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ARTICLE

# Research on Government Compensation for Toll Road Public-Private Partnerships (PPP) Projects

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ABSTRACT

With the continuous implementation of the PPP projects, due to the imperfection of relevant policies, the blindness of government subsidy is constantly emerging. Thus, it is important to put forward a practical approach for valuing the subsidies and risk. In this paper, the revenue subsidies model and traffic subsidies model are established. Then combined with practical cases, Monte Carlo simulation is used to get the value and probability of government subsidies under different compensation ways. On this basis, the influence of initial traffic volume and traffic growth rate on government subsidies and net present value of investors is analyzed. The research findings can provide theoretical guidance for the government to choose a reasonable way of subsidies, balance the risk of compensation, and formulate subsidies policies.

## 1. Introduction

Nowadays, China vigorously advocates PPP mode to relieve financial pressure and effectively introduce market competition. Most of the projects built by PPP mode are infrastructure projects, which usually have high investment amount, long payback period and low return rate. In order to attract investment, the government often provides some compensation to share the project risk. The government has been plagued by many problems, such as how much should compensate for these projects, how to compensate, and how to evaluate the risk of project compensation. Wibowo (2004) studied the impact of government compensation on project value[1]. Cheah and Liu (2005) used Monte Carlo method to simulate the appropriate amount of subsidy for a highway bridge project in Malaysia[2]. Brandao and Saraiva (2008) estimated the value of minimum traffic guarantee and its cost-benefit[3]. Galera and Soliño (2010) evaluated the value of minimum revenue guarantee based on real option[4]. Jun (2010) analyzed the government payment and the net present value of concessionaire when implementing the minimum traffic guarantee in BOT projects[5]. Liou and Huang (2012) take a high-speed railway project in southern Taiwan as an example to illustrate the government compensation amount and risk of infeasible projects in financial evaluation[6]. Ashuri and kashani (2012) use the risk neutral pricing theory to study the minimum revenue guarantee for highway BOT projects[7]. Chiara and Kokkaew(2013) analyzed the impact of minimum revenue

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guarantee using Monte Carlo simulation[8]. Feng and Shuai (2015) discussed the impact of government compensation on toll rate, road quality and road capacity from the perspective of private investors[9].

These studies have a good role in promoting the government to clarify the compensation ideas and establish a perfect compensation policy, but there are still some shortcomings. First, most of the models are theoretical models with poor feasibility, which are difficult to be applied in practical projects. Next, application scope and conditions of different compensation methods are not clear. Finally, the willingness of both government and investors to participate in investment under different compensation limits is ignored. In this paper, two compensation methods, revenue compensation and traffic compensation, are selected to study. The government compensation model is established based on the real option theory. Combined with the actual case and Monte Carlo simulation, the compensation times, average value and net present value of project are analyzed. The research findings are to provide theoretical guidance for the government to choose compensation methods, weigh compensation risks and formulate reasonable compensation policies.

## 2. Model Building

### 2.1 Revenue Compensation Model

If the annual revenue $R_{aj}$ is less than a% of the expected revenue $R_{pj}$, the government compensates the private sectors an equivalent amount. The guarantee is available in concession period. The value of revenue compensation in year j $AS_j^R$ and government total subsidies in concession period $TS^R$ is given by

$$AS_j^R = \begin{cases} 0 & if\ R_{aj} \geq a \times R_{pj} \\ a \times R_{pj} - R_{aj} & otherwise \end{cases} \tag{1}$$

$$TS^R = \sum_{j=1}^{T} \frac{AS_j^R}{(1+r)^j} \tag{2}$$

$$R_{aj} = Q_{aj} \times P \tag{3}$$

$$Q_{aj} = Q_{aj-1} \times (1+\alpha) \tag{4}$$

Where $P$ = toll rate, $Q_{aj}$ = annual operating traffic volume in year j, $\alpha$ = growth rate of traffic volume, $r$ = discount rate.

If the annual revenue $R_{aj}$ is more than b% of expected revenue $R_{pj}$, the private sector provide the c% of excess profit to government. The annual excess profit sharing $AP_j^R$ and total excess profit sharing $TP^R$ are shown as below

$$AP_j^R = \begin{cases} 0 & if\ R_{aj} \leq (1+b) \times R_{pj} \\ (R_{aj} - (1+b) \times R_{pj}) \times c & otherwise \end{cases} \tag{5}$$

$$TP^R = \sum_{j=1}^{T} \frac{AP_j}{(1+r)^j} \tag{6}$$

Expected revenue $R_{pj}$ is calculated according to the method proposed by the Ministry of Finance[10], in which the construction cost $I$, operation cost $C$, and rate of reasonable profit $\beta$ are considered.

$$R_{pj} = \left[ \frac{I \times (1+r)^j}{T} + C_j \right] \times (1+\beta) \tag{7}$$

### 2.2 Traffic Compensation Model

If the annual traffic $Q_{aj}$ is less than $d$% of the expected traffic $Q_{pj}$, the government compensates the private sectors an equivalent amount. The guarantee is available in concession period. The value of traffic compensation in year j $AS_j^T$ is given by

$$AS_j^T = \begin{cases} 0 & if\ Q_{aj} \geq d \times Q_{pj} \\ (d \times Q_{pj} - Q_{aj}) \times P_j & otherwise \end{cases} \tag{8}$$

Similarly, if the annual traffic $Q_{aj}$ is more than $e$% of expected traffic $Q_{pj}$, the private sector provide the $f$% of excess profit to government. The annual excess profit sharing in traffic compensation $AP_j^T$ is expressed by

$$AP_j^T = \begin{cases} 0 & if\ Q_{aj} \leq (1+e) \times Q_{pj} \\ (Q_{aj} - (1+e) \times Q_{pj}) \times P \times f & otherwise \end{cases} \tag{9}$$

### 2.3 Investment Willingness of Government and Private Sectors

The net present value (NPV) of project is net profit of private sector, which is shown as

$$NPV_p = \sum_{j=1}^{T} NPV_j - I = \sum_{j=0}^{T} \frac{R_{aj} + AS_j - C_j}{(1+r)^j} - I \tag{10}$$

Where $NPV_p$ = NPV of project, $T$ = concession period, $I$ = investment value of private sector.



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The NPV of government $NPV_g$ should consider the social benefits and net government payment, as in (11).

$$NPV_g = \sum_{j=1}^{T} \frac{G_j - AS_j + AP_j}{(1+r)^j} \tag{11}$$

Here, $G_j$ = social benefit of the project in year j.

The social benefits of expressways are mainly reflected in the pulling effect of the construction period of Expressways on the construction industry and the operation period on the gross national product (GDP) of the transportation industry [13].

$$G_j = \left[\frac{\mu \times I \times (1+r)^j}{T}\right] + \delta \times Q_j \tag{12}$$

In (12), $\left[\frac{\mu \times I \times (1+r)^j}{T}\right]$ describes the construction of toll road promotes the development of construction industry, which average discount to each year of concession period, while $\delta \times Q_j$ is the driving effect of the project operation period on the transportation industry. $\mu$ and $\delta$ are constant and greater than zero.

The effect of government compensation is simulated by Monte Carlo Simulation. The simulation process is show as Fig. 1.

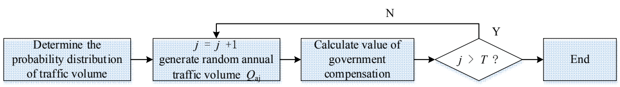


**Figure 1.** The simulation process

## 3. Case Study

### 3.1 Project Background and Simulation Parameters

A toll road will be built in a province, public bidding will be carried out by PPP mode, and construction will start in 2009, with a construction period of three years and 30 years operation period. At the end of the concession period, the private sector should deliver the project to government for free. According to the contract, the toll rate of the project is 0.48 yuan / vehicle · km.

The construction period *n* is 3 years, discount rate *r* is 10%. According to the *Annual Report of Highway Traffic Investigation and Statistics* issued by the Highway Bureau of Sichuan Provincial Department, the parameters in equation (12) are fitted, $\mu = 0.27$ , $\delta = 27.95$ . The cost of toll road operation period is mainly composed of operation management fee and daily maintenance fee, which is increased every year according to different usage. The value is calculated by the feasibility study report of the project. The initial traffic volume is 3.4204 million vehicles / year. The traffic growth rate is divided into two stages: short term (2012-2026) and long term (2027-2041). The corresponding traffic growth rate is 12% and 6%. The probability distribution of initial traffic and growth rate of traffic are listed in Table 1.

**Table 1.** Probability Distribution of Non-fixed Parameters

| Parameters | Probability Distribution | |
|---|---|---|
| Initial traffic | Normal distribution, | Mean value: 3.4204 million, std.:0.34 |
| Growth rate of traffic | Normal distribution | In short term, mean value 12, std.: 4 |
| | | In long term, mean value 6, std.: 2 |

### 3.2 Simulation of the Model

#### 3.2.1 Discussing about Revenue Compensation

According to the above revenue compensation model, assuming that when the annual revenue is lower than 90% of the expected revenue, start the revenue compensation, using MATLAB (R2015a version) for simulation, and the number of simulation is set as 20000 times.

Figure 2 shows that during the 30-year concession period of the project, the government needs to provide 11.83 times of revenue compensation on average, with a standard deviation of 8.35. Figure 3 shows the probability of providing revenue compensation each year during the operation period. In the short term, due to the relatively high traffic growth rate, the revenue increases gradually, and the government's compensation probability decreases gradually. With the passage of time, the growth rate of traffic volume will decrease. When the increase of revenue cannot cover the increase of cost, the government's compensation probability increases gradually.

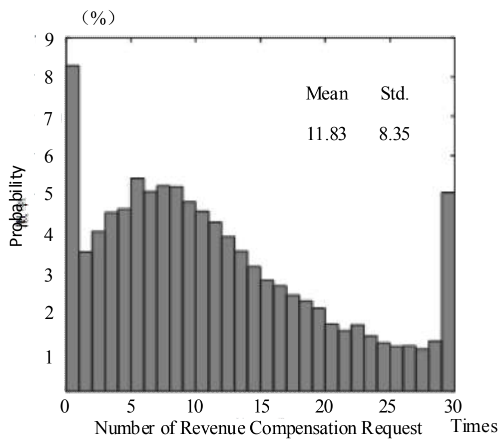


**Figure 2.** Probability distribution of number of revenue compensation

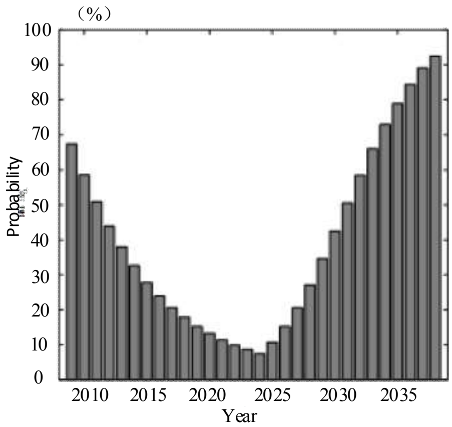


**Figure 3.** Probability of revenue compensation provided in each year

### 3.2.2 Discussing about Traffic Compensation

According to the traffic compensation model, if the traffic volume is less than 90% of the expected traffic volume, the traffic compensation is started, and the simulation times are 20000. Compared with the revenue compensation, the number of traffic compensation request are relatively low. The average number of compensation in a concession period is 6.54 (as shown in Fig. 4). Figure 5 shows the probability of compensation for each year of the concession period under traffic compensation. Traffic compensation is only related to the change of traffic volume. Therefore, in the short term of the project, due to the large fluctuation of traffic volume, the probability of compensation is high and increases year by year. In the long term of operation, the traffic volume tends to be stable, and the probability of compensation is relatively low. There is a big change difference in the figure 5, which is caused by different traffic growth rates and volatility in the short-term and long-term stages of operation.

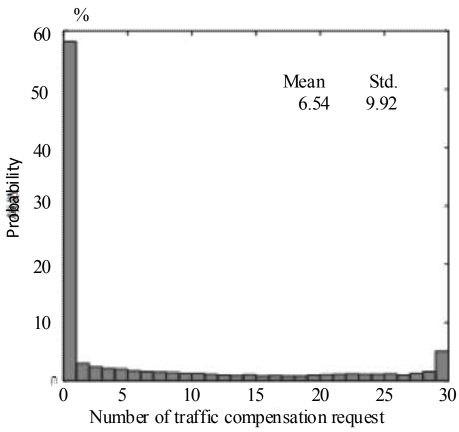


**Figure 4.** Probability distribution of number of traffic compensation

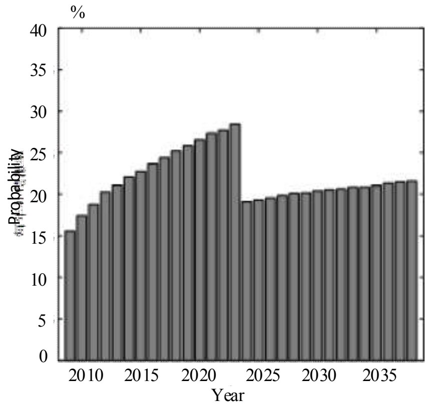


**Figure 5.** Probability of traffic compensation provided in each year

### 3.2.3 Comparison of Simulation Results

The simulation results of revenue compensation and traffic compensation are compared as shown in Table 2. The revenue compensation shares the revenue risk of the project, while the traffic compensation only shares the traffic risk. Therefore, compared with the traffic compensation, the frequency and amount of the revenue compensation provided by the government are higher, and the value of the shared excess profit is lower, which makes the government's financial net present value lower. But at this time, the project's profit is considerable, and the rate of return is 11.63%, which is higher than the profit of the transportation project, private sectors have a higher willingness to invest. When considering the social benefits of the project, the government's NPV is higher, indicating that the project has a higher construction value, and the government has a certain willingness to compensate, while the government's NPV is low, which requires a lot of expenditure. Traffic

**Table 2.** Comparative Analysis of Simulation Results

| Items | Revenue compensation | Traffic compensation |
|---|---|---|
| Mean value of number of compensation | 11.83 times | 6.54 times |
| Mean value of annual compensation | 97.518 millions | 18.057 millions |
| Mean value of total compensation | 1183.597 millions | 81.772 millions |
| Excess profit sharing | 1.446 millions | 101.025 millions |
| NPV of private sector | 595.348 millions | 397.932 millions |
| Rate of return | 11.63 (%) | 7.77 (%) |
| NPV of government (including social benefits) | 3998.502 millions | 4185.340 millions |
| Financial NPV of government (excluding social benefits) | -1182.145 millions | 19.253 millions |

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compensation mainly shares the traffic volume risk of the project, with fewer number of compensation request and relatively low amount of compensation. The government has certain financial revenue to participate in the project, good social benefits and high willingness to participate. On the other hand, the investor's return on investment is basically the same as the return on investment of other transportation projects. The investor is willing to invest, but the enthusiasm for investment is less than the project under revenue compensation.

## 4. Conclusion

Monte Carlo simulation is used to analyze the actual case, and the compensation provided by the government and the net present value of private sectors under revenue compensation and traffic compensation are obtained. The results show that under revenue compensation, the number and amount of compensation provided by the government are higher than that of traffic volume compensation, but the private sectors have better return on investment and stronger willingness to invest. Therefore, revenue compensation is more suitable for projects with better financial situation of the government, which need to attract investors to invest, or projects with high social benefits. Under the mode of traffic compensation, the number of times of compensation is small and the amount of compensation is relatively low, which can share the traffic volume risk of the project to some extent. Thus, the traffic compensation is applicable to the government with poor financial situation and project has high traffic risk, which can guarantee the investors' income to a certain extent. In addition, the uncertainty of initial traffic volume and traffic growth rate affect the NPV of private sectors, and the greater the uncertainty, the greater the NPV of private sectors. The NPV of private sectors under revenue compensation is always greater than that under traffic compensation, so it is more appropriate to adopt traffic compensation when the traffic risk is large. The conclusions of this study can provide guidance for the government to choose compensation methods, make compensation scheme decisions, and formulate and improve relevant policies of PPP projects.

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