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Modelling and Design Analysis of Contract Payment Methods in Civil Engineering Projects

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Abstract. Contract payment method in a civil engineering project, to a certain extent, determines the distribution of project risk and benefits. Up till now, several types of contract payment method have been formed. However, with the continuous development and innovation of project delivery system, new contract payment methods are required to match with project delivery methods. By comparing the existing classic payment methods, this paper analyzes the effects of variable contract payment methods on risk allocation. Based on a unified view, existing contract payment methods are expressed by mathematical models and compared with parameters, and then the way of contract payment method design is discussed. Finally, a case study was presented to illustrate the design of contract payment method for a specific project in Chinese context.

1. Introduction

How to share risk through contract will affect the final cost of a civil engineering project directly, while it is an important guarantee to motivate the contractor to accomplish expected results and achieve desired objectives through selecting a right contract type (contract payment method) that is suitable for project environment and characteristics (including project risk and information integrity) [1-2]. With the continuous development and innovation of project delivery system, it is objectively necessary to get the support from contract payment method which should match with a certain new delivery method. Therefore, it is of practical significance to conduct research on innovation of contract payment method.

Contract payment methods in civil engineering projects are usually classified into several types, including lump sum contract, unit price contract, cost-plus contract and guaranteed maximum prices (GMPs), etc. [3]. Nevertheless, existing literature launched relatively more discussions on fixed-price contract and cost-plus contract. In the traditional fixed-price contract, the owner pays a fixed contract payment to the contractor in line with the work content stipulated in the contract, and the contractor bears nearly all the risks of cost overrun. According to the assumption, in economic incentive theory, that contractors are generally risk averse, they will seek protection through pricing of accidents to deal with uncertainties in engineering projects [4]. Levine et al. argues that fixed-price contract inhibits contractors' cost overruns, which can encourage contractors to make their best effort to reduce costs. And it is suggested that the incentive to reduce costs must be weighed against the increase in risk costs stipulated in the contract terms, instead of transferring all the risks to the contractor thoroughly and blindly [5]. Under the framework of fixed-price contract, the contractor tends to be conservative and do not dare to use innovative technologies, since the high risk of new technologies will lead to other compromises of performance such as quality level [6]. Branconi et al. studied the fixed-price Turnkey contract, under which the owner gives all the responsibilities on project completion to the contractor,



who was responsible for managing the whole process of project implementation and taking corresponding risks [7]. By doing this, it can give the contractor the right to control the entire process of project execution, and also reduce work interface and increase work efficiency as much as possible, thereby relieving the cost pressure undertaken by the contractor under fixed price constraint. Chen analyzed the data from 181 projects to investigate the performances under different delivery methods and payment methods based on three indicators, i.e. rework cost, change cost and cost growth. The results show that DB method has a significantly lower cost growth in comparison to DBB method, with a lower rework cost and change cost, though not significant. In respect of payment methods, cost growth is the lowest in lump sum contract through negotiation with a mean value of -1.97%, and it is the highest in unit price contract with a mean value of 10.70%. Taking these two aspects into consideration together, projects with DB method and lump sum contract through negotiation have the lowest cost growth, accompanied with the highest change cost, which should draw project participants' attention [8]. Miguel presents a proposal for adapting earned value management (EVM) method to contractors when using the unit-prices payment agreement. Using a case study to illustrate, an additional baseline to account for production and profitability, as well as new indicators, is applied to allow contractors using EVM with the unit-prices payment approach [9].

For cost-plus contract (or cost reimbursable contract), the contractor can be compensated under approved conditions according to the actual costs [10]. These costs include all costs other than actual costs, such as off-site management fees and fixed profit margins. The profit rate can be fixed or be the percentage of actual cost, that is, the cost plus fixed fee contract and the cost plus the percentage contract, respectively [11]. In the pure cost-plus contract, the cost risk is borne by the owner entirely [10]. The cost-plus contract arrangement will ensure that the contractor can get a portion of the profits regardless of his performance [12]. The main drawback of this type of contract is lacking of contractor performance incentives, which leads to minimizing costs and achieving other project objectives, such as quality, duration and safety. Hence, if the pure cost-plus contract wants to be successful, the owner must invest a lot of energy to supervise the contractor. Therefore, the owner is often very reluctant to use the pure cost-plus contract, since they lack sufficient resources for specific project management, so the cost-plus contract is less applied to engineering practices at present [10].

As one kind of incentive contract derived from the cost-plus contract, the Target Cost Contract (TCC) has gradually received more attention in recent years. Under this contract, a target price, i.e. a reasonable price for completing the work within the scope of the contract, is agreed by both sides. The key mechanism is the so-called "pain/gain" mechanism. When the final cost is lower than the target price, it means cost savings occur and is called "in gain", while it is called "in pain" when the target price is higher than the price. The idea of TCC is that both pain and gain are distributed between the two contract sides [13]. Rusk argues that the objective of a target cost contract is to allocate the risks reasonably between the two sides [14]. Yan gave a more comprehensive explanation of target cost contract model. He focuses on the analysis of the operating mechanism, risk management, as well as advantages and disadvantages of target cost contract, pointing out that the key to the implementation of target cost contract lies in setting target cost and allocation ratio reasonably [15]. Chan et al. considered the guaranteed maximum price (GMP) contract as a derivative of target cost contract and conducted an empirical investigation of the motivations and advantages of the two contracts [16], and at the same time, he studied the key risks and risk mitigation measures [17]. Molenaar discovered after the scan that a form of target pricing has been employed in the state of Washington. Target pricing concepts from the Highways Agency in England, South Carolina DOT, and Washington State DOT are summarized. The aim of the target pricing technique is to align team goals by establishing the contractor's role early in the project development process and then sharing risks rationally and equitably through to project completion [18]. Recently, a new hybrid contracting strategy called "competitive GMP" in which an alternative delivery method combines with low-bid procurement and "open book" GMP payment provisions, has been used in the construction industry. In their study, Tran et al. expected to advance the understanding of the impact of the competitive GMP contracting strategy on project costs. The exploratory structured interviews were conducted to identify

the perception of the owners and contractors on selecting a contracting strategy. Three empirical case studies were then performed to examine the cost implications on the competitive GMP contracts [19].

In terms of contract type selection, Veld and Peeters emphasized the impact of three contract parameters particularly, that is, cost, delivery time and performance. Meanwhile, they proposed a decision tree model which can be used to select the contract types objectively [20]. Turner and Simister discussed the relationship between contract type selection and project uncertainty. The choice of contract type is determined by the uncertainty of the project itself and the project transfer process. When the project itself and the transfer process are highly uncertain, the most suitable type of contract is pure cost-plus contract. When the project itself is clear, but the transfer process is uncertain, then the Turnkey contract is more appropriate. When the project itself and the process are both uncertain, the cost-plus incentive contract can achieve optimal results [11]. De Meyer et al. studied the uncertainty of contract management and concluded that a high degree of uncertainty (meaning high risk) would greatly reduce the role of the contract. An unstable project environment meant that the terms could not be properly defined in the contract. At the same time, the goals of different project participants are also different. If some flexible arrangements are set in the project implementation process to accommodate changes in the project environment, such as the impact of market fluctuations on the supply price [21], which supports the concept of hybrid pricing contract, using different contract types according to the changing risk level, so as to make full use of the advantages of various contracts in project implementation process [22]. For instance, a cost-plus contract can be applied to feasibility study phase with very limited engineering information, and converted into a fixed-price contract when the scope of work and cost are more certain. Although there are incentives to reduce costs in fixed-price contracts, the strict price terms increase the risk of contractors, as well as the price's uncertainty. This will inevitably cause the contractor's compromise with other project objectives, such as quality and safety. A cost-plus contract can neither encourage contractors to lower costs nor achieve other project objectives [10]. In order to promote the improvement of the payment method of general contracting contract conditions, Zhang et al. proposed that the way to improve the standard contract conditions is to construct a payment method between unit price contract and lump sum contract, which can maintain the incentive of lump sum contract to the contractor, and give full play to the advantages of the unit price contract for reasonable risk allocation, so as to achieve a win-win situation for both sides [23]. Dai established a contract payment plan comparison model under the PMC mode. Firstly, he determined the construction of the comparison model and the index system of the comprehensive quality of the construction project, then link the indicator system with the project, and analyzing the impact of different contract pricing plans on the actual operation of the project under PMC mode [24]. Chen et al. provide empirical evidence from real DB projects that can be used by owners to select appropriate contract types and eventually improve future project performance [25]. Tran et al. to advance the understanding of the impact of the competitive GMP contracting strategy on project costs. The exploratory structured interviews were conducted to identify the perception of the owners and contractors on selecting a contracting strategy [26].

From a comprehensive view of existing research, we can find that studies on contract payment method of civil engineering project are not systematic enough. It is a problem worth deeply studying that how to design a contract payment method that matches well with project delivery method based on specific project characteristics. By designing the contract payment method that matches the engineering characteristics, the risk or benefit of the project can be reasonably distributed between both sides, which can promote the realization of project added-value. Therefore, this paper attempts to discuss how to conduct innovative design of contract payment method on the basis of comparing existing classical ones.

2. Material and Methods

2.1. A qualitative comparison of different contract payment methods

2.1.1. Comparison of classical contract payment methods in practical application

Contract payment method is the payment form of the owner for the service provided by the contractor, and it is a crucial part of project contract, determining the distribution of most engineering risks between the owner and the contractor. In engineering practice, there are nearly 20 kinds of contract types. Different types of contracts have different application conditions, different distribution of rights and responsibilities, different pricing and payment methods, and also means different risks for both sides. Sometimes in a project contract, different engineering sub-items will use different payment methods [27].

Generally, there are currently two major types of engineering contracts that can be divided into price-based contracts and cost-based contracts. The price-based contract includes lump sum contract and unit price contract, while the cost-based contract includes cost-plus contract, target cost contract (TCC), guaranteed maximum price (GMP) and so on. Through summary of existing practices and research, the types of contract payment methods (or derivatives), features, scope and application conditions, as well as the practical application are compared and shown in Table 1.

Table 1. Comparison of different contract payment methods.

Contract type	Sub-type /derived type	Features	Application scope and conditions	Practical application
Lump Sum Contracts	Fixed-price contract; Escalation lump sum contract; Contract of lump sum on firm bill of quantities; Management fee lump sum contract.	The owner's project management is simple, and the risk is small; both parties to the contract may have conflicts and disputes on final price and duration adjustment when engineering changes occur.	Clear project content, complete design drawings, accurate project scope and engineering measurement basis, and relatively ample bidding time; more suitable for projects with small quantity, simple structure, less complicated technology, less risk and short duration.	FIDIC's Conditions of Contract for Plant and Design-Build, and EPC/Turnkey Projects
	Unit Price Contracts	Unit price priority is more reasonable for both parties; in the implementation of the project, the owners need to invest more on-site management manpower for measurement and control; the final cost cannot be determined at an early stage.	Relatively complete design drawings; the bill of quantities provided by the owner should meet the requirements of bidding; more suitable for projects with unclear definition and inaccurate measurement before the start of the project.	FIDIC's Conditions of Contract for Construction; Conditions of Construction Contract for Water Conservancy and Hydropower projects (China).
Cost-Plus Contracts	Cost plus fixed fee contract; Cost plus fixed rate fee contract; Cost plus bonus contract.	The contractor does not bear any risk, while the owner bears nearly all the risks; able to start as soon as possible; the contractor does not have initiative for cost control; the owner need more on-site personnel for cost control.	Project scope cannot be defined and accurately evaluated; the project is particularly complex, and the technical and structural plans cannot be determined in advance, or new technologies, new processes need to be adopted; time is particularly urgent, requiring the commencement as soon as possible.	Often used in some projects with research and development nature, as well as some rescue or emergency projects with very urgent time.
Target Cost		Making the goals of	Project scope is not fully	NEC target

Contracts (TCC)	both contract parties converge, encouraging more cooperation; able to maximize the contractor's project management initiative.	defined or predicted to be with greater risk.	contract published by ICE.
Guaranteed Maximum Price (GMP)	The owner's risk is small; greater binding force on the contractor.	More suitable for projects with clear scope definition, especially Turnkey projects.	Commonly used in DB or Turnkey projects.

2.2. Impact of different contract payment methods on risk allocation

Among the five kinds of contracts shown in Table 1, the unit price contract and lump sum contract are price-based contracts, while the cost-plus contract, target cost contract, and guaranteed maximum price are cost-based contracts. The target cost contract and guaranteed maximum price can be regarded as a derivative form of cost-plus contract. In addition, the target cost contract and guaranteed maximum price are incentive contracts, which are contracts in between, with the lump sum contract and cost-plus contract being two extremes. Figure 1. describes the intrinsic links of the five contract payment methods mentioned above.

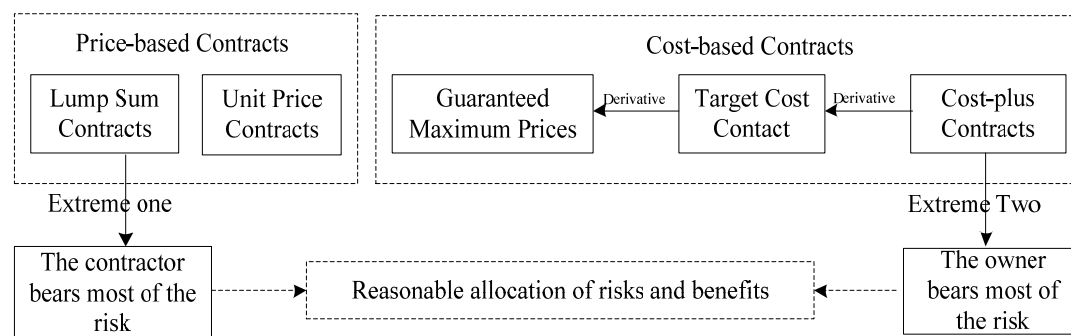


Figure 1. Intrinsic links between the common contract payment methods.

Different contract payment methods will not only affect the owner's payment, but also have a great impact on the distribution of risks and benefits between the owner and contractor. Actually, the selection of contract payment method by the owner is an effective way to allocate risk. As for risk allocation in a contract, it is mainly reflected in the distribution of both quantity risk and price risk. In the lump sum contract, the contractor bears almost all the quantity and price risks, while it is just the opposite in the cost-plus contract, that is, the owner takes all the risks. Therefore, the lump sum contract and cost-plus contract can be regarded as two extreme cases. For other types of contract payment method, the risk allocation patterns are in between. Among them, the owner assumes the quantity risk in unit price contracts, while the contractor bears the risk of price changes in this payment approach. In a target cost contract, the final cost overrun risk is shared by both sides, that is, both the quantity risk and price risk are borne by both contract sides. In a GMP contract, the cost that exceeds the GMP value will be borne by the contractor, so the contractor's risk will be greater than the target cost contract when using GMP contract. There are also some differences in the risk distribution between various subdivision contract types. In general, the risk allocation of different contract payment methods can be illustrated in Figure 2.

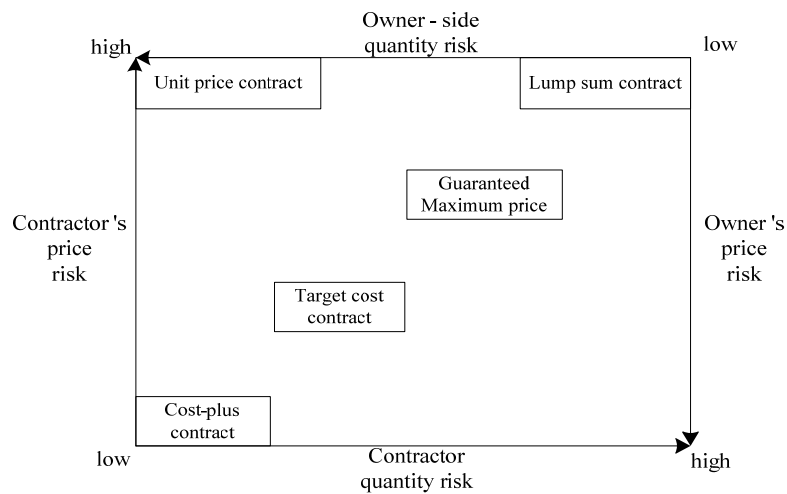


Figure 2. Risk allocation diagram for different contract payment methods.

According to Figure 2, it is not difficult to find that only the unit price contract clearly distinguish between unit price risk and engineering quantity risk in terms of risk allocation, which are undertaken by the contractor and the owner respectively. By contrast, the other four kinds of contracts mostly mix the unit price risk with engineering quantity risk together to allocate them between the owner and contractor. And the unit price risk and quantity risk can be unified as project cost risk.

3. Results

3.1. Modelling Expression and Parameter Comparison of Contract Payment Methods

3.1.1. Modelling expression

For a more intuitive comparison of different contract payment methods, their typical forms are discussed here, drawing lessons from a unified point of view [28]. As it is mentioned above, the unit price contract has particularity comparing with the other four kinds of contract payment method since it clearly distinguish the unit price risk and quantity risk, so we wouldn't analyze it for the present, while focusing on the other four kinds. The other four typical contract forms, including fixed-price contract, cost plus fixed fee contract, TCC and GMP, essentially contains the following parameters: fixed or target cost, actual cost, risk (or income) allocation ratio (referred to as allocation ratio for short). For convenience of discussion, the "fixed cost" under fixed-price contract which is based on price, and the "target cost" (the cost corresponding to GMP in GMP contract can be regarded as target cost) under the other three types of contracts which is based on cost, are collectively referred to as the "target cost" in this paper, so the above four kinds of contract payment method are actually determined by four parameters: target profit, target cost, actual cost and allocation ratio. Only for some contract payment methods, one or two of the four parameters are constant (or 0).

Let the target profit be Π_T , the target cost be C_T , the actual cost be C_A , the allocation ratio be α , the contractor's actual profit be Π_C , then the target cost contract can be expressed as:

$$\Pi_C = \Pi_T + \alpha(C_T - C_A) \quad (1)$$

Then,

(1) When $\alpha = 1$, $\Pi_C = \Pi_T + C_T - C_A = P_T - C_A$, where P_T is the target price, if we regard it as a fixed cost, then the contract becomes a fixed-price contract.

(2) When $\alpha = 0$, $\Pi_C = \Pi_T$, i.e. the contractor's actual profit is only the target profit, then the contract can be regarded as a cost plus fixed fee contract, which belongs to cost-plus contracts.

(3) When $C_T - C_A < 0$, in the case of $\alpha = 0$, if the target cost is regarded as the corresponding cost of GMP, the contract becomes a GMP contract.

(4) When $\alpha \in (0,1)$, the contract is a typical target cost contract.

Thus, in addition to unit price contract, the above four kinds of contracts have similarities in the form.

In fact, a unit price contract can also be expressed in a similar form. Assuming that the “integrated unit price” is denoted as p , the unit price excluding the profit portion is denoted as p_c (called “cost unit price”), the quantity shown in the bill of quantities is denoted as Q_B , and the actual quantity is represented by Q_A , thus if the profit calculated based on the bill of quantities is regarded as the target profit, the actual profit of the contractor under unit price contract can be expressed as:

$$\begin{aligned}\Pi_C &= P_A - C_A = pQ_A - p_cQ_A = (p - p_c)Q_A \\ &= (p - p_c)Q_B + (-1)(p - p_c)(Q_B - Q_A) \\ &= \Pi_T + [(-1)(p - p_c) / p_c](p_cQ_B - p_cQ_A) \\ &= \Pi_T + [(p_c - p) / p_c](C_T - C_A)\end{aligned}\quad (2)$$

Obviously, the form of Eq. (2) is similar to Eq. (1), corresponding to $\alpha = (p_c - p) / p < 0$ which is negative. Different from other contracts, the profit in a unit price contract is implied in the unit price, which clearly divides risks into unit price risk and quantity risk. This is the special feature of unit price contract compared with other types of contracts.

3.1.2. Parameter comparison

According to the above analysis, fixed-price contracts and cost-plus contracts are always two extremes, regardless of risk allocation or cost-saving sharing, while other contracts fall in between. In order to more clearly show the differences in distribution of risks or benefits of various contracts, quantitative methods are used here for deduction. For the sake of easy analysis, assuming that:

(1) $V_C = \Delta C = C_T - C_A$, being the cost savings. When $\Delta C > 0$, cost savings are positive, which is expressed as income. When $\Delta C < 0$, it means that cost overruns, manifested as cost risk.

(2) The contractor's ordinary profit or target profit denoted as Π_T (without considering cost risk) is equal under various contract payment methods. Therefore, we can subtract the ordinary profit from the owner's payment function for the contractor, i.e. $P_A = P(C_T, C_A, \alpha)$, without affecting the discussion. In this case, the contractor's profit is the cost risk reward denoted as Π_R (which may actually be the distribution share of cost-saving income or cost over-expenditure).

(3) The contractor's profit (risk reward) is the owner's payment minus the actual project cost, namely, $\Pi_R = P_A - C_A$.

On the basis of the above assumptions, as well as the unified analysis of different contracts, the payment of the owner's and the contractor's income in various contract types can be expressed in the following forms.

The owner's payment:

$$P_A = P(C_T, C_A, \alpha) = C_A + \alpha(C_T - C_A) = C_A + \alpha V_C = C_T + (\alpha - 1)V_C \quad (3)$$

Contractor's income:

$$\Pi_R = P_A - C_A = \alpha V_C \quad (4)$$

Taking the fixed-price contract, target cost contract and cost plus fixed-rate cost contract as examples, the comparison of P_A , Π_R and α in different contracts are shown in Table 2.

Table 2. Comparison of parameters in different contract payment methods.

Contract type	α	P_A	Π_R
Fixed-price contract	1	C_T	V_C
Unit Price Contract	$1 - p / p_c < 0$	$C_T + (-p / p_c)V_C$	$(1 - p / p_c)V_C$
Target Cost Contract	$(0, 1)$	$C_T + (\alpha - 1)V_C$	αV_C
Cost plus fixed-rate fee contract	$(-1, 0)$	$C_T + (1 + \alpha)(-V_C)$	$\alpha(-V_C)$

From Table 2, it can be more clearly to see the differences between various contracts in terms of owner's risk and contractor's return. For example, in cost plus fixed-rate fee contracts, there is a minus sign before V_C , which means that this type of contract actually acts as a “negative incentive” to the contractor, that is, when the actual cost overruns, the contractor can get more benefits instead. In general, as for the three types of contract including fixed lump sum contract, unit price contract and cost plus fixed-rate fee contract, it is not easy to achieve the following goals: controlling the owner's risk and encouraging contractor's optimization, no matter which type of contract payment method is used. Thus it is difficult to solve the high risk problem resulting from large uncertainties. Therefore, these payment methods need to be improved at least or we can make a mixed use of several contract payment methods.

The comparison results in Table 2. also show that the use of target cost contracts is relatively ideal, and successful risk allocation and benefit sharing can be achieved between the contractor and the owner as long as the allocation ratio or sharing ratio, denoted as α , can be reasonably determined. However, it is a relatively difficult task to determine the target cost, due to the fact that the cost is the contractor's private information and he may possess the motive to conceal the real cost. Hence, the owner needs to pay close attention to the contractor's level of integrity and other information when using target cost contracts.

4. Discussion

4.1. Design of Contract Payment Method

As mentioned above, a variety of contract payment methods have emerged in practical projects all over the world. Different contract payment methods are suitable for different types of civil engineering project, with different risk and responsibility distribution. As each engineering project is unique, an appropriate contract payment method should be determined according to the specific characteristics for a particular project. In this sense, the contract payment method is not only the product of choice, but also should be the product of design. Broadly speaking, contract payment method design may select an appropriate one from the existing classical contract payment methods, or improve the existing methods, and may also create a new payment method.

4.1.1. Design factors

Contract payment method is closely related to project delivery method, both of them are usually mentioned at the same time. Different project delivery methods require different contract payment methods to support, that is, different contract payment methods are needed to be matched with different delivery methods. For example, as to DB or EPC model, some people think that the suitable payment methods include fixed lump sum contract, adjustable lump sum contract, two-stage lump sum contract and cost plus contract, etc. [29]. It was also suggested that the most commonly used four kinds of contract payment methods are fixed lump sum contract, cost-plus contract, cost-plus contract with ceiling price, and unit price contract, while unit price contract is generally only used as a supplement to the fixed-price contract or cost-plus contract to compensate for the special part of the project [30]. However, for a complex DB/EPC project with high uncertainties and a long duration, it is obvious that single fixed lump sum contract or cost-plus contract can hardly overcome the problem of excessive risk or insufficient incentive caused by unreasonable risk or benefit allocation. Therefore, it is necessary to redesign reasonable contract payment methods for complex DB/EPC projects. Take the comprehensive treatment project of Shenzhen-Dongguan Maozhou river basin (Shenzhen part) as an example, it adopts EPC model, and the design part of this EPC project adopts fixed price contract, while the construction part adopts fixed unit price contract.

Under normal conditions, the contract payment method is determined after the project delivery method is selected, or both of them are designed at the same time. In addition to matching with the selected project delivery method, the optimal contract payment method should also meet the key objectives and constraints of the project, dealing with the identified risks most properly, and adapting

to the complexity of the project [31]. For a specific project, contract payment method design is affected by many factors, and the core factors include project clarity and design depth, project size and complexity, and the urgency of project progress. Besides, there are obviously some differences in the preference of the owner and the contractor for contract payment method. The selection or design of the contract payment method is a vital task before the contract is signed between the owner and contractor. As it involves the interests, responsibilities and authority scope of them, the owner and contractor should take account of the above factors according to actual situation and weigh the advantages and disadvantages. They would design the contract payment method together through full consultation, in accordance with the specific internal and external conditions of the project, and the result will be accepted by both sides.

4.1.2. Basic design path

Among the four parameters including target profit, target cost, actual cost and allocation ratio, assuming that the target profit is the same under various contract payment methods, then it can be initialized to zero, which will not affect our discussion. Thus, when designing the contract payment method, it is mainly necessary to consider three parameters, that is, target cost, actual cost and allocation ratio. It is precisely because of the differences in these parameters that the effect of different contract payment methods varies greatly. In the design process of contract payment method, a totally new method can be made from perspective of these three parameters. More often, the owner select a suitable contact type among existing ones, and set reasonable parameters, or improve this contract type, or make a hybrid use of multiple types of existing contract payment methods. From the whole process, the basic design path of contract payment approach is shown in Figure 3.

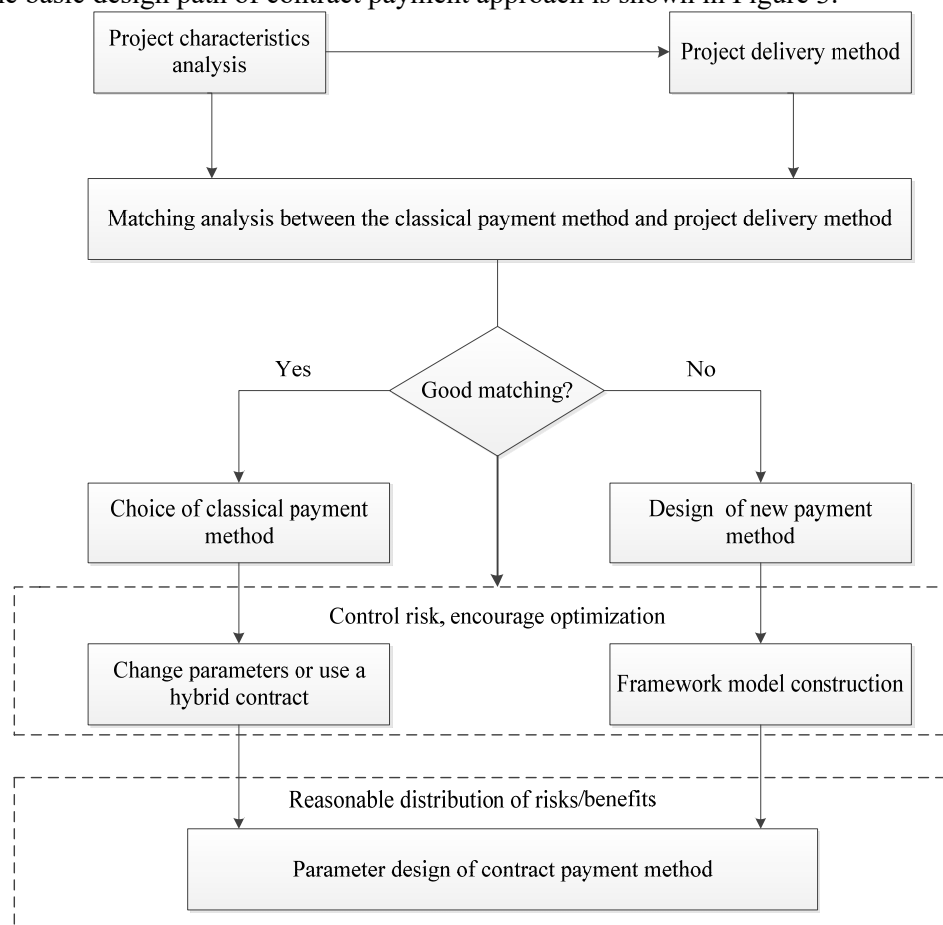


Figure 3. Design path of contract payment method .

In Figure 3, the key issues involved are as follows:

(1) Project characteristics analysis and project delivery method selection. The decision maker should analyze the internal and external conditions of the project, with a focus on project complexity and uncertainty, and select the optimal project delivery method accordingly.

(2) Matching analysis between contract payment method and project delivery method. According to the specific characteristics of the project and the optimal delivery method, it is very necessary to analyze the matching of classic contract payment method and the delivery method. For example, it is common practice to select a lump sum contract to match with the DB model, if the project has a high degree of certainty.

(3) Selection or design of contract payment method, and corresponding parameters setting. If there is a contract payment method among classic contract payment methods that well matches with the given project delivery method, then this payment method may be selected directly, otherwise a new payment method may be designed. Whether it is a choice or a design, the payment method should be able to control risk and encourage optimization. By reasonable parameters setting, the risks or benefits will be reasonably distributed between the two contract sides.

4.2. Case study

The comprehensive treatment project of Shenzhen-Dongguan Maozhou river basin (Shenzhen part), located in Baoan district of Shenzhen City, plans to carry out comprehensive treatment to the land replacement section of the Shenzhen side and the Dongguan side of Maozhou river, a boundary river of the two cities. The treatment scope of Shenzhen side is the section from Maozhou estuary to Xiachong, with a total length of 11.85 kilometers. The main construction contents include river flood control works, riverside landscape, sewage interception works and other auxiliary projects. Among them, the Shenzhen part of the main stream boundary river section of Maozhou river would be improved by raising the flood control standard to be once-in-a-century. The riverside landscape project includes green belt, turf slope protection and so on. The sewage interception works are mainly used to intercept the draining sewage along the river, including new sewage interception pipe construction with a total length of about 10.29 km. The auxiliary projects mainly contain the tasks to rebuild 9 crossing-dyke sluices, and newly build 12-kilometers flood control roads, and develop new information management and automatic control systems.

The comprehensive treatment project of Shenzhen-Dongguan Maozhou river basin (Shenzhen part) is invested by Shenzhen government, with an estimated total investment of 881.71 million yuan, and a planned duration of 72 months. Since the project uncertainty is relatively low and the owner is government sector without enough project management professionals, the owner is suggested to adopt EPC delivery approach, which is a relatively new delivery method that is being promoted by local governments all over China in recent years.

Under EPC model, the comprehensive treatment project mainly includes two parts: design and optimization of construction drawings (Part A), construction and installation of the project (Part B). As EPC is a relatively new method in China, without adaptable policies, totally lump sum contract is not accepted by both sides at present. Thus the owner needs to use other payment approach except totally lump sum contract. Due to the differences between the part of construction drawing design and optimization (Part A) and the part of construction and installation (Part B), different contract payment methods may be adopted. According to Fig. 3, the contract payment method should be designed taking into account project features, and aiming to make reasonable allocation of risks and interests between the two sides of the project. Finally, the owner is suggested to use a hybrid of fixed-price contract and fixed unit price contract, that is, Part A uses fixed-price payment approach, while Part B adopts fixed unit price contract. This solution complies with the requirements of Chinese existing laws and policies, and thus can be accepted by relevant stakeholders. On the other hand, a fixed-price for project design and optimization (Part A) can encourage the contractor to conduct design optimization, while the fixed unit price contract for project construction and installation (Part A) can allocate risks relatively

reasonably between the two contract parties, since the duration is not too long, meaning that the price risk will be under control to a great extent.

5. Conclusions

In a civil engineering project, contract is a mechanism of risk and benefit distribution or transfer for the owner and contractor, aiming to distribute risks and benefits between the two sides. While project risks or benefits distribution in a contract largely depends on the selection or design of contract payment method.

This paper compares the characteristics and application of classic contract payment methods, analyzes the different impacts of different contract payment methods on risk allocation, expresses the typical contract payment methods through modelling based on a unified view, and compares their main parameters. Then this paper analyzes the main influencing factors and the basic design path of contract payment method. Taking the comprehensive treatment project of Shenzhen-Dongguan Maozhou river basin (Shenzhen part) as an example, the contract payment method proposal is analyzed for different parts, providing a clear design idea for contract payment method. However, the setting of specific parameters is very difficult, which is related to many factors such as risk preference of both sides. The detailed design of contract payment method needs in-depth research in combination with project best practice in the future.

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