# Rural Infrastructure PPP Project Risks Analysis Based on Monte Carlo Method

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**Abstract.** The diversity, complexity, and particularity of PPP projects put forward higher requirements for financial evaluation. To make more accurate financial evaluation, this paper uses Monte Carlo simulation method to establish the risk evaluation model of rural infrastructure PPP project, based on the internal rate of return and net present value of the project. The results show that the Monte Carlo simulation method can effectively assess the investment risk of rural infrastructure PPP projects and help investors make correct investment decisions.

## 1 Introduction

The 19th National Congress of the Communist Party of China planned a grand blueprint for the development of agriculture and rural areas in the new era. Rural infrastructure is an important public basic condition for improving farmers' living standards. However, for a long time, the construction of rural infrastructures in China has mainly been funded by the government, and there are widespread problems such as insufficient government investment, and low management efficiency, which seriously restricts the development of rural economy[1]. Therefore, China's rural infrastructure construction urgently needs an innovative governance model, and introduces new investment entities on the basis of government investment[2].

The PPP (Public-Private Partnership) model, refers to a way for government departments to provide quasi-public goods or services through partnerships with private capital[3]. Applying the PPP model to rural infrastructure construction will help reduce financing risks and achieve control over project construction and operation, and further promote the quality of the supply of rural infrastructures[4].

The rural infrastructure PPP project has the characteristics of huge investment scale, complex contractual relationship, many uncertain factors and long cooperation period, which put higher requirements on financial evaluation work. Traditional risk assessment methods such as break-even analysis and sensitivity analysis cannot analyze the combined effects of multiple risk factors. Monte Carlo simulation method can quantitatively evaluate the impact of multiple risk factors more comprehensively and accurately[5]. Therefore, using Monte Carlo simulation method, taking the PPP project of township sewage treatment plant in Hunan Cili County as an example, to carry out the risk analysis and evaluation of rural infrastructure PPP project in China, in order to prove effectiveness of the method in the risk analysis of rural infrastructure PPP project, and then guide investors in making the right investment decisions.

## 2 Risk Analysis of Rural Infrastructure PPP Project

The risk of a PPP project refers to the uncertainties that affect the various stages of the project construction process throughout the life of the project. It includes political risks, legal contract risks, financial risks, and so on. At the same time, the rural infrastructure PPP project has the characteristics of complex risk-bearing subjects, long risk period, and large investment scale. Therefore, risks become the key to the success or failure of the project[6].

In the economic evaluation of investment projects, the basic data used generally comes from the estimation of future conditions, which increases the risk of investment decision-making. Therefore, when conducting economic evaluation of the project, risk analysis should be carried out to provide more

reliable and comprehensive basis for investment decision-making. The risk analysis of investment projects can be divided into three phases: risk identification, risk estimation and risk assessment[7].

In the face of many uncertain factors, strong correlations and complex changes, the traditional economic evaluation method cannot accurately describe the influence of simultaneous multi-factor changes on the results. Therefore, using the Monte Carlo simulation method, and combining the impact of simultaneous multi-factor changes on economic indicators, is a more reasonable method to quantitatively describe the project's ability to resist risks based on the probability of occurrence of events.

## 3 Monte Carlo Simulation

Monte Carlo Simulation analyzes the probability distribution by selecting the uncertainty factor as a random variable, and uses computer technology to conduct random sampling experiments on selected random variables to obtain a large number of outputs [8].

The basic principle of the Monte Carlo simulation method is to assume that the function Y=F(X1, X2, X3..., Xn), in which the random variables X1, X2, X3, ..., Xn are independent of each other and obey a certain probability distribution. These N variables are randomly sampled and substituted into the function Y=F(X1, X2, X3..., Xn). Multiple independent sampling is performed to obtain the probability distribution and mathematical characteristics of the function Y.

## 4 Empirical Analysis

### 4.1 Project overview

There is a recent construction scale of the PPP project of the township sewage treatment plant in Cili County, Hunan Province. According to the project feasibility study report, the project is expected to invest 82 million yuan; the project calculation period is 22 years (including the 2-year construction period), the first year of the production period is 60%, and the second year is 80%. Income tax is calculated at zero tax rate. The working capital of the project is estimated to be 540,000 yuan, the residual value of fixed assets is 4%, the annual sales income is expected to be 10.95 million yuan, and the annual operating cost is estimated to be 2.51 million yuan. According to the industry's internal rate of return standards, the benchmark yield is 4%.

### 4.2 Evaluation indicators determination

The internal rate of return IRR and the financial net present value NPV are selected as financial evaluation indicators to establish a risk decision model. The calculation formulas are as follows:

$$NPV = \sum_{t=1}^{n}(CI - CO)_t(1+i)^{-t} \quad (1)$$

$$\sum_{t=1}^{n}(CI - CO)_t(1+IRR)^{-t} = 0 \quad (2)$$

In formulas (1) and (2), CI is the cash inflow, including sales income, recovery of working capital and recovery of fixed assets balance; CO represents cash outflow, including construction investment, working capital, operating costs, sales tax and surcharges Income tax; (CI-CO)t is the net cash flow for the t-year; i is the industry's benchmark rate of return or the set discount rate; n is the project calculation period. If NPV$\geqslant$0 and IRR$\geqslant$i, the investment project is considered to be financially viable; otherwise it is not.

### 4.3 Determination of risk factors and their probability distribution

In the investment process of the sewage treatment plant PPP project, there are many risk variables, and according to the general laws of the same industry in the country, factors such as construction investment, sales income and operating cost are mainly selected as sensitive risk variables. Therefore, the above three key risk variables are used to measure the project financial indicators.

To perform a Monte Carlo simulation, you need to assign a specific distribution of random numbers to key risk variables, that is, establish a probability model. For engineering projects, historical data estimation or Delphi method is generally used to obtain the probability distribution of key risk variables. According to the relevant data, historical data and expert opinions in the feasibility study report, the probability distribution of key risk variables is determined, as shown in Table 1.

Table 1 Probability distribution table of key risk variables Ten thousand Yuan

| variables | Compliance distribution | parameter |
|---|---|---|
| Construction Investment | Triangle distribution | Minimum value 8200.83<br>Maximum value 8414.85<br>Most likely value 8254 |
| Operating costs | Normal distribution | Expected value 245.9<br>Standard deviation 16.22 |
| Sales revenue | Normal distribution | Expected value 1062<br>Standard deviation 104.46 |

### 4.4 Simulation result

Monte Carlo simulations were performed using Crystal Ball software. The Crystal Ball software greatly simplifies the programming of Monte Carlo simulations in the past. Through table and data analysis, the impact of variable changes on the model can be clearly presented [9]. By setting the distribution function, distribution interval, target variable, and simulation times of the corresponding risk factors, Crystal Ball software can perform risk analysis simulation on the project.

Set the simulation times to 10,000 times, and obtain the probability distribution map, statistical table and probability table of the net present value and internal rate of return of the sewage treatment project, as shown in Fig. 1, Fig. 2, Table 2 and Table 3, respectively.

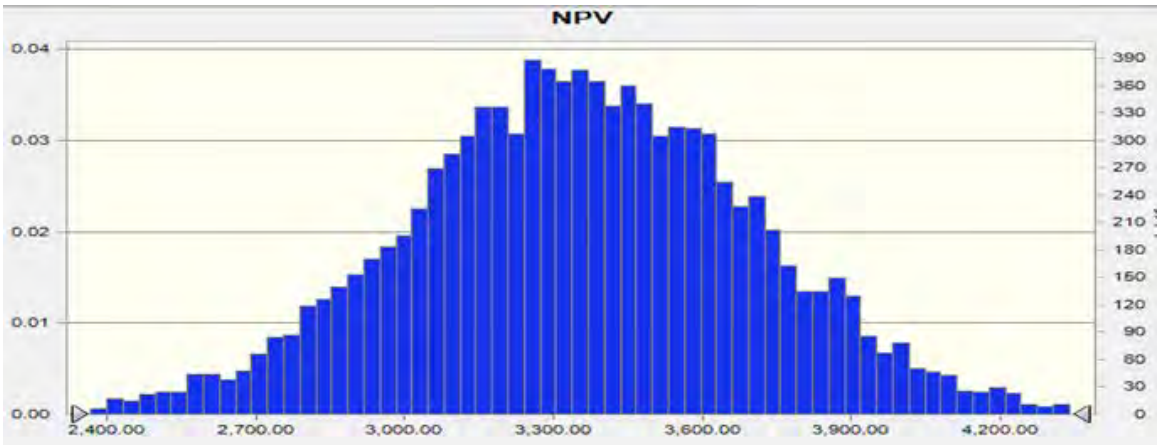


Fig. 1 Net present value probability distribution map

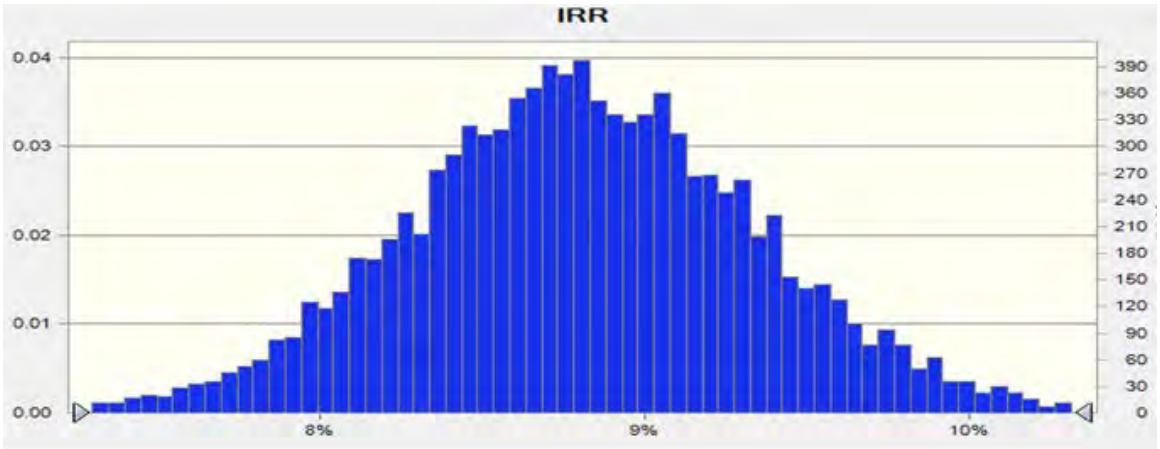


Fig. 2 Internal rate of return probability distribution map

Table 2 Table of net present value and internal rate of return statistics

| Predictive value | NPV | IRR |
|---|---|---|
| Number of experiments | 10,000 | 10,000 |
| average value | 3,353.77 Ten thousand Yuan | 9% |
| Median | 3,351.13 Ten thousand Yuan | 9% |
| standard deviation | 351.71 Ten thousand Yuan | 1% |
| Coefficient of variation | 0.1049 | 0.0610 |
| Minimum value | 2,095.87 Ten thousand Yuan | 7% |
| Maximum value | 4,601.77 Ten thousand Yuan | 11% |

Table 3 Net present value and internal rate of return probability table

| Probability ratio | NPV(ten thousand Yuan) | IRR |
|---|---|---|
| 0% | 2,095.87 | 7% |
| 10% | 2,899.82 | 8% |
| 20% | 3,064.52 | 8% |
| 30% | 3,170.97 | 8% |
| 40% | 3,266.43 | 9% |
| 50% | 3,351.13 | 9% |
| 60% | 3,442.87 | 9% |
| 70% | 3,539.68 | 9% |
| 80% | 3,647.41 | 9% |
| 90% | 3,804.68 | 10% |
| 100% | 4,601.77 | 11% |

According to the above simulation results, the standard deviation of the simulated net cash flow after 10,000 times has been approximately converged. According to the statistical table, the average value of net present value is 33,537,700 Yuan, the minimum value is 20,958,800 Yuan, and the maximum value is 4,601,777 Yuan; the average internal rate of return is 9%, the minimum value is 7%, and the maximum value is 9%. It can be seen from the probability distribution map that the probability that the net present value of the project is greater than zero is 100%, and the probability that the internal rate of return is greater than 4% of the industry benchmark yield is 100%, indicating that the project has strong financial feasibility and ability to resist risks. It can be seen from the case that the Monte Carlo method is used for the risk assessment of the rural infrastructure PPP project, which can synthesize the simultaneous changes of multiple risk variables, accurately and objectively determine the probability and consequences of the occurrence of the risk event, effectively judge the project risk, and guide Investment decision.

## 5 Conclusion

In view of the shortcomings of the common rural infrastructure project income risk assessment method, taking the PPP project of Hunan Cili Wastewater Treatment Plant as an example, based on the Monte Carlo simulation method, the risk assessment model is established based on the internal rate of return and the net present value of the project, to make risk analysis of the rural infrastructure PPP project. The research results show that the case project has strong financial feasibility and anti-risk ability. For such projects, the Monte Carlo method is a good risk analysis method, which fully considers the probability of occurrence of various factors or ranges of various factors, and overcomes the limitations of traditional sensitivity analysis methods that are individually changed by each variable. Sexuality makes the evaluation results better reflect objective laws, more comprehensive and intuitive description of project investment risks, and helps investors make correct investment decisions.

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