Study on the Sharing of Geological Condition Risks in PPP Projects of underground pipe gallery

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Abstract: Because of the particularity of geological risk, the risk-sharing problem of PPP projects in underground pipe gallery is crucial for the distribution of interests between the two parties. Through literature analysis, the risk of geological conditions is defined and classified. Based on the three principles of risk-sharing proposed by Xinpeng Liu and Shouqing Wang, which are highly recognized by academic community, this thesis discusses the sharing schemes of different types of geological conditions risks between public and private parties.

1. Introduction
Since the State Council proposed the idea of "carry out the pilot project of urban underground pipe gallery", China has successively identified 25 pilot cities[1], and the construction of underground pipe gallery has shown a vigorous development trend. As a kind of construction of urban underground space, underground pipe gallery's characteristics of wide coverage area, large spatial span[2], high water-proof requirement, and incomplete, inaccurate[3],complex geological environment[4] of underground space information jointly determine that geological condition risk is an important risk in the construction of underground pipe gallery. The basic characteristics of PPP projects are "benefit sharing and risk sharing". However, geological condition risks are likely to bring serious economic losses[5]. If only one party is allowed to bear such risks, it will easily lead to conflicts of interest between the two parties. Therefore, reasonable risk sharing is very important. However, at present, there is still a great controversy on the allocation of this risk in PPP projects[6]. Therefore, this thesis will study this issue based on the three principles proposed by Xinpeng Liu and Shouqing Wang, which are highly recognized by the academic community: the party that has the most control over the risk should control the corresponding risk; the risk should be matched with the benefits, and the risk allocation should have an upper limit[7].

2. Research preparation
2.1 Definition and Classification of Geological Condition Risks
At present, there are few definitions of geological condition risk in relevant research in the field of engineering management. Therefore, this study consulted the definitions of other risks in CNKI that are similar in content and nature to geological conditions risk. In this study, the concept of geological condition risk that has been put forward in the literature is summarized and sorted out, which can be roughly divided into the following three types: ① refers to geological problems beyond reasonable survey and risks that affect the continued implementation of the project, such as faults and karst caves encountered during construction[8];② refers to adverse geological structures or characteristics, which
have a negative impact on the project construction, such as extension or termination of project construction period caused by abnormal geological conditions [9]; ③ refers to the risk that the inaccurate and untimely geological survey data will cause negative impact on the construction of the project, such as the large discrepancy between the geological data provided and the actual geological conditions, resulting in the increase of engineering quantity, etc. [10]. In summary, this study defines the risk of geological conditions as the risk of economic or financial loss due to the inability to predict geological conditions completely and accurately, which has a negative impact on the project. And classify according to the cause of formation, as shown in Figure 1.

![Figure 1 Classification of geological conditions risks](image_url)

Source: Self-mapping

2.2 Identification of Sharing Subject of Geological Condition Risk

According to the construction process of underground pipe gallery, the main work related to the analysis of geological conditions during the construction of the underground pipe gallery is the planning and investigation. The investigation work is mainly to find out the buried objects, stratum structure, foundation engineering properties, special rock and soil distribution, etc. It can be seen that this work may have an impact on geological condition risks, which is highly correlated with geological condition risks. It is more important to identify the survey subjects for formulating reasonable risk sharing schemes. This study summarizes all the 21 national demonstration projects in utility tunnel that are currently in the implementation stage and have been publicized with clear information in the PPP project library. It is found that the main body of exploration work may be social capital or government departments. In view of the fact that in practice, when the government department is responsible for the investigation work, based on the behavior guarantee mechanism, geological condition risks caused by negligence and other reasons shall generally be borne by themselves [11]. Therefore, this study will mainly analyze the sharing of geological condition risks when social capital undertakes survey work.
3. Risk sharing is not allowed for geological data in utility tunnel PPP project

3.1 Determination of the Party with the Most Control Power

In the PPP project of underground pipe gallery, there are mainly two situations when social capital undertakes the investigation work: ① Social capital organizes the investigation by itself. ② Social capital selects qualified survey units to carry out investigation according to law. For the former, social capital can predict the problems that may lead to such risks according to the survey work process, and prevent or reduce the occurrence of the risks of geological data by strengthening personnel training, introducing advanced technologies [12], improving management systems and other means, while government departments can only supervise and inspect the survey work. For the latter, social capital can conduct strict qualification examination on the survey unit, or consult experts in relevant disciplines (such as design, construction or supervision) to compare and select the survey unit [13]. Therefore, in contrast, social capital has more control over the risks of geological data exclusion. Therefore, it can be considered that it is more reasonable for social capital to bear the risk of not allowing geological data.

3.2 Upper limit analysis of social capital's bearing of the risk of geological data

At present, there is no specific regulation on the upper limit of risk-taking in PPP related documents. In view of this, this study traces back to the source and establishes a reasonable upper limit for social capital to bear the risk according to the most basic principle of "profit but not profiteering" insisted by PPP mode, so that it can recover costs and obtain reasonable benefits. Reasonable return is usually reflected in the rate of return on investment. According to the Ministry of Finance's document "Guidelines for Demonstration of Financial Bearing Capacity of Government and Social Capital Cooperation Projects" (Financial document [2015] No.21), reasonable return is an indicator of the rate of return on investment. It is mainly based on the level of medium-term and long-term loan interest rates of commercial banks, fully considering the different scenarios of availability payment, usage payment and performance payment, and is determined in combination with risks and other factors. The project financial internal rate of return can reflect the actual income level of the project and the project's ability to bear risks. Therefore, this study combines the project's financial internal rate of return with the rate of return on investment to judge the upper limit of social capital's risk, as shown in Table 1. Therefore, the social capital is "profitable" only when the financial internal rate of return is not lower than or greater than the rate of return on investment [14,15].

Table 1. Comparison and upper limit analysis of investment return rate and project financial internal return rate

| Indicators | mercantile rate of return | Project Financial Internal Rate of Return |
|------------|---------------------------|-----------------------------------------|
| **Meaning** | It is agreed that based on the medium and long-term loan interest rate level of commercial banks, different scenarios of availability payment, usage payment and performance payment shall be fully considered and determined in combination with risks and other factors. | Refers to the discount rate at which the present value of net cash flow in each year is equal to zero in the whole calculation period of the project. |
| **Characteristics** | Reflect the reasonable economic returns that social capital can get from the project. | Reflect the actual income level of the project, and can reflect the project's ability to bear risks. It is not easy to be affected by external parameters and depends entirely on the cash flow during the project implementation process, which is relatively objective. |
| **Conclusion** | When the project's financial internal rate of return is greater than or equal to the rate of return on investment, social capital can bear the risks of geological data and obtain reasonable returns; When the financial internal rate of return of the project is less than the rate of return on investment, the geological data risk borne by social capital has exceeded the upper limit. | |
4. Sharing of Risks with Unknown Geological Conditions in PPP Projects in utility tunnel

4.1 Risk Sharing in Unexpected Geological Conditions

Unforeseen geological conditions refer to specific geological conditions that cannot be surveyed in the survey work. The risk is caused by objective factors such as limited resolution and precision of exploration technical instruments, and neither public nor private parties have control over the risk. There are only three studies on the risk sharing under PPP mode in the existing literature, and the conclusions should be shared by public and private parties, government departments and social capital. Therefore, this study refers to the way of sharing this risk in general projects. In general projects, this risk is treated as "adverse material conditions" and shall be borne by the employer according to the relevant clauses of FIDIC contract, as shown in Table 2.

Table 2. Risk Sharing of unforeseen geological conditions in general projects

| Serial number | Author | Year | Risk             | Risk content                                      | Risk taker |
|---------------|--------|------|------------------|---------------------------------------------------|------------|
| One           | Shujie Zhang[16] | 2016 | Unforeseen risk  | Unforeseen groundwater, silt, or rocks, etc.       | √          |
| Two           | Zhiliang Zhang[17] | 2013 | Unforeseen risk  | Karst caves, faults, are encountered in construction | √          |
| Three         | Tongsheng He[18]  | 2013 | Abnormal condition | Bad geological properties and structures            | √          |
| Four          | Weidong Jia[19]   | 2004 | Unforeseen risk  | —                                                 | √          |
| Five          | Xiangmin Cheng[20] | 2000 | Geological risk  | Economic losses due to unforeseen geological conditions | √          |

4.2 Risk Sharing for Discovery of Fossils, Tombs, Cultural Relics, et

Through the analysis of PPP contracts in practice, it is found that risks such as fossils, ancient tombs and cultural relics are usually stipulated in separate contract terms. Since there is no unified model contract text for PPP projects in utility tunnel, this study consulted the contracts of 21 national model PPP projects in utility tunnel published in the PPP project library, and found that except for the underground utility tunnel pilot project in Baiyin City, the underground utility tunnel and synchronous construction project in the north section of Cuicheng Road in Cuicheng New District of Zhongshan City, and the 3 PPP projects in the underground utility tunnel in Xiangan New Airport Area in Xiamen City, Fujian Province, the remaining 18 projects have corresponding clauses when fossils, ancient tombs and cultural relics are found and the risk allocation schemes are basically the same. To sum up, the existing PPP projects in our country usually assume the allocation scheme of such risks for government departments.

4.3 Risk Sharing of Geological Disasters

According to the "Regulations on the Prevention and Control of Geological Disasters" (State Council Decree No. [2003]394), geological disasters usually refer to various disasters related to geological processes such as mountain collapses, landslides and debris flows. Since such risks cannot be reasonably foreseen, avoided and overcome by both parties to the project contract, reference is made to the risk sharing scheme of force majeure in PPP projects. This study selected the latest 10 national demonstration comprehensive pipeline PPP projects in the PPP project database and found...
that in practice, the comprehensive pipeline PPP projects generally share the risk of Force Majeure for both sides. The risk of geological hazards that neither side can control nor fault-free should be shared by both public and private parties. The losses caused should follow the principle of "each party shall bear its own losses". At the same time, the completion delay caused by geological disasters should be postponed.

5. Summary

Based on the principle of risk sharing and related documents, this study analyzes the problem of risk sharing of the geological conditions in underground pipe gallery; The results have the following practical significance: (1) it is beneficial to social capital to obtain reasonable returns and improve investment enthusiasm; (2) It can reduce disputes between public and private parties and maintain a good public image of government departments; (3) It is conducive to maintaining the good cooperation between the two sides and achieving a win-win results; (4) It is conducive to promoting the wide application of PPP mode in the underground pipe gallery and ensuring the high-quality development of underground pipe gallery.

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