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Cost-benefit Analysis of PPP Construction Projects

-- Taking Y Bridge across the River in Y City as an example

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Abstract: This paper discusses the cost and benefit of the cross-river Bridge PPP construction project in Y City, and analyzes the application of PPP model in China and its economic benefits. Research shows that PPP model not only effectively alleviates traffic pressure and promotes regional economic development, but also significantly reduces project construction and transportation costs and improves the quality of public services through social capital investment and operation. As a typical case, the cross-River Bridge project accounts for 95% of social capital, and its successful implementation validates the significant advantages of the PPP model in improving economic and social benefits. In the national economic evaluation, the project made fine adjustments to the investment cost, including the application of shadow price and the adjustment of the conversion factor of labor wages, to ensure the accuracy of the evaluation results. In addition, the technical and economic data of various types of motor vehicles are listed in detail, especially the adjustment of the cost of motor transportation related to time, which provides an important cost reference for the transportation industry. Through the comprehensive analysis of the theoretical basis, practical application and economic cost and benefit of PPP model, this paper not only enriches the cost and benefit analysis theory of PPP projects, but also provides valuable practical experience and theoretical support for similar projects. Looking ahead, suggestions such as improving the governance system and strengthening risk management and control will promote the widespread application of the PPP model in China and inject new vitality into economic and social development.

Keywords: PPP, Cost-benefit analysis, Construction projects.

1. Introduction

With the acceleration of urbanization and the advancement of global economic integration, the investment demand for public infrastructure construction is growing, which puts higher demands on financial pressure and operational efficiency. Public-private Partnership (PPP) model, as an innovative project financing and operation model, has been widely used in the world. Especially in China, in order to promote the rapid development of public infrastructure construction, the government has vigorously promoted the PPP model, adopted policies and measures to encourage social capital to participate in public infrastructure, promoted government-enterprise cooperation, and achieved resource sharing and win-win development.

As an important transportation infrastructure project in Y City, the construction of Y City Bridge across the River is of great significance to alleviate urban traffic congestion and promote regional economic prosperity. However, the demand for construction funds of the project is huge, and it is difficult to rely on government finance alone to meet it. Therefore, the PPP model for project construction and operation, the introduction of social capital participation, has become a practical solution.

This paper focuses on the PPP construction project of cross-River Bridge in Y City, aiming to analyze the cost composition and benefit sources of the project, evaluate the investment value and sustainability of the project, discuss the application effect of PPP model in the construction of public infrastructure, analyze the economic and social benefits of the project through in-depth cost-benefit analysis, and provide reference for the decision-making of similar projects.

The research of this paper can not only enrich and improve the theoretical system of PPP model, but also provide a new perspective for the theoretical research of PPP model and have corresponding theoretical value. At the same time, it can provide useful reference for the decision-making of similar projects, and promote the wide application and development of PPP model in public infrastructure construction.

2. Literature Review

2.1. Introduction and Development of PPP Model in China

China has been actively implementing the PPP model since 2014, with the goal of optimizing the efficiency of public service supply and reducing the financial burden on the government. Domestic scholars have conducted in-depth research on the introduction and development of PPP model in China, and analyzed its development process, current situation and future trend. For example, by comparing the basic data of some PPP projects, Li Bingkun and Liu Yu (2016) concluded that although PPP projects in China are involved in various industries and regions, the overall concentration is relatively high and the capital demand and gap increase at the same time [1]. Wang Xuejun and Yu Haoran (2024) pointed out that PPP model is a new way of public service supply, and in the process of promotion and application in China, both economic PPP projects and social PPP projects show structural imbalance in terms of quantity and investment [2].

2.2. Theoretical Basis and Practice of PPP Model

Domestic scholars have also made an in-depth discussion on the PPP model from a theoretical point of view, and analyzed its theoretical basis, operating mechanism and

advantages. They believe that the PPP model can improve the decision-making efficiency and economic benefits of public projects by introducing social capital and market competition mechanism, and also help promote the transformation of government functions and market-oriented reform. For example, Sheng Hetai et al. (2014) constructed the theoretical analysis framework of PPP model in their research and discussed its practical application in China [3]. Ying Yihua (2023) proposed to improve the integration governance system, strengthen risk management and control, clarify property rights, realize flexible conversion of PPP model and special debt model, and standardize corresponding accounting and tax treatment, so as to provide theoretical support and practical guidance for the integration of PPP model and special debt model [4].

2.3. Economic Cost-benefit Analysis of PPP Projects

Domestic scholars have carried out empirical research on the economic cost benefit of PPP projects, and analyzed the investment return, social benefit and economic benefit of the projects. The PPP model is regarded as an effective way to reduce project construction and transportation costs and improve the efficiency and quality of public service supply. At the same time, PPP projects can also promote economic growth and job creation, with significant economic and social benefits. For example, Chen Liuqin (2008) analyzed the economic cost-effectiveness of PPP projects in his research and discussed its development prospects in China [5]. Ruan Xuetao (2023) proposed that PPP model can not only introduce social capital to ease the financial pressure of the public sector, but also make use of the innovation ability and operational experience of social capital [6]. Zhong Hao (2023), aiming at the complexity of highway PPP projects and the uncertainty of dynamic investment payback period, deeply analyzed the composition of project cost and benefit system, and then constructed a feedback mechanism model reflecting the interaction between cost and benefit. [7].

3. Selection of Research Methods and Cases

The purpose of this study is to deeply explore the cost-benefit analysis of construction projects under the PPP (public-private partnership) model, taking the Y Bridge across the River in Y City as an example, using case analysis and cost-benefit analysis to conduct in-depth research.

The case analysis method reveals the implementation background, construction process, operation management and other specific conditions of the project through a comprehensive review of the Y cross-River Bridge project.

Cost-benefit analysis focuses on the cost input and benefit output of a project. Firstly, the construction cost and operation cost of the project are calculated in detail, and the dynamic cost analysis is carried out considering the time value. Secondly, through market research and forecast, the economic and social benefits of the project are evaluated. Finally, through the calculation of cost-benefit ratio, the investment efficiency of the project is quantified, which provides a scientific basis for project decision-making.

As a case study of the cost-benefit analysis of PPP construction projects, the Y-River Bridge in Y City has strong representativeness and typicality, which can provide powerful practical experience and theoretical support for the cost-benefit analysis of PPP projects. This study not only enriches the theoretical system of cost-benefit analysis of PPP construction projects, but also provides useful reference for the practice of similar projects.

4. Case introduction

4.1. Project Background

In view of the rapid economic development of Y City and its region, the traffic pouring in from the surrounding areas at high speed has increased significantly, especially concentrated in the southern region of Y City, resulting in a sudden increase in the load load of the urban network. Therefore, it is particularly urgent to construct transit lines to divert traffic demand. In response to the overall deployment of the development strategy of Y City, aiming to solve the bottleneck problem of cross-strait regional traffic in the future, promote the optimization of urban spatial structure and cluster development on both sides of the strait, and accelerate the pace of industrial upgrading and development of regional economic zones, Y City has put forward the planning of the construction of Y bridge across the river and its wiring in the corresponding planning reports, aiming at accelerating the industrial development and urbanization construction of Y City. Improve inter-regional road network planning, improve urban traffic conditions, promote leapfrog economic development, and promote better and faster economic and social development.

4.2. Introduction to the Project PPP Mode

The government representative and the social capital (selected through the procurement process) jointly establish the project company, and its implementing agency is solely responsible for the design optimization, investment and financing, construction, operation, maintenance and final handover of the project. The project company provides bridge and municipal road services to the public, and receives investment recovery and reasonable profits through government payments in accordance with the agreement. The property rights of the project belong to the government, and social capital enjoys the right to use the assets and the right to profit, of which the project capital is composed of 5% government investment and 95% social capital investment. The scope of cooperation covers the financing and engineering construction during the construction period, as well as the maintenance and management of Bridges, roads, public green Spaces, lighting systems, traffic safety facilities, water supply and drainage facilities and their ancillary facilities during the operation period, and includes sanitation and cleaning services.

4.3. Project Implementation Status

By the end of 2016, the project has completed the preliminary work of project approval, environmental assessment, fishing assessment, water protection, earthquake safety and other special projects, construction drawing design and review of sub-projects, PPP social capital bidding and other work; Construction began in early 2017, the main bridge load test passed in June 2021, and the trial traffic was opened to the public in July, and the rest of the connecting line project was opened to the public at the end of the year.

Up to now, Y City Y Bridge across the river has completed all construction, successfully put into operation, and achieved good economic and social benefits in a certain period of time.

5. Economic Cost-benefit Analysis

5.1. Parameter Selection and Determination

Based on the rational allocation of resources, the national economic evaluation evaluates the benefits and costs of the project from a national perspective, and adopts parameters such as shadow price, shadow wage, shadow exchange rate and social discount rate to analyze the net contribution of the project to the national economy and assess its economic rationality. This project has set relevant parameters for comprehensive evaluation:

5.1.1. Social discount rate

Social discount rate, as a key index to measure the opportunity cost and time value of capital from a national perspective, is an indispensable universal parameter for national economic evaluation. According to the guiding principles of "Methods and Parameters of Economic Evaluation of Construction Projects (Third Edition)", 8% is selected as the social discount rate in this evaluation to ensure the standardization and accuracy of the evaluation.

5.1.2. Shadow Wage (SWR)

Shadow wages can be calculated by:

$$SWR = MWR \times CF2 \quad (1)$$

Where: MWR - salary in financial evaluation; CF2 - Shadow wage conversion factor.

The shadow wage coefficient is set according to local labor market characteristics, including labor supply and demand, composition, and employment rate. According to the characteristics of this project, the shadow wage coefficient of technical work is set at 60%, and that of non-technical work is set at 40%. After weighted calculation, the determined coefficient is CF2=0.80, so as to accurately reflect the economic impact of labor cost.

5.1.3. Project evaluation period and evaluation base year

According to the standard of "Economic Evaluation Method of Highway Construction Project" of the Ministry of Communications, the evaluation period covers two stages of construction and operation. This project is assumed to start at the end of 2016 and be completed at the end of 2018, and the entire construction phase will last for two years, based on which economic evaluation will be conducted.

5.1.4. Residual value

For the residual value of the project, 50% of the adjusted economic cost is used as the estimated value, and at the end of the evaluation cycle, the negative form is included in the total economic cost to fully reflect the final economic impact of the project.

5.2. Economic Cost Adjustment

5.2.1. Investment cost adjustment

The investment of this project covers highway construction costs and operating costs (including maintenance and management costs), which should be converted into economic costs in the national economic evaluation to reflect the real value of resources and social and economic effects.

(1) Highway construction expenses

Highway construction costs cover construction and installation costs, equipment and tools purchase costs, other capital construction costs and reserves. In national economic evaluation, it is necessary to adjust the economic cost of the key input factors.

A. In the national economic evaluation, the shadow price mechanism is used to calibrate the prices of core building materials such as steel, wood, cement and asphalt. Based on the current situation of the road building materials market in Shaanxi Province, logs, sawn timber, steel bars, steel, steel wire, petroleum asphalt are identified as foreign-trade dependent materials, and cement is sourced from local supply, so as to ensure that the price adjustment strategy not only conforms to the market reality, but also reflects resource scarcity and economic efficiency. The shadow price adjustment results of main materials are shown in Table 1.

Table 1. Shadow price adjustment of main materials

materials	unit	Estimated price (yuan)	Shadow price (yuan)
log	M^3	1600.00	1545.00
Converted timber	M^3	1969.71	1490.00
Grade I reinforcement	t	2981.00	2826.00
Grade ii reinforcement	t	2891.00	2832.00
steel wire strand	t	5700.00	6800.00
rolled steel	t	5075.00	5488.32
concrete	t	380.00	400.00
petroleum asphalt	t	4500.00	4300.00

B. Adjustment of labor wages. As mentioned earlier, labor wages are adjusted at a conversion factor of 0.80.

C. Land cost adjustment. Land is the special input of the project. In the national economic evaluation, the land cost shall be calculated according to Article 3.16 of the Economic Evaluation Methods and Parameters of Construction Projects (Third Edition). The land cost shall not be adjusted in this project.

D. Deduct taxes, domestic loan interest and other expenses.

(2) Project construction cost

The project construction cost was 1998.76 million yuan. Among them, the construction and installation costs are 1378.56 million yuan, and other capital construction costs and reserve costs are 58911 million yuan. The project design is divided into four bidding sections according to the requirements of the owner. As the economic evaluation of the project, the total cost of the project construction is more reasonable, so the evaluation is carried out according to the project construction. Tax deduction of 47.01 million yuan expenses. Economic cost adjustments for this item are shown in Table 2.

Table 2. Adjustment of construction costs

item	Custom Paper-LabelPrinter	Unit	Estimated cost (ten thousand yuan)	Shadow price or conversion factor	Economic cost (ten thousand yuan)
1. Adjust the project					
1	construction cost	ten thousand yuan	137856	0.98	135099
2	taxes	ten thousand yuan	4701	0.00	0.00
summation			142557		135099
2.Not adjust the project		ten thousand yuan	57319	1.00	57319
summation			199876		192418

(3) Highway maintenance, overhaul and management costs

Based on the practice and management cost analysis of road maintenance costs in the existing project area, the financial maintenance cost of the bridge in the first year of the project is set at 0.5% of the cost. Large-scale maintenance is carried out once every ten years, and the maintenance cost is 13 times the daily maintenance cost of the current year, and the daily maintenance cost is not double-counted in the year of major repair. The management budget for the first year is based on a team of 50 people, with an average annual cost of 20,000 yuan per person, totaling 1 million yuan for the first year. In view of the increasing traffic volume resulting in increased road wear and tear, operating costs are forecast to increase in tandem with overhead costs, with an annual growth rate of 3.0%.

5.2.2. Motor transport cost adjustment

One of the core benefits of the new project is the significant reduction in vehicle transportation costs, which is due to the reduction in various expenses, especially the reduction in the consumption of basic materials (fuel, tires, accessories, etc.). Different vehicle speeds and road conditions have a significant impact on transportation costs. Therefore, it is necessary to distinguish in detail the transportation costs of various types of vehicles before and after the implementation of the project under each characteristic vehicle speed to ensure the accuracy and comprehensiveness of the assessment.

Motor transport costs consist of the following two components:

The costs associated with the distance traveled by the car - including fuel consumption, lubricating oil consumption, tire consumption and the cost of routine repairs to the car.

Part of the cost related to time - including depreciation and interest, personnel salaries, benefits, bonuses, insurance, road maintenance, vehicle and vessel use, license tax, vehicle overhaul costs and business management fees.

(1) Adjustment of vehicle transportation costs related to distance traveled

The consumption of range-related materials, such as fuel, lubricants and tires, is influenced by the quality of the road, traffic conditions and vehicle performance. Highway quality includes road evenness and slope; Traffic conditions are related to speed, congestion and lateral interference. Based on the prediction of specific highway and traffic conditions in Table 3 and the technical indicators of regional vehicles in Table 4, the project set the benchmark consumption rate (Table 5), which is based on the ideal conditions of 50km/h speed, good road surface (roughness <2, slope <2%), free flow and no lateral interference. In order to be more realistic, further consider the comprehensive impact of road (pavement condition, width, slope) and traffic (speed, congestion, lateral interference), and fine-tune the benchmark consumption rate. Through this revision process, it is possible to accurately calculate the economic cost of fuel, lubricating oil, tire consumption and vehicle repair for each model under different conditions, so as to comprehensively evaluate the contribution of the project to reducing the cost of motor transportation.

Table 3. Main traffic conditions of the project

highway classification	Flatness (IRI)	Slope (%)
expressway	2	2
secondary road	4	3

Table 4. Technical and economic data of motor vehicles

item	Unit	passenger car		trucks			
		minibus	motorbus	mini truck	medium truck	large truck	Container trailer
Financial price of new car	RMB/car	185000	255000	115000	150000	230000	255000
New car economic price	RMB/car	158000	223000	89000	131000	169600	188000
service life period	Year	12	12	12	12	12	12
road haul	Km/year	30000	80000	50000	50000	58000	58000
type of fuel	gasoline	gasoline	gasoline	gasoline	gasoline	diesel	diesel
Number of tire	Strips/car	4	6	4	6	10	14
Tyre endurance distance	Km/strip	50000	60000	80000	80000	80000	80000
Financial price of tire	RMB/piece	400	800	400	800	1400	1400
Economical price of tyre	RMB/piece	348	696	348	696	1217	1218

Table 5. divides the basic consumption of vehicle types

vehicle model			Minor Passenger car	large-scale Passenger car	Minor truck	middle-sized truck	large-scale truck	container trailer
fuel	consumption	Liter/hundred car kilometers	8.7	27	16	23	26	32
	economic cost	Yuan/hundred car kilometers	57.16	177.39	105.12	151.11	167.70	106.40
lube	consumption	Liter/hundred car kilometers	0.26	0.31	0.28	0.3	0.33	0.35
	economic cost	Yuan/hundred car kilometers	4.70	5.60	5.06	5.42	5.96	6.32
tyre	economic cost	Yuan/hundred car kilometers	4.16	15.12	6.06	15.12	24.73	26.32
Material consumption	economic cost	Yuan/hundred car kilometers	6.58	2.32	1.48	2.18	2.44	2.7
Labor consumption	economic cost	Yuan/hundred car kilometers	0.83	1.04	0.75	1.17	1.29	1.44

(2) Time related motor transport cost adjustment

A. Depreciation charges

Vehicle depreciation charges are funds allocated for a given number of years to ensure the continuous operation of the transport industry and are dedicated to the replacement of vehicles. China generally adopts the age method to calculate depreciation, that is, to share the cost year by year according to the service life of the vehicle. According to the investigation, the goods transportation in the project area is dominated by domestic trucks, so the prices of trucks in this project are based on domestic models. However, with the upgrading of consumption, the passenger car tends to be high-end and international, and its economic cost evaluation directly uses the international market price forecast value to reflect its real value. For the adjustment of the economic cost of the truck, the vehicle purchase surcharge and other related taxes are excluded to ensure the accuracy and rationality of the assessment.

B. Employee salaries, incentives, benefits and administrative expenses

The unit economic cost of employee wages, incentives and benefits is based on the number of drivers per vehicle multiplied by the annual working hours and hourly labor costs, and then calculated according to the vehicle mileage per hundred vehicle kilometers. Administrative expenses are calculated in proportion to other expenses.

C. Transportation fees, vehicle and vessel use tax, insurance and license tax Vehicle and vessel use tax, insurance and license tax are not included in the economic cost. The time-dependent motor transport costs are shown in Table 6.

Table 6. Time-related costs Unit cost adjustments

motorcycle type		minibus	motorbus	mini truck	medium truck	large truck	trailer
depreciation cost (Yuan /100km)	Financial Price	51.39	26.56	19.17	25	33.05	36.64
	Economical price	43.89	23.23	14.83	21.83	24.37	27.01
wage and welfare (Yuan /100km)	Financial Price	22.86	40.62	5.04	14.42	24.62	29.96
	Economical price	22.86	40.62	5.04	14.42	24.62	29.96
insurance expenses (Yuan /100km)	Financial Price	21.00	9.9	2.775	4.5	10.35	5.25
	Economical price	0	0	0	0	0	0
Taxes (Yuan /100km)	Financial Price	0.96	5.2	0.46	1.3	2.22	2.72
	Economical price	0	0	0	0	0	0
road toll (Yuan /100km)	Financial Price	3.07	34.08	11.64	33.26	56.79	69.07
	Economical price	0	0	0	0	0	0
Handling fee (Yuan /100km)	Financial Price	0.22	1.62	0.86	2.48	4.22	5.14
	Economical price	0.22	1.62	0.86	2.48	4.22	5.14
Summation (Yuan /100km)	Financial Price	99.50	117.98	39.95	80.96	131.25	148.78
	Economical price	66.97	65.47	20.73	38.73	53.21	62.11

In exploring the time-related portion of motor transportation costs, these expenses can be considered fixed costs over a specific period of time, such as one year. Assuming that the annual use time of the vehicle remains constant, the annual mileage can be effectively increased by optimizing the driving conditions and improving the driving speed of the vehicle, thus reducing the fixed cost shared by each unit mileage of the vehicle. In short, there is an inverse relationship between the speed of travel and the fixed cost per unit of mileage traveled. For specific explanation, detailed transportation cost data of each vehicle under different road and traffic conditions have been sorted out and presented in the table for intuitive comparison and analysis.

Table 7. Cost of motor transport (unit: RMB /100km)

minibus	speed(km/h)	45	50	60	70	80	85	90
	expressway	156.34	147.54	136.41	131.09	129.07	128.49	128.18
	speed(km/h)	15	20	25	30	35	40	45
	secondary road	389.34	301.03	248.57	214.17	190.45	173.23	160.44
motorbus	speed(km/h)	45	50	60	70	80	85	90
	expressway	304.58	292.18	278.66	275.03	276.14	286.30	295.38
	speed(km/h)	15	20	25	30	35	40	45
	secondary road	791.23	620.22	519.23	453.65	405.21	369.95	344.80
minivan	speed(km/h)	45	50	60	70	80	85	90
	expressway	154.63	150.13	146.91	145.47	156.24	164.77	171.89
	speed(km/h)	15	20	25	30	35	40	45
	secondary road	336.56	264.36	222.10	194.92	176.53	163.75	154.59
medium truck	speed(km/h)	45	50	60	70	80	85	90
	expressway	252.11	239.74	225.22	216.82	226.50	232.16	238.79
	speed(km/h)	15	20	25	30	35	40	45
	secondary road	719.32	553.81	456.05	391.90	346.97	314.27	288.32
large truck	speed(km/h)	45	50	60	70	80	85	90
	expressway	304.03	293.72	276.71	278.37	291.96	297.82	304.62
	speed(km/h)	15	20	25	30	35	40	45
	secondary road	705.90	572.97	494.05	441.92	405.39	378.66	357.71
Heavy duty special truck	speed(km/h)	45	50	60	70	80	85	90
	expressway	373.04	360.49	335.22	349.94	361.09	368.42	376.93
	speed(km/h)	15	20	25	30	35	40	45
	secondary road	859.10	698.55	603.19	540.81	497.60	466.63	444.03

D. Traffic volume and speed model

When evaluating the transportation cost of each vehicle at different speeds, the first step is to accurately calculate the speed of each vehicle according to different traffic flow conditions. The process follows specific calculation formulas that take into account various factors such as the traffic environment, vehicle performance and road conditions to arrive at accurate speed predictions.

$$Speed=a\cdot\exp[b\cdot(v/c)^2] \text{ when } (v/c)\leq 0.8 \text{ (highway)} \quad (2)$$

$$Speed=a1\cdot\exp[b_1\cdot(v/c)^8] \text{ when } (v/c) > 0.8 \text{ (highway)} \quad (3)$$

$$Speed=a*\exp[b*(v/c)^2] \text{ when } (v/c)\leq 0.75 \text{ (secondary highway)} \quad (4)$$

$$Speed=a_1+b_1*(v/c) \text{ when } (v/c) > 0.75 \text{(secondary highway)} \quad (5)$$

Where: Speed - speed (km/h); V - standard car hour traffic volume; C - Standard vehicle capacity per hour.

a, a_1, b, b_1, m are the coefficients, and their values are shown in Table 8.

Table 8. Model coefficients of traffic volume and vehicle speed

road grade	vehicle model	a	b	m	a_1	b_1
expresswa y	minibus	96.55	-0.350	0.8	86.039	-0.648
	motorbus	79.08	-0.154	0.8	78.710	-0.559
	minivan	73.67	-0.160	0.8	71.925	-0.469
	medium truck	68.31	-0.060	0.8	70.956	-0.455
	large truck	65.00	-0.150	0.8	62.375	-0.327
	container trailer	61.43	-0.107	0.8	60.227	-0.291
secon dary road	minibus	60.00	-1.42	0.7 5	65.10	-50.80
	motorbus	43.90	-0.86	0.7 5	65.10	-50.80
	minivan	50.50	-1.11	0.7 5	65.10	-50.80
	medium truck	46.70	-0.97	0.7 5	65.10	-50.80
	large truck	48.40	-1.04	0.7 5	65.10	-50.80
	container trailer	40.00	-0.70	0.7 5	65.10	-50.80

E. Speed and transportation cost model

The speed-cost model is based on the correlation quantity regression analysis, and the following model is obtained:

$$C=A+B*S+D*S^2 \quad (6)$$

Formula: C- vehicle transportation cost (yuan / 100 vehicle kilometers); S-Speed (km/h);

A, B and D are regression coefficients, and their values are shown in Table 9.

Table 9. Coefficient of speed-cost model

highway classification	coefficient	minibus	motorbus	mini truck	medium truck	large truck	Container trailer
expressway	A	263.14	520.88	277.87	475.08	516.54	617.32
	B	-3.3039	-7.1123	-4.2864	-7.3130	-7.1632	-8.3350
	D	0.0202	0.0511	0.0346	0.0523	0.0538	0.0634
secondary road	A	673.08	1355.40	568.90	1246.10	1130.20	1376.00
	B	-23.5790	-45.1630	-19.3810	-43.7660	-35.2140	-42.9630
	D	0.2739	0.5201	0.2287	0.5055	0.4057	0.5000

5.2.3. Calculation of economic benefits

The direct economic benefits of the project include three aspects: First, the significant reduction of operating costs through the synergistic effect of the proposed project with the existing related highways (B1); The second is the benefit of passengers due to shorter travel time (B2); Third, the loss caused by the reduction of traffic accidents is reduced (B3). In order to accurately quantify these benefits, the project adopts the "without comparison method", that is, the cost changes before and after the implementation of the project are carefully compared. The specific calculation method is described as follows, and a scientific and reasonable evaluation model is designed for each benefit to ensure the accuracy and comprehensiveness of the benefit evaluation.

(1) Reduce the operating cost benefit (B_1), which is calculated by the following formula:

$$B_1=B_{11}+B_{12} \quad (7)$$

Formula:

B_{11} - Benefits of the proposed project to reduce operating costs (ten thousand yuan)

B_{12} - Benefits of reducing operating costs of the existing road (ten thousand yuan)

a) The calculation formula of B_{11} is:

$$B_{11}=0.5(T_{1p}+T_{2p}) \times(VOC'_{1b}\times L'-VOC_{2p}\times L)365 \quad (8)$$

Formula:

T_{1p} - Normal traffic volume of the proposed highway under "project condition" (vehicles/day)

T_{2p} - Total traffic volume of the proposed highway under "project condition" (vehicles/day)

VOC'_{1b} - The average unit operating cost (yuan/vehicle-kilometre) of various vehicles on the existing relevant road under normal traffic conditions under the "base case"

VOC_{2p} - The average unit operating cost (yuan/vehicle-kilometre) of various vehicles in the total traffic volume of the proposed project under "project scenario"

L - Length of road of the proposed project (km)

L' - Length of the original relevant road (km)

b) The calculation formula of B_{12} is as follows:

$$B_{12}=0.5 \text{ x } L' \text{ x } (T'_{1p}+T'_{2p}) \text{ x } (VOC'_{1b}-VOC'_{2p}) *365 \quad (9)$$

Formula:

T'_{1p} - Normal traffic volume of the existing relevant road (vehicles/day) under "project condition"

T'_{2p} - Total traffic volume (vehicles/day) of the existing relevant highway "subject to project conditions"

VOC'_{1b} - The average unit operating cost (yuan/vehicle-kilometre) of various vehicles on the existing relevant road under normal traffic conditions under the "base case"

VOC'_{2p} - the average unit operating cost (yuan/vehicle-kilometre) of various vehicles on the existing relevant road under the condition of total traffic volume "with projects"

(2) Passenger travel time saving benefits

The core of the calculation of passenger running time saving benefit is to evaluate the improvement of the value of passenger transit time. This increase in value is quantified in terms of the additional gross domestic product (GDP) that passengers can generate as a result of shorter travel times. The specific calculation formula is designed to accurately reflect the economic value of this time benefit and ensure the accuracy and rationality of the evaluation results.

$$B_2=B_{21}+B_{22} \quad (10)$$

Formula:

B_{21} - Time savings for passengers using the proposed project (ten thousand Yuan)

B_{22} - Time-saving benefits of using the original road passengers (ten thousand yuan)

a) The calculation formula of B_{21} is:

$$B_{21}=0.5\times H\times E\ (T_{1pp}+T_{2pp})\times (L'/S'_{1b}-L/S_{2p})\times 365 \quad (11)$$

Formula:

H-Passenger unit time value (Yuan/person · hour)

E-Average passenger car carrying coefficient (person/vehicle).

S'_{1b}-The average speed (km/h) of various passenger vehicles on the existing relevant road under normal traffic conditions under the "base case"

S_{2p}-The average speed (km/h) of various passenger vehicles under the total traffic conditions of the proposed highway project "with project conditions"

T_{1pp}-Normal passenger car traffic of the proposed project under "project condition" (vehicles/day)

T_{2pp}-Total passenger car traffic of the proposed project under "project availability" (vehicles/day)

b) The calculation formula is: B_{22}

$$B_{22} = 0.5*H*E\ 'L*(T'_{1\,pp} + T'_{2\,pp}) * (1 / S/S'_{1\,b} - 1'_{2\,p})* 365 \quad (12)$$

Where: S'_{2p} - the average speed (km/h) of various passenger cars on the original relevant highway under the condition of total traffic volume under "project condition"

T'_{1pp} - Normal passenger traffic volume of the existing relevant road under "project condition" (vehicles/day)

T'_{2pp} - Total passenger traffic on the existing relevant road (vehicles/day) under "project condition"

(3) Benefits of reducing traffic accident losses (B_3)

The formula for reducing traffic accident loss is as follows:

$$B_3=B_{31}+B_{32} \quad (13)$$

Formula:

B_{31}-Traffic Accident loss reduction benefits of the proposed project (ten thousand Yuan)

B_{32}-Traffic accident loss reduction benefit of existing related roads (ten thousand yuan)

(1) The B_{31} formula is:

$$B_{31}=0.5(T_{1p}+T_{2p})*(\Upsilon'_{1b}*L*C'_b-\Upsilon_{2p}*L(C'_p) *365*10^8 \quad (14)$$

Formula:

C'_b-the average economic loss cost of the original relevant road unit accident under the "base case" (yuan/ time)

C_p-Under the "project situation", the average economic loss cost of the proposed project unit (Yuan/time)

γ'_{1b}-Accident rate (trips per vehicle-kilometre) of the existing relevant road under normal traffic conditions under "base case"

γ_{2p}-Accident rate for total traffic volume of the proposed project in the "project scenario" (trips per billion vehicle kilometres)

(2) B_{32} calculation formula is:

$$B_{32}=0.5*L'*(T'1_p+T'_{2p})*(\Upsilon'_{1b}*C'_b-\Upsilon'_{2p*}C'_p)*365*10^8 \quad (15)$$

Formula:

C'_p-the average economic loss cost of the original relevant highway unit accident under "project condition" (Yuan/time)

γ'_{2p} - Accident rate of the existing relevant highway under the condition of total traffic volume (trips per billion vehicle-kilometres) "with projects"

In the above formula, the average economic loss of the unit accident is obtained by referring to the "PPK report", and the accident rate is determined by referring to the research results of relevant domestic units.

The accident rate is calculated as follows:

$$R = 37+0.03*AADT \quad (16)$$

Where: R--the number of accidents (times / 100 million vehicle kilometers); AADT - Annual daily traffic volume (vehicles/day, medium vehicles);

Refer to the "PPK report", the average loss cost of a grade-one highway accident is 14,000 yuan/time.

5.2.4. Calculation of economic cost-benefit analysis index

Based on the above analysis, the project was evaluated on the national economy. The evaluation results are shown in Table 10 and Table 11.

Table 10. Indicators of national economic evaluation

internal rate of return EIRR (%)	benefit-cost ratio EBCR	Net present value (ten thousand yuan) ENPV	Payback period EN (including construction period)
11.65	4.11	70208	16.5year

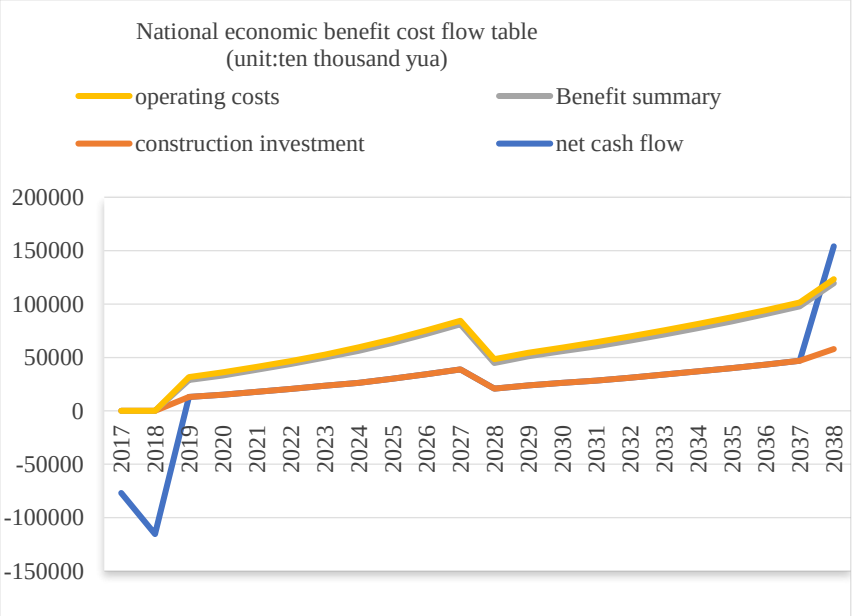

Figure 1. National economic benefit cost flow table

Table 11. Sensitivity analysis of national economic evaluation

thermal analysis option	Economic net present value ENPV (ten thousand yuan)	Economic internal rate of return EIRR (%)	Economic benefit cost ratio EBCR	Payback period (years)
Charge increase by 10%	50458	10.63	4.92	18.34
10% drop in efficiency	39904	10.37	4.69	18.80
Charge increase by 10% 10% drop in efficiency	20154	9.42	4.43	19.82
15% increase in cost Efficiency drop by 15%	-4874	8.39		

5.2.5. Sensitivity analysis

The sensitivity analysis aims at exploring the specific impact of the two key factors of cost and benefit on the economic cost-benefit analysis index of the project when they encounter adverse changes. By simulating cost increases or benefit decreases under different scenarios, the resilience of a project can be more fully assessed. Table 11 shows the results of economic sensitivity analysis in detail, which provides strong data support for project decision-making.

5.2.6. Evaluation conclusions

The evaluation results of the national economy show that the internal rate of return of the project has reached 11.65%, which is significantly higher than the social discount rate benchmark of 8%, fully indicating that the project not only has profitability, but also produces positive economic benefits to the society. Further, through the national economic sensitivity analysis, the performance of the project under the extreme adverse scenario (that is, the cost increases by 10% and the benefit decreases by 10%) is simulated, and it is found that the internal rate of return can still maintain a high level of 9.42%, which still exceeds the social discount rate. This series of analyses strongly proves that the project has strong economic resilience and risk resistance, and the implementation of the project is completely feasible from an economic perspective.

6. Results of Case Analysis

6.1. Cost-benefit Analysis

From a cost-benefit point of view, the IRR of the project reached 11.65%, which significantly exceeded the social discount rate of 8%. This shows that the project has achieved remarkable success in terms of economic benefits, and its investment income exceeds the social average level, bringing considerable returns to investors and society. This high internal rate of return reflects the efficiency of the project in terms of resource allocation, operational efficiency and management level.

6.2. Strong Economic Risk Resistance

The results of sensitivity analysis further reinforce the successful experience of the project. Even in the most adverse economic scenario, where project costs rise by 10% and benefits shrink by 10%, the IRR remains solidly high at 9.42%, well above the social discount rate benchmark. This remarkable performance demonstrates the excellent risk resistance ability of the project in the face of external economic fluctuations, which can effectively cushion the impact of adverse factors on the economic benefits of the project, so as to ensure the long-term economic feasibility and stability of the project.

6.3. Remarkable Social Benefits

In addition to the economic benefits, the social benefits of the project are also worthy of recognition. The internal rate of return is higher than the social discount rate, which means that the project not only brings economic returns to the investors, but also creates value for the society and improves the overall social welfare level.

Although the project has demonstrated strong economic benefits and risk resistance from a cost-benefit and accounting point of view, it is worth noting that there may be the following potential issues related to accounting during the implementation and operation of the project:

The first is the accuracy of expense accounting. The accurate accounting of project cost is very important to evaluate the economic benefit of the project. If there are errors or omissions in the cost accounting, it may lead to misjudgment of the economic benefit of the project. It is therefore necessary to ensure the accuracy and completeness of cost accounting. Secondly, the recognition and measurement of revenue is also an important issue in the field of accounting. In the process of project operation, it is necessary to recognize and measure project income reasonably in strict accordance with the requirements of accounting standards and relevant regulations to ensure the accurate reflection of project economic benefits. In addition, risk management and internal control are also worthy of attention. Although the project shows strong economic anti-risk ability, it still needs to strengthen risk management and internal control. By establishing a sound risk management and internal control system, potential risk factors can be discovered and dealt with in time to ensure the steady operation of the project and the continuous growth of economic benefits.

To sum up, the project has performed well in terms of cost effectiveness and economic risk resistance, but potential problems related to accounting still need to be paid attention to during the project implementation and operation to ensure the sound operation and sustainable development of the project.

7. Conclusion

This paper discusses the economic and social benefits of the project by analyzing the cost and benefit of the PPP construction project of the Y-River Bridge in Y City. The research results show that the application of PPP model in the construction and operation of public infrastructure has shown multiple positive effects: it is not only an effective way to alleviate the financial burden of the government, but also greatly improves the efficiency of project management and execution. More importantly, this model has strongly promoted the prosperity of regional economy, accelerated the pace of urban development, and promoted the significant improvement of the overall efficiency of the city.

From the perspective of economic benefits, PPP mode achieves diversified financing of project funds and reduces the financial burden of the government by introducing social capital. At the same time, in the implementation and operation of PPP projects, the introduction of market competition mechanism has become a highlight. It not only accelerates the optimization of the project decision process, ensures the efficiency of the decision, but also improves the overall economic benefits of the project by stimulating the market vitality. Under this model, the return on investment of the project is significant, bringing considerable benefits to all parties involved, and fully demonstrating its unique economic value and market potential.

From the perspective of social benefits, the construction of public infrastructure has effectively alleviated urban pressure and improved the convenience and efficiency of urban construction. In addition, PPP model also has a profound impact on the growth trajectory of regional economy, it accelerates the improvement of infrastructure, effectively improves the overall style and image of the city, and then enhances the magnetic effect and competitiveness of the city. The wide realization of these social benefits not only enriches the connotation of the PPP model, but also confirms once again its unique advantages and key role in promoting the construction of public infrastructure.

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