 billion kilowatts, and most of the hydropower resources to be developed will be concentrated in Africa, South America, and Southeast Asia, which is sure to provide a good development opportunity for China's hydropower industry [4].

1.1. Project Delivery Methods and EPC

The project delivery method/system (PDM/PDS) is also sometimes known as the project procurement method [5,6] or the project transaction method [7]. Currently, there are several PDM options available in the construction industry, and the most typical ones are Design-Bid-Build (DBB), Design-Build (DB), and EPC in many countries. Every project is unique and has its own unique set of challenges. Therefore, the industry consensus is that every project should be considered on a case-by-case basis to determine the most appropriate project delivery method [8]. From this perspective, project delivery methods are products of design, not simple selection. Besides, it is important to match the appropriate contract strategy with the right project delivery option when selecting and implementing any project delivery option, since PDM cannot function independently without the support of reasonable contract strategies [9].

For a long time, the DBB project delivery method was used in most of China's hydropower projects. For example, DBB was adopted in the famous Three Gorges Dam project, the Xiluodu Dam project, and so forth. Design and construction are separate in DBB, which leads to some serious waste phenomena in some hydropower projects, such as having budgets exceeding actual investment [10]. Since the uncertainty of "site data" of hydropower projects is usually large, the possibility of achieving cost savings is theoretically large—that is, there is a large potential for adding value to the project. Through the integration of design and construction, the introduction of the EPC model can not only reduce the risk of project uncertainty but also provide a platform for the EPC general contractor to optimize the project [11]. With the continuous development of construction management reform in China's hydropower industry and the extensive application of EPC in the Architecture, Engineering & Construction (AEC) industry worldwide [12,13], both theoretical and practical experts have agreed that it is imperative to further develop the EPC project delivery system in order to improve the level of management and productivity of the hydropower industry in China. Since 2009, several pilot projects have been implemented to take the lead in using EPC in Guangdong Province, China [14]. The practices of the pilot EPC projects showed that the enthusiasm of contractors to optimize the project had been greatly stimulated after the implementation of EPC with incentive contracts in some complicated and uncertain hydropower projects, which brought significant added value to the project and showed the strong vitality of EPC application in hydropower projects.

However, the high uncertainty of hydropower projects also means high risks, which challenge the implementation of the EPC method. About 10 years ago, the EPC model was usually associated with the fixed lump-sum contract in China, and this practice restricted the application of EPC in hydropower projects which contained large uncertainty of onsite data. The EPC projects' practices in Guangdong has shown that "whether the risk (or benefit)-sharing is reasonable" is one of the key factors for project delivery success, especially when project uncertainty is high [10]. For EPC hydropower projects, especially those with high uncertainty of "site data", knowing how to break through the traditional framework of fixed-price contracts and unit-price contracts, how to rationally allocate the interests or risks resulting from design and construction optimization among stakeholders, and construct a contract-pricing mechanism with incentive attributes are key issues that need to be addressed. In this way, the EPC project delivery method can reach the expected targets of encouraging the general contractor to optimize the project or actively respond to risks, as well as reducing the owner's overall payment cost, thus achieving win–win outcomes and improving the overall project performance compared with traditional DBB delivery methods [10,15,16]. Therefore, for a specific EPC hydropower project with high uncertainty, it is necessary to innovate a new incentive payment method or to redesign a payment method based on classic ones. The Target Cost Contract (TCC), another kind of incentive contract, is a type of contract payment method with the characteristics of "risk-sharing and benefit-sharing", where the key to its successful application in EPC hydropower projects is that the owner should design mutually satisfactory benefit- and risk-sharing ratios (collectively referred to as added-value sharing ratios in this study) to motivate the EPC general contractor to carry out design optimization, making full use of the value-added advantages of the EPC model compared to the traditional delivery system. More specifically, for an EPC hydropower project under TCC, the difference between the actual project cost and the target cost is compared at the time of project settlement, and the final settlement price is adjusted according to the predetermined sharing ratio. If the actual cost exceeds the target cost, the increased cost relative to the target cost will be shared by the two contract parties in accordance with the agreed ratio, i.e., risk-sharing. If the actual cost is lower than the target cost, the savings will also be shared by the two parties using the agreed ratio, i.e., benefit-sharing. Here, we collectively refer to risk-sharing and benefit-sharing as added-value sharing.

1.2. Literature Review

Until now, researchers have not paid enough attention to the contract payment method, risk- and benefit-sharing of EPC hydropower projects. Cai [17] analyzed the necessity and advantages of carrying out EPC general contracting for hydropower projects with designer as the leader, analyzed the supervision system under the EPC general contracting model, and elaborated the management contents and tasks for general contractors and owners of EPC hydropower projects. Shorney-Darby [18] systematically studied the Design-Build (DB) method applied to water/wastewater engineering, covering most aspects of this method in water/wastewater engineering applications. However, neither Cai [17] nor Shorney-Darby [18] paid enough attention to the contract payment method in their studies. Based on the value chain and institutional change theory, Feng [19] analyzed the value growth principles of the EPC mode in water conservancy projects, as well as reasons for the slow development of the EPC mode in water conservancy projects in China. The development model of EPC in water conservancy projects was established, with an empirical analysis through questionnaire experiments. The results can provide a reference for China's water conservancy and hydropower industry to take targeted measures to innovate and develop the EPC mode.

Wang et al. [20] analyzed the value-added advantages and methods of EPC compared to DBB, and discussed the key factors of added value as well as their influences on various value-added methods. In their study, a value-added analysis matrix was established, and the decision-making criteria were suggested for the adoption of the EPC mode. Jian et al. [21] established a new decision-making index system, and suggested using the intuition fuzzy selection method instead of the traditional fuzzy comprehension evaluation in the decision-making practice of general contracting delivery methods of hydraulic engineering projects and translating the decision information into accurate real numbers by the intuitionistic fuzzy weighted aggregation operators (IFWA), then ranking the alternatives. Besides, Zhao et al. [22] proposed the whole-process, all-round, full-factor, and team-wide risk management methods for EPC hydropower projects, aiming to improve the risk-management level of the contractor. Table 1 presents the main points of the related work mentioned above. To some extent, these studies would help people to better understand the applications of EPC mode in hydropower projects in depth. However, these studies did not focus on the rational sharing of risks or benefits for EPC hydropower projects with considerations of their characteristics.

Table 1. Related work on engineering, procurement, and construction (EPC) hydropower projects.

Authors	Topics and Methods
Cai [17]	Theories and practices of EPC hydropower project management, including supervision system under EPC model, the management contents and tasks of general contractors and owners, and risk analysis, etc. Theoretic analysis and case studies.
Shorney-Darby et al. [18]	DB method applied to water/wastewater projects. Collection of 30 articles which can provides a basic template of how DB projects can be planned, procured and executed.
Feng et al. [19]	Driving factors for the development of general contracting modes including EPC in the water conservancy project. Value chain theory and SEM (Structural Equation Modeling).
Wang et al. [20]	Value-added approach for the adoption of general contracting modes including EPC in hydropower projects. Value-added analysis matrix.
Jian et al. [21]	Selection of general contracting delivery methods for hydropower projects. Intuition fuzzy selection method.
Zhao et al. [22]	Risk Identification of EPC hydropower projects. TOC (Theory of Constraints) and SPA (Set Pair Analysis).

For EPC hydropower projects, the owners have the opportunity to make better use of the advantages of EPC mode and achieve the goal of project success. Firstly, the owner should consider the vertical relationship at the first level, which is the vertical principal-agent relationship between the owner and the general contractor. Then the horizontal relationship at the general contractor level, such as a consortium relationship, should be considered. However, studies on risk- or benefit-sharing of EPC projects in various construction fields are currently focused on the contractor level. Parrod et al. [23] pointed out that the reasonable benefit-sharing mechanism is the basis and key to participate in the cooperation of EPC enterprises. Guan et al. [24] used the triggering strategy to analyze the problem of benefit-sharing among the general contractors of the repetitive cooperative consortium. Zhang et al. [25] proposed a method for benefit-sharing between engineering general contractors and subcontractors based on the revenue-sharing theory and Stackelberg game model. Hu et al. [26] constructed a benefit-sharing and incentive mechanism between engineering general contractors and subcontractors based on the multi-stage game theory. The above studies can also provide ideas or theoretical references for the rational sharing of risks or benefits of EPC hydropower projects.

To conclude, there exist some limitations in the previous studies. Firstly, the existing research, as listed in Table 1, focuses on the value-added advantages, necessities and selection of the EPC mode in hydropower projects, which can help the industry to better understand the applications of the EPC mode in hydropower projects. However, these studies have not paid enough attention to the contract payment method, as well as the risk- and benefit-sharing problem. Secondly, some researchers focused on the risk- or benefit-sharing of EPC projects in various fields, but paid more attention to the contractor level while ignoring the risk- or benefit-sharing between the owner and contractors.

1.3. Uniqueness and Contributions

This paper tries to break through the limitations of the related work, further enrich the research content and expand the perspective of research on risk- or benefit-sharing. It focuses on the risk- or benefit-sharing, i.e., added-value sharing issue in EPC hydropower projects under the framework of TCC.

(1) While DBB is a common project-delivery method adopted in China's hydropower projects, EPC has not been widely used. Based on the current situation, the authors call for innovation on the contract payment method, and to use TCC to better incentivize the contractors' motivation.
(2) This paper identifies the added-value sharing ratio as the core element in the implementation of TCC and looks at the added-value sharing ratio closely, and builds a mathematical model based on the principle agent theory. The mathematical model can better investigate how the added-value sharing ratio is influenced by various factors, and how the added-value sharing ratio influences the owner, the contractor, and their relationship.
(3) Since the added-value problem has many influencing factors, as a first step, this paper simplifies the model by assuming that the added value and the level of effort of the EPC contractor are discrete logical functions.
(4) On the basis of the simplified model, the authors construct a principle-agent model considering various factors in continuous conditions. By calculating the partial derivatives of the mathematical equations with each variable, the authors can better observe the relationship between each factor and added-value sharing ratio.
(5) Besides from getting insights from the mathematical model, the authors also give some suggestions on current practice in applying TCC in EPC hydropower projects in China.

2. Added-Value Sharing Problem of EPC Hydropower Projects

Due to the uncertainty of "site data", the transaction process of EPC hydropower projects often faces great risks. While risks always coexist with interests, the potential benefits of the project are correspondingly relatively large. Under the premise of guaranteeing project quality, the EPC general contractor can actively implement project optimization and respond to project risks with design-construction integration, which may make the actual project cost lower than the contract price, thus realizing project added-value. It may also be the case that the actual project cost is higher than the contract price when transaction risk or negative added-value occurs. Furthermore, the added-value and transaction risks may occur simultaneously [10]. For convenience, the added-value and transaction risks are collectively referred to as added-value in this paper, which refers to the added-value (positive or negative) to the project that results from reduction of construction costs or shortening of construction duration in the transaction process, under the condition that the engineering function, scale, and quality requirements are not changed. The risks or benefits of the EPC hydropower project are ultimately reflected in project objectives. Therefore, the project added-value mainly includes the added value of project goals, such as cost and duration.

In an EPC hydropower project, the general contractor is usually more effective than the owner in controlling the risk of "site data" uncertainty. The project's added value from cost savings or shortened duration is produced by the general contractor through design optimization, based on the project's uncertainty. In the process of project optimization, the general contractor pays "extra effort" costs. Therefore, it is necessary to allocate the added value between the owner and the general contractor in a rational manner, according to the principles of "risk-sharing and benefit-sharing", and make the goals of both parties as consistent as possible. A reasonable added-value sharing plan will encourage the general contractor's motivation to optimize the project and reduce costs, as well as maximize the advantages of the EPC mode. How the project added-value is to be distributed depends on the design of the price clauses in the transaction contract. When the actual project added-value occurs, the contractual parties will share the added value of the actual project according to the previous agreement in the contract. On the contrary, if the general contractor cannot reasonably participate in sharing the project's added value, it will decrease their motivation to optimize the project, meaning the advantages of the EPC mode will not be used, and the owner's desire to save investment will not be achieved. In short, the ultimate goal of rational sharing of a project's added-value is to achieve a win–win situation. Figure 1 shows the internal driving mechanism of value-added sharing in EPC hydropower projects.

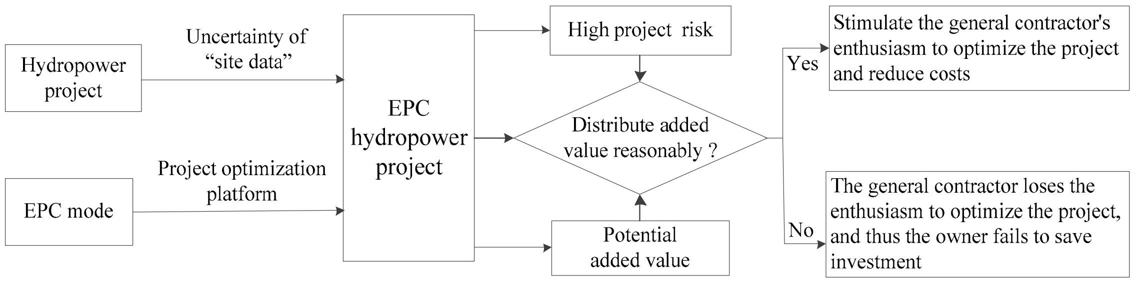

Figure 1. Internal driving mechanism of value-added sharing in EPC hydropower projects.

The added-value sharing of EPC hydropower projects is determined firstly by the contract payment method, and then the sharing plan can also be agreed in advance of the contract. In the common contract payment method, the target cost contract is used as an incentive contract, the purpose of which is to distribute risks reasonably between the two parties [27]. In a target cost contract, a target cost (or price) is negotiated by the two parties. At the time of project settlement, the difference between the actual project cost and the target cost is compared, and the final settlement price is adjusted according to the predetermined sharing ratio, no matter whether the actual cost is higher or lower than the target cost [28]. The target cost contract can be expressed as:

$$\Pi_{\mathrm{C}} = \Pi_{\mathrm{T}} + \alpha(C_{\mathrm{T}} - C_{\mathrm{A}}) \tag{1}$$

In Equation (1), Π_{C} is the contractor's actual profit, Π_{T} is the contractor's target profit, C_{T} is the target cost, C_{A} is the actual cost, while α is the contractor's risk- (or benefit)-sharing ratio, and it is called the contractor's added-value sharing ratio in this paper, referred to as the contractor's sharing ratio for short. Obviously $0 \le \alpha \le 1$, and the owner's sharing ratio is $(1-\alpha)$.

Under the target cost contract, the total payment of the owner can be expressed as:

$$P_{\mathrm{A}} = C_{\mathrm{A}} + F + (C_{\mathrm{T}} - C_{\mathrm{A}}) \times \alpha \tag{2}$$

In Equation (2), P_{A} is the actual total payment of the owner, C_{A} is the actual cost of the contractor, and F is a fee paid by the owner to the contractor beyond the actual cost (including management fees and profits, etc.), C_{T} is the target cost, and α is the contractor's sharing ratio of the cost savings or the cost overrun, called the contractor's sharing ratio for short. In practice, α may be a fixed value or multiple values in stages, depending on the value of cost savings or overspending. The target price is assumed to be P_{T}, $P_{\mathrm{T}} = C_{\mathrm{T}} + F$, and the project's added-value shared by the owner and the contractor is S_{O} and S_{C}, respectively. Therefore, when the sharing ratio is a fixed value, Equation (2) can be plotted in Figure 2.

In Figure 2, the difference between the actual payment P_{A} and the target price P_{T} is distributed between the owner and the contractor, regardless of its specific value—namely, whether the actual payment P_{A} is higher or lower than the target price P_{T}. As the sharing ratio α is a constant, the part between $C_{\mathrm{A}} + F$ and the sharing line is the contractor's project added-value share S_{O}, while the part between P_{T} and the sharing line is the owner's project added-value share S_{C}. This reflects the principle of risk-sharing and benefit-sharing. Therefore, the target-cost contract can maximize the cooperation between the two parties to work together so as to save costs and reduce risks. Thus, in theory, using value-added sharing under TCC is reasonable.

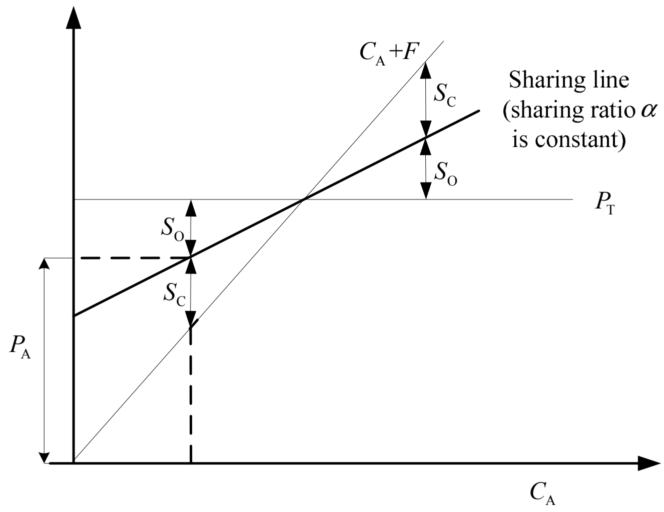

Figure 2. Target-cost contract with a fixed ratio (constant).

Studies have showed that the key to the implementation of the target-cost contract is to set a reasonable target cost and sharing ratio [29,30]. In this paper, the authors will not discuss the determination of the target cost, but mainly focus on analyzing the added-value sharing ratio on the assumption that the target cost is determined. The following sections will discuss the issue of the added-value sharing ratio under the TCC contract framework in two conditions—the discrete simplified condition, and the continuous condition.

3. Sharing Ratio in Discrete Simplified Condition

From an economic perspective, the added-value sharing of EPC hydropower projects can be regarded as an incentive mechanism. Since there is a principal-agent relationship between the two parties, the principal-agent theory can be used to analyze the sharing ratio of project added-value. According to the viewpoint of economics, the basic principles of all incentives are as follows: the agent always needs to pay a certain price when taking a certain work behavior (or effort), so the agent tends to reduce the level of effort if there is no incentive mechanism (punishment can be regarded as a special incentive). On the contrary, any incentive mechanism requires the client to pay a certain price (which may be an extra expense in the case of reward, and may be a monitoring cost in the case of punishment), so excessively high incentives will also damage the interests of the principal. Therefore, the goal of a good incentive mechanism is to maximize the dual utility of the principal and the agent. The specific goal is to make the agent raise their level of effort as much as possible under a certain payment. In the case of the added-value sharing problem in EPC hydropower projects, the basic incentive mechanism can be used to design a reasonable added-value sharing ratio to achieve "risk-sharing and benefit-sharing" between the owner and the EPC general contractor. In this way, the EPC general contractor's motivation will be boosted to reduce costs.

3.1. Basic Assumptions

Since there are many factors affecting the added value of hydropower projects, this paper firstly considers the simplification condition which takes asymmetric information as discrete types, and makes the following assumptions:

(1) Suppose the project's added value, $V = C_T - C_A$, presents two states. When the actual cost C_A is lower than or equal to the target cost C_T, that is, $V = V_1 = C_T - C_A \geq 0$, the project's added value is positive. Otherwise, when the actual cost C_A is higher than the target cost C_T, i.e., $V = V_2 = C_T - C_A < 0$, the project's added value is negative.

(2) Assume that the level of effort of the EPC general contractor in the contract performance process is ε, and it also has two states, positive effort and zero effort. When the EPC general contractor makes efforts to optimize the project for cost savings, it means that their effort is a positive effort, denoted as $\varepsilon = 1$. When the EPC general contractor does not make any effort in design optimization for cost saving, it indicates its effort level is zero, expressed as $\varepsilon = 0$. It is assumed that the total cost of the EPC general contractor due to positive effort is $C(\varepsilon = 1) > 0$, and the total cost due to zero effort is $C(\varepsilon = 0) = 0$.

(3) Because the factors affecting the project's added value are very complicated, positive added value may not necessarily be achieved when the EPC general contractor makes positive effort, and it is not necessarily impossible to achieve positive added value with zero effort, but the possibility of gaining positive added value is obviously much greater than zero effort. Based on past engineering experiences, it is possible to estimate the probability distribution of the EPC general contractor's effort affecting the project's added value. Here, suppose $P(V = V_1|\varepsilon = 1) = p_1$, $P(V = V_1|\varepsilon = 0) = p_0$, and $p_1 > p_0$.

(4) Both the owner and the EPC general contractor are risk neutral, thus their utilities and their expected returns are equivalents.

(5) Assume that the sharing ratio, denoted as α, has only one value—that is, it is not set by segmentation.

Under the above assumptions and simplified conditions, the sharing ratio of the project's added value under TCC can be analyzed.

3.2. Added-Value Sharing Model

Under the target cost contract, when the EPC general contractor makes positive efforts, the increased cost beyond the target cost will be shared by the two contract parties according to the agreed ratio if the actual cost exceeds the target cost, and the cost savings will also be shared by two parties using the agreed ratio if the actual cost is lower than the target cost. However, the sharing ratio in these two conditions may be the same or may be different. The assumptions can be made that the sharing ratios are the same in different conditions, i.e., α is a constant. Then the utility of the general contractor, when he puts forward a positive effort, can be expressed as:

$$\mathrm{EU_C} = \alpha(p_1V_1 + (1 - p_1)V_2) - C(\varepsilon = 1) \quad (3)$$

The utility of the owner can be given by:

$$\mathrm{EU_O} = (1 - \alpha)(p_1V_1 + (1 - p_1)V_2) \quad (4)$$

According to the principal-agent theory, the owner is the principal, and the contractor is the agent. The owner entrusts the contractor to carry out the construction of the project, while the contractor always needs to pay a certain price when undertaking a certain work behavior (or effort), so the contractor tends to reduce the level of effort if there is no incentive mechanism. Thus, an incentive mechanism is needed to motivate the contractor, the goal of which is to maximize the owner's utility under the condition that both the incentive compatibility constraint and the participation constraint are met. Thus, the project's added-value sharing model can be expressed as follows:

$$\mathrm{MaxEU_O} = (1 - \alpha)(p_1V_1 + (1 - p_1)V_2) \quad (5)$$

$$s.t.\ \alpha(p_1V_1 + (1 - p_1)V_2) - C(\varepsilon = 1) \geq \alpha(p_0V_1 + (1 - p_0)V_2) \quad (6)$$

$$s.t.\ \alpha(p_1V_1 + (1 - p_1)V_2) - C(\varepsilon = 1) \geq 0 \quad (7)$$

wherein Equation (6) is the incentive compatibility constraint, while Equation (7) is the participation constraint.

Denote $V_0 = p_0 V_1 + (1 - p_0) V_2$. If $V_0 > 0$, the objective function of Equation (5) obviously takes the maximum value when Equation (6) takes the equal sign. Therefore, the optimal sharing ratio of added value can be given by Equation (8):

$$\alpha^* = \frac{C(\varepsilon = 1)}{(p_1 - p_0)(V_1 - V_2)} = C(\varepsilon = 1)/(\Delta p \Delta V) \tag{8}$$

If $V_0 \leq 0$, it is apparent that the objective function of Equation (5) takes the maximum value when the Equation (7) takes an equal sign. Therefore, the optimal sharing ratio of added value can be given by Equation (9):

$$\alpha^* = \frac{C(\varepsilon = 1)}{p_1 V_1 + (1 - p_1) V_2} \tag{9}$$

4. Sharing Ratio of Added Value in Continuous Condition

4.1. Principal-Agent Model in Continuous Condition

In general, the level of effort and project's added value are continuous, and different levels of effort gain different added value. This paper, based on existing studies [31,32], analyzes the sharing ratio of added value within the target cost contract under continuous conditions. First of all, some assumptions, considering the characteristics of typical hydropower projects, are set as follows:

(1) ε is defined as the level of effort by the EPC general contractor. For simplicity, let ε be a one-dimensional variable starting from 0 to 1, which means that the level of effort can be indicated by a real number from 0 to 1. However, it is not convenient for us to observe the value of ε directly because of incomplete information.

(2) As in the risk environment, the project's added value from cost savings is not only related to the level of effort of the EPC general contractor, but is also affected by various uncertainty factors from internal and external project environments. Here, let $V = V(\varepsilon, \tau) = \Delta C(\varepsilon) + \tau$, where V is the added value through the EPC general contractor's optimized engineering to reduce project costs, while τ is an exogenous random variable that is not controlled by the owner or the EPC general contractor and satisfies a normal distribution N(0,σ^2). In addition, $\Delta C(\varepsilon)$ denotes the corresponding cost savings when the EPC general contractor's effort is ε and satisfies the following conditions:

- $\Delta C\prime(\varepsilon) > 0$, $\Delta C''(\varepsilon) < 0$, in other words, cost savings are an increasing function of the level of effort of the EPC general contractor, but the marginal effects are decreasing;
- $\lim\limits_{\varepsilon \to 1} \Delta C(\varepsilon) = \Delta C_{\max}$, meaning cost savings reach the maximum when the EPC general contractor makes the highest level of effort. That is to say, the potential added value comes true completely. Let $\overline{V}$ be the potential EPC added value. Then, $\overline{V} = \Delta C_{\max}$.

In order to facilitate the analysis, the following equation is supposed.

$$\Delta C(\varepsilon) = \Delta C_{\max} - \lambda_{\mathrm{e}}(1 - \varepsilon)^2 = \overline{V} - \lambda_{\mathrm{e}}(1 - \varepsilon)^2 \tag{10}$$

In Equation (10), λ_{e} denotes the effect coefficient of the EPC general contractor's efforts to reduce costs. Transform $\Delta C(\varepsilon)$ given in Equation (10), then:

$$\Delta C(\varepsilon) = \Delta C_{\max} - \lambda_{\mathrm{e}}(1 - \varepsilon)^2 = \Delta C_{\max}\left[1 - \frac{\lambda_{\mathrm{e}}}{\Delta C_{\max}}(1 - \varepsilon)^2\right] = \overline{V}\left[1 - \frac{\lambda_{\mathrm{e}}(1 - \varepsilon)^2}{\overline{V}}\right] \tag{11}$$

Let $\gamma = 1 - \frac{\lambda_{\mathrm{e}}(1-\varepsilon)^2}{\overline{V}}$ be the achievement level of the potential EPC added value. Obviously, $\gamma = 0$ means that the EPC project, like the traditional DBB project, does not carry out any optimization work and thus does not achieve the project's added value. In the contract, the potential added value can be achieved completely when $\gamma = 1$.

Based on the above conditions, it can be seen that the function of $\Delta C(\varepsilon) = \gamma \Delta C_{\max} = \gamma \overline{V}$ satisfies the normal distribution, with the mean value being $\gamma \Delta C_{\max}$ and the variance being σ^2.

(3) Define $C(\varepsilon)$ as the cost function of the EPC general contractor's efforts to optimize the project, thus $C\prime(\varepsilon) > 0$, $C''(\varepsilon) > 0$. That is to say, the effort cost is the increasing function of the level of effort and the marginal effort cost is also increasing. Thus, set $C(\varepsilon) = \lambda_c \varepsilon^2$, and here λ_c indicates the cost coefficient of the EPC general contractor's efforts to save costs.

(4) It is assumed that the absolute risk-aversion degree of both the owner and the contractor are constants, named k_O and k_C respectively.

Based on the above assumptions, if a hydropower project adopts a target cost contract, the owner's expected utility function will be expressed as follows:

$$\mathrm{EU_O} = \mathrm{U_O}((1-\alpha)V) = \mathrm{U_O}((1-\alpha)[\overline{V} - \lambda_e(1-\varepsilon)^2]) \tag{12}$$

while the expected utility function of the EPC general contractor can be expressed as Equation (13).

$$\mathrm{EU_C} = \mathrm{U_C}(\alpha V - C(\varepsilon)) \tag{13}$$

According to the method of the certainty equivalent value, the effectiveness can be reflected by the "certainty equivalent value" of the utility function [33]. When setting $u(x)$ as the utility function of the decision-maker, for random-action result X, its certainty equivalent value is defined as Equation (14).

$$\mathrm{EV} = u^{-1}(E[u(x)]) = E(X) - K(X) \tag{14}$$

Then, the following equation can be obtained:

$$K(X) \approx \frac{D(X)}{2}\left(-\frac{u''(E[X])}{u\prime([X])}\right) = \frac{1}{2}D(X)r(x) \tag{15}$$

where $E(X)$ and $D(X)$ are the expected value and variance respectively, and $r(x)$ denotes the absolute risk level.

When the stochastic outcome satisfies the $N(\mu, \sigma^2)$ distribution, the corresponding utility function can be reflected by the certainty equivalent value given by Equation (16).

$$\mathrm{EV} = \mu - \frac{1}{2}r(x)\sigma^2 \tag{16}$$

Thus, the certainty equivalent values of the utility functions of the owner and the EPC general contractor can be given by:

$$\mathrm{EV_O} = (1-\alpha)[\overline{V} - \lambda_e(1-\varepsilon)^2] - \frac{(1-\alpha)^2\sigma^2 k_O}{2} \tag{17}$$

and

$$\mathrm{EV_C} = \alpha[\overline{V} - \lambda_e(1-\varepsilon)^2] - \frac{\alpha^2\sigma^2 k_C}{2} - \lambda_c\varepsilon^2 \tag{18}$$

Here, this paper is discussing how to determine the added-value sharing ratio α to maximize the utility of both parties—that is, where their certainty equivalent value reaches the maximum.

When calculating the first-order derivative in Equation (18), the result is $\mathrm{EV_C}\prime = 2\alpha\lambda_e - 2\alpha\lambda_e\varepsilon - 2\lambda_c\varepsilon$. Then through further calculation of the second-order derivative, the result is $\mathrm{EV}''_C = -2\alpha\lambda_e - 2\lambda_c < 0$. Let $\mathrm{EV_C}\prime = 2\alpha\lambda_e - 2\alpha\lambda_e\varepsilon - 2\lambda_c\varepsilon = 0$, then:

$$\varepsilon = \frac{\alpha\lambda_e}{\alpha\lambda_e + \lambda_c} = \frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}} \tag{19}$$

Therefore, the principal-agent model for the optimal sharing of the project's added value can be given by:

$$\mathrm{MaxEV_O} = (1-\alpha)\left[\overline{V} - \lambda_e(1-\varepsilon)^2\right] - \frac{(1-\alpha)^2\sigma^2 k_O}{2} \tag{20}$$

$$s.t.\ \mathrm{EV_C} = \alpha\left[\overline{V} - \lambda_e(1-\varepsilon)^2\right] - \frac{\alpha^2\sigma^2 k_C}{2} - \lambda_c\varepsilon^2 \geq 0 \tag{21}$$

$$s.t.\ \varepsilon = \frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}} \tag{22}$$

Here, Equation (21) is the participation constraint, and Equation (22) is the incentive compatibility constraint.

4.2. Analysis of Value-Added Sharing Ratio

Firstly, the optimal added-value sharing ratio can be obtained from each party's perspective.

From the view of the EPC general contractor, according to Equation (21), $\mathrm{EV_C}$ reaches the maximum when α takes the following values.

$$\alpha = \frac{\lambda_c}{\lambda_e}\frac{\varepsilon}{1-\varepsilon} = \frac{dC(\varepsilon)}{d\varepsilon} / \frac{d\Delta C(\varepsilon)}{d\varepsilon} \tag{23}$$

From the perspective of the EPC general contractor, the optimal added-value sharing ratio is equal to the marginal cost of effort divided by the marginal effect. By transforming Equation (23), the following equation can be obtained.

$$\alpha\frac{d\Delta C(\varepsilon)}{d\varepsilon} = \frac{dC(\varepsilon)}{d\varepsilon} \tag{24}$$

In Equation (24), the left side can be seen as the marginal return of the EPC general contractor, and the right side is the marginal cost of the EPC general contractor's effort. The marginal cost is increasing while the marginal return is decreasing. Thus, when the marginal cost is equal to the marginal return, the EPC general contractor will not make more effort. At this time, the corresponding added-value sharing ratio is optimal for the EPC general contractor.

Therefore, when the marginal cost is high or the marginal effect is poor, the EPC general contractor should obtain a larger added-value sharing ratio. In other words, the added-value sharing ratio α should be relatively larger, which can motivate the EPC contractor to work hard in order to optimize the project and save costs.

The following step is to analyze from the view of the owner. In the case where the EPC general contractor's effort is determined, we can calculate that the first-order derivative of Equation (17) can be obtained and made to be equal to zero. Then, the certainty equivalent value $\mathrm{EV_O}$ of the owner takes the maximum when α takes the following value.

$$\alpha = 1 - \frac{\overline{V} - \lambda_e(1-\varepsilon)^2}{\sigma^2 K_O} = 1 - \frac{V}{\sigma^2 K_O} \tag{25}$$

For the owner, the decisive factors of the optimal added-value sharing ratio include the following two aspects.

(1) The overrun risk degree of project cost, expressed by project cost variance σ^2. Obviously, the greater σ^2 is, the greater the sharing ratio α should be.
(2) The owner's risk aversion, denoted as K_O. The bigger K_O is, the bigger the value-added sharing ratio α should be. That is to say, the worse the owner's risk tolerance is, the smaller the share of risk the owner is willing to bear (negative added value). Thus, the owner tends to allow the EPC general contractor to get larger added-value sharing.

However, in the real practice of hydropower EPC projects, both the owner and the EPC general contractor are pursuing the goal of maximizing their own profits. Therefore, both parties need to negotiate to reach an added-value sharing ratio that maximizes utility (strictly speaking, relative maximization) for each other. The optimal solution of the model expressed by Equations (20)–(22) needs to be found.

When substituting Equation (22) into Equation (20) and Equation (21), the following equation can be obtained

$$\mathrm{MaxEV_O} = (1-\alpha)\left[\overline{V} - \lambda_e\left(1 - \frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}}\right)^2\right] - \frac{(1-\alpha)^2\sigma^2 k_O}{2} \tag{26}$$

$$\text{s.t. } \mathrm{EV_C} = \alpha[\overline{V} - \lambda_e(1 - \frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2] - \frac{\alpha^2\sigma^2 k_C}{2} - \lambda_c(\frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2 \geq 0 \tag{27}$$

Through Equation (27), the following equation can be obtained.

$$\alpha\left[\overline{V} - \lambda_c\left(1 - \frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}}\right)^2\right] \geq \frac{\alpha^2\sigma^2 k_C}{2} - \lambda_c\left(\frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}}\right)^2 \tag{28}$$

When substituting Equation (28) into Equation (26), it becomes:

$$\begin{aligned} \mathrm{MaxEV_O} &= (1-\alpha)[\overline{V} - \lambda_e(1 - \tfrac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2] - \tfrac{(1-\alpha)^2\sigma^2 k_O}{2} \\ &= [\overline{V} - \lambda_e(1 - \tfrac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2] - \alpha[\overline{V} - \lambda_e(1 - \tfrac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2] - \tfrac{(1-\alpha)^2\sigma^2 k_O}{2} \\ &\leq [\overline{V} - \lambda_e(1 - \tfrac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2] - [\tfrac{\alpha^2\sigma^2 k_C}{2} - \lambda_c(\tfrac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2] - \tfrac{(1-\alpha)^2\sigma^2 k_O}{2} \end{aligned} \tag{29}$$

Hence, the problem is translated into solving the maximum of the following equation.

$$\mathrm{MaxEV_O} = \underset{\alpha}{\mathrm{Max}}\left\{[\overline{V} - \lambda_e(1 - \frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2] - [\frac{\alpha^2\sigma^2 k_C}{2} - \lambda_c(\frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}})^2] - \frac{(1-\alpha)^2\sigma^2 k_O}{2}\right\} \tag{30}$$

Calculating the first-order derivation in the following equation:

$$\mathrm{EV_O} = \left[\overline{V} - \lambda_e\left(1 - \frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}}\right)^2\right] - \left[\frac{\alpha^2\sigma^2 k_C}{2} - \lambda_c\left(\frac{\alpha}{\alpha + \frac{\lambda_c}{\lambda_e}}\right)^2\right] - \frac{(1-\alpha)^2\sigma^2 k_O}{2} \tag{31}$$

And Equation (32) can be obtained.

$$\mathrm{EV_O}\prime = \frac{2\lambda_e\theta}{(\alpha+\theta)^2} - \frac{2(\lambda_e + \lambda_c)\theta\alpha}{(\alpha+\theta)^2} - [(k_C + k_O)\alpha - k_O]\sigma^2 \tag{32}$$

Here, $\theta = \frac{\lambda_c}{\lambda_e}$. Let $\mathrm{EV_O}\prime = 0$, then:

$$[(k_C + k_O)\alpha - k_O]\sigma^2 = \frac{2\lambda_e\theta}{(\alpha+\theta)^2} - \frac{2(\lambda_e + \lambda_c)\theta\alpha}{(\alpha+\theta)^3} \tag{33}$$

In order to facilitate the discussion of the relationship between the added-value sharing ratio and other parameters in the formula, the following simplifications can be made.

Let $k_C + k_O = 1$ and $\varphi = \frac{k_O}{k_C + k_O}$, here φ denotes owner's relative risk-aversion relative to the EPC general contractor. Compared with the EPC general contractor, the bigger φ is, the greater the risk tolerance of the owner will be in contrast to the EPC general contractor.

Let $\lambda_e = 1$, then $\theta = \frac{\lambda_c}{\lambda_e}$ means the EPC contractor's relative effort cost coefficient relative to the effort effect coefficient. Clearly, the larger θ indicates the higher cost for the EPC general contractor to get the same effort effect.

After simplification, the following equation can be obtained.

$$(\alpha - \varphi)(\alpha + \theta)^3\sigma^2 - 2\theta^2(1 - \alpha) = 0 \tag{34}$$

The solution of Equation (32) is the optimal added-value sharing ratio.

In Equation (34), when calculating the first-order partial derivatives of φ, θ, and σ^2, respectively on both sides, the results are as follows.

$$\frac{\partial\alpha}{\partial\varphi} = \frac{(\alpha + \theta)^3\sigma^2}{(\alpha + \theta)^3\sigma^2 + 3(\alpha - \varphi)(\alpha + \theta)^3\sigma^2 + 2\theta^2} \tag{35}$$

$$\frac{\partial\alpha}{\partial\theta} = \frac{4\theta(1 - \alpha) + 3(\alpha - \varphi)(\alpha + \theta)^2\sigma^2}{(\alpha + \theta)^3\sigma^2 + 3(\alpha - \varphi)(\alpha + \theta)^3\sigma^2 + 2\theta^2} \tag{36}$$

$$\frac{\partial\alpha}{\partial\sigma^2} = \frac{-(\alpha - \varphi)(\alpha + \theta)^3}{(\alpha + \theta)^3\sigma^2 + 3(\alpha - \varphi)(\alpha + \theta)^3\sigma^2 + 2\theta^2} \tag{37}$$

By combining Equations (34)–(37), the following equations can be obtained.

$$\alpha - \varphi = \frac{2\theta^2(1 - \alpha)}{(\alpha + \theta)^3\sigma^2} > 0 \tag{38}$$

$$\frac{\partial\alpha}{\partial\phi} \geq 0, \frac{\partial\alpha}{\partial\theta} \geq 0, \frac{\partial\alpha}{\partial\sigma^2} \leq 0 \tag{39}$$

Let $\theta = \frac{\lambda_c}{\lambda_e} = 1$, and then:

$$(\alpha - \varphi)(\alpha + 1)^3\sigma^2 - 2(1 - \alpha) = 0 \tag{40}$$

Simulate Equation (40) and the results can be obtained as shown in Figures 3 and 4. In Figure 2, the vertical axis is α and the horizontal axis is σ^2. It can be seen that the larger the value of ϕ is, the higher the curve is.

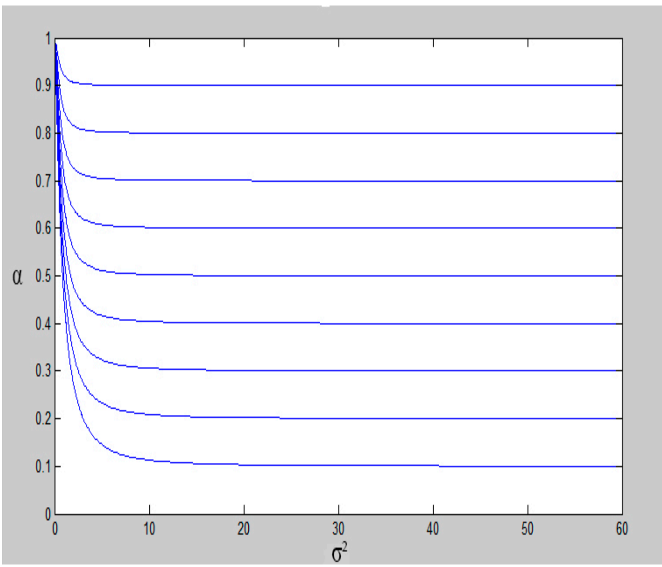

Figure 3. Relationship of α with φ and σ^2 (a).

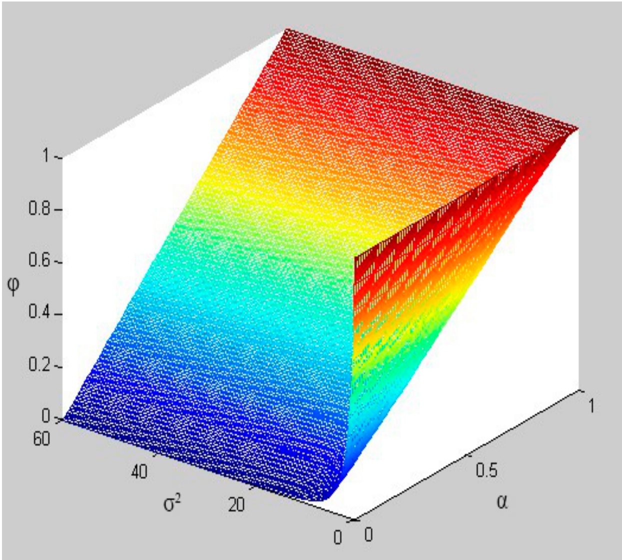

Figure 4. Relationship of α with φ and σ^2 (b).

Set φ = 0.5, and Equation (41) can be obtained.

$$(\alpha - 1/2)(\alpha + \theta)^3\sigma^2 - 2\theta^2(1 - \alpha) = 0 \tag{41}$$

Similarly, simulate Equation (41), then Figures 5 and 6 can be obtained. In Figure 5, the vertical axis is α and the horizontal axis is σ^2. It can be seen that the larger θ is, the higher the curve is.

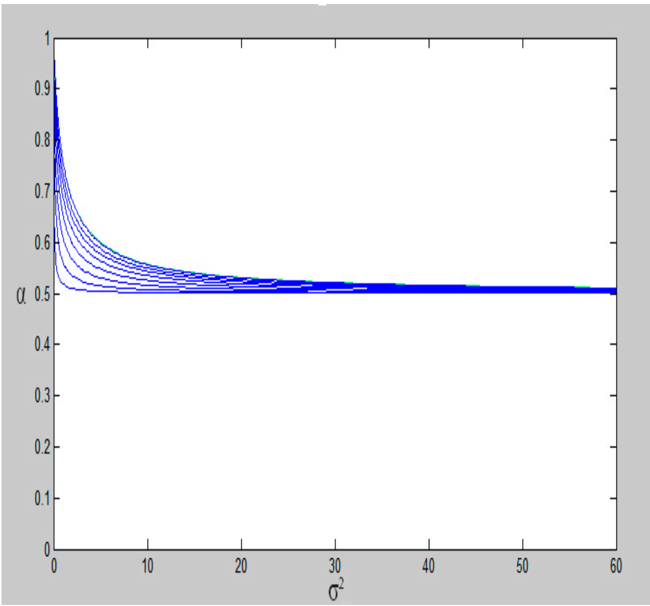

Figure 5. Relationship of α with θ and σ^2 (a).

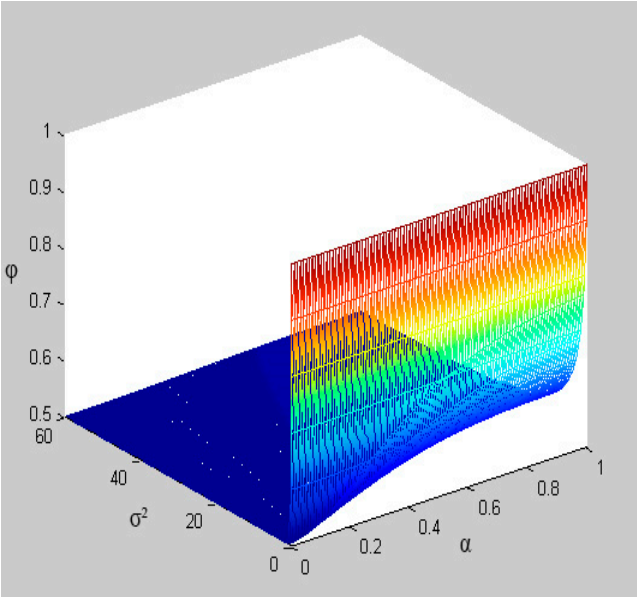

Figure 6. Relationship of α with θ and σ^2 (b).

Clearly, according to Equation (39) and Figures 3–6, the following conclusions can be achieved.

(1) The greater the relative risk-aversion of the owner towards the EPC general contractor is, the greater the added-value sharing ratio will be. Compared with the EPC general contractor, if the owner's relative risk-aversion is bigger, it means that the risk tolerance of the owner is worse in contrast to EPC general contractor. Thus, the owner is willing to bear less share of risk (negative added-value). Therefore, he would like to allow the EPC general contractor to get a larger added-value share.

(2) The greater the relative effort cost coefficient of the EPC general contractor is, the greater the added-value sharing ratio should be. If the EPC general contractor's relative effort cost coefficient is larger relative to the effort effect coefficient, it means that the EPC general contractor will take a higher cost to get the same effort effect. Therefore, if the owner cannot provide an added-value sharing ratio which is big enough, then the EPC general contractor tends to make less effort.

(3) The greater the risk of cost overruns is, the smaller the added-value sharing ratio should be. As for an EPC hydropower project with a high risk of cost overruns, if the sharing ratio is big, it means that the EPC general contractor will take high risk, which may be beyond its risk-bearing capacity. Under this situation, the contractor may take measures to transfer the risk to the owner, thus causing damage to the owner's interests. Therefore, it is not reasonable to set a big value for the sharing ratio when the risk of cost overruns is high.

On the whole, the owner should determine a relative rational added-value sharing ratio through synthetical consideration of these main factors mentioned above. It is obviously a very difficult problem both in theory and in practice.

5. Discussion on Actual Situation

Based on the analysis above, conclusions can be made that the added-value sharing ratio is affected by many factors in EPC hydropower projects, such as the attitude of both the owner and the general contractor to treat risks, the effort cost of the general contractor to optimize the project, the risks of project cost overruns, and so forth. Theoretically, the added-value sharing ratio can be obtained by using the calculations given in Equations (20)–(22). By substituting certain parameters, such as the risk aversion of both parties and cost coefficient of the contractor into Equation (34), then the specific added-value sharing ratio can be solved.

However, there exist several problems in solving the added-value sharing ratio according to Equation (34) under the actual situation. On one hand, it's difficult to find the exact value of the parameters. Taking the risk-aversion parameter for example, it is difficult for each party to give their specific values. On the other hand, analysis of the added-value sharing ratio above was carried out on the premise that the target cost and other parameters were determined reasonably. However, this research has not considered the impact of target cost- and target profit-setting on the added-value sharing ratio, while studies have shown that their impact on the added-value sharing ratio should not be ignored. In other words, there are interaction mechanisms between the target cost, target profit, and added-value sharing ratio. For instance, if the added-value sharing ratio is too low, the contractor will increase the target profit and reduce the target cost to ensure a certain level of income. In this way, contractors rarely consider optimizing the project to save costs. In addition, the added-value sharing ratio is also affected by other factors, such as the contractor's expectations of long-term profits, both parties' perception of risks, etc. Hence, it is necessary to consider the above factors comprehensively to determine the added-value sharing ratio of EPC hydropower projects.

Based on the analysis above, Equations (20)–(22) are mainly applied to theoretical analysis, and the analysis can determine the influencing factors of the added-value sharing ratio and their interrelationships. While in the actual hydropower EPC projects, a more operative approach is needed to find the specific value of the added-value sharing ratio. With these considerations, it is difficult to add a practical example to conduct the case study at present.

As a matter of fact, it is very difficult to determine the added-value sharing ratio. At present, there are no reasonable proofs or mathematical calculations to determine the ratio. Some people hold the idea that the ratio should be larger than 0.5, while others consider that the ratio should be 0.3–0.7, which is more reasonable and empirical. In addition, the ratio of 0.5 is considered to be fair. Compared with the traditional fixed ratio, studies found that it has become increasingly common for ratios to change, considering whether cost savings or cost overspending is achieved.

However, one thing is clear: the reason why the added-value sharing ratio is difficult to determine accurately is because of information asymmetry. For this reason, it can be feasible that the owner will propose an added-value sharing ratio firstly according to existing information at the time of bidding. Under this condition, the contractor will respond accordingly and adjust their bidding strategy based on their own attitude to risk. At present, the contract price of an EPC hydropower project is generally determined based on the approved preliminary design budget by a "floating down rate", which means that the bidder is required to provide a "floating down rate" during the bidding stage. Therefore, when the TCC contract is determined, the owner proposes an added-value sharing ratio at the time of bidding. Accordingly, the contractor proposes a "floating down rate", and then the owner will make a final selection by evaluating the "floating down rate" of different bidders. In the eight pilot EPC projects carried out in the Guangdong Province of China from 2009–2011 [14], as well as the comprehensive improvement project of the water environment in the Mazhou River Basin (Baoan area) in the Shenzhen City of China which started in 2016 [34], the "floating down rate" method was applied and recognized by both the owners and the contractors.

In the long run, with the application of modern technologies such as BIM (Building Information Modeling), the information asymmetry between the contract parties will be gradually reduced with the advances of information sharing. Thus, the owner will be able to observe almost all the cost information of the contractor, which makes parameters like target cost more accurate. Actually, determining the added-value sharing ratio is a process in which the owner's utility reaches the maximum under the constraint that a given general contractor is doing their best to maximize their own utility. Therefore, in theory, when the information asymmetry between the two parties is low, the final added-value sharing ratio determined through negotiations will be the optimal one.

6. Conclusions

For a given large-scale EPC hydropower project with high uncertainty, it is crucial to share the added-value between the owner and the general contractor, since the final project outcome is affected by the complexity of their interests and the liabilities involved. As one kind of incentive contract, the target cost contract, on the whole, has the characteristics of "risk-sharing and benefit-sharing"—thus, theoretically speaking, if the EPC hydropower project adopts the TCC contract, it will reach the added value of the EPC model by sharing risks and benefits. However, it objectively calls for the owner's designing specific plans and consulting with the contractor on how to share the project's added value. One of the key issues is how a reasonable project added-value sharing ratio should be determined. That is to say, the key to the successful application of TCC in EPC hydropower projects is to design a mutually satisfactory added-value sharing ratio to motivate the EPC general contractor to carry out design optimization, making the potential added-value of EPC come true in practice.

This paper focused on the added-value sharing problem of EPC hydropower projects based on the TCC contract. By using the principal-agent theory, this paper focused on how to determine the added-value sharing ratio of EPC hydropower projects under discrete and continuous cases. In the discrete case, the sharing ratio was clearly obtained. The result shows that the optimal sharing ratio of added value can be determined by the total cost of the EPC general contractor due to positive effort, the potential added value under different conditions, and the probability distribution of the EPC general contractor's effort.

Under the continuous situation, the optimal added-value sharing model is more complicated, which can be used to analyze the relationship between the project's added-value sharing ratio and its influencing factors, including the attitude of both the owner and the general contractor to treat risks, the effort cost of the general contractor to optimize the project, and the risks of project cost overruns, etc. Through modeling analysis and simulation, it is found that the sharing ratio of added value has different relationships with the relative risk aversion of the owner, the relative effort cost coefficient of the EPC general contractor, and the risk of cost overruns. Therefore, the following conclusions can be summarized: (1) The greater the relative risk aversion of the owner towards the EPC general contractor is, the greater the added-value sharing ratio will be; (2) the greater the relative effort cost coefficient of the EPC general contractor is, the greater the added-value sharing ratio should be; (3) and the greater the risk of cost overruns is, the smaller the added-value sharing ratio should be.

However, in an actual situation, the added-value sharing ratio may be affected by some other factors in EPC hydropower projects aside from the factors discussed in this paper, and it is difficult to find the exact value of these parameters. Thus, the model presented in this paper is more suitable for theoretical analysis, but difficult to be applied to real engineering practice. From this point of view, this paper briefly discussed how to determine the added-value sharing ratio in actual EPC hydropower projects. Suggestions were made that the owner should determine a sharing ratio at the time of bidding, then the potential bidders will respond accordingly and thus reflect their attitude to risk in the bidding price. As for the quantitative estimation of the project's added-value sharing ratio, it is necessary to carry out further research to find reasonable methods to determine the values of related parameters and to find a simpler and more practical approach to share the added value in EPC hydropower projects.

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