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Selection of PPP program models based on ecological compensation in the Chishui Watershed

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Abstract

Choosing the right structural model for projects in various fields has become an important subject of research, and adopting a suitable model has been recognized as crucial to a project's success. For public–private partnership (PPP) programs involving ecological compensation in the Chishui Watershed, implementers are required to give extensive considerations to balancing economic, societal, and ecological impacts and benefits, connected to numerous stakeholders. Any program model choice is made difficult by various influencing factors introduced by these stakeholders. This paper examines models of PPP eco-compensation programs in the Chishui Watershed, a region that faces an acute conflict between protection and growth, and is in urgent need of eco-compensation mechanisms. For this purpose, we have developed an indicator system with three hierarchical levels containing, respectively, two, five, and 18 indicator items. A list of feasible PPP models are chosen based on existing programs in the region. Analytic hierarchy process (AHP)/fuzzy analysis is used to establish an integrated decision-making framework. The suitability of the models in each field can then be ranked by their integrated decision score. The differences between models are also analyzed to find the main limiting indicators on PPP programs.

Keywords: Chishui Watershed; Ecological compensation; Limiting indicator; Model selection; PPP program

1. Introduction

The Chishui River is a primary tributary on the southern bank of the upper Yangtze River (Figure 1). Originating in Zhenxiong County, Yunnan Province, it flows along the Sichuan–Guizhou border until reaching the town of Maotai. After taking in the rivers of Tongzi and Gulin, it arrives at the city of Chishui and meets the Xishui River at Hejiang County, Sichuan Province, before converging into the Yangtze. Due

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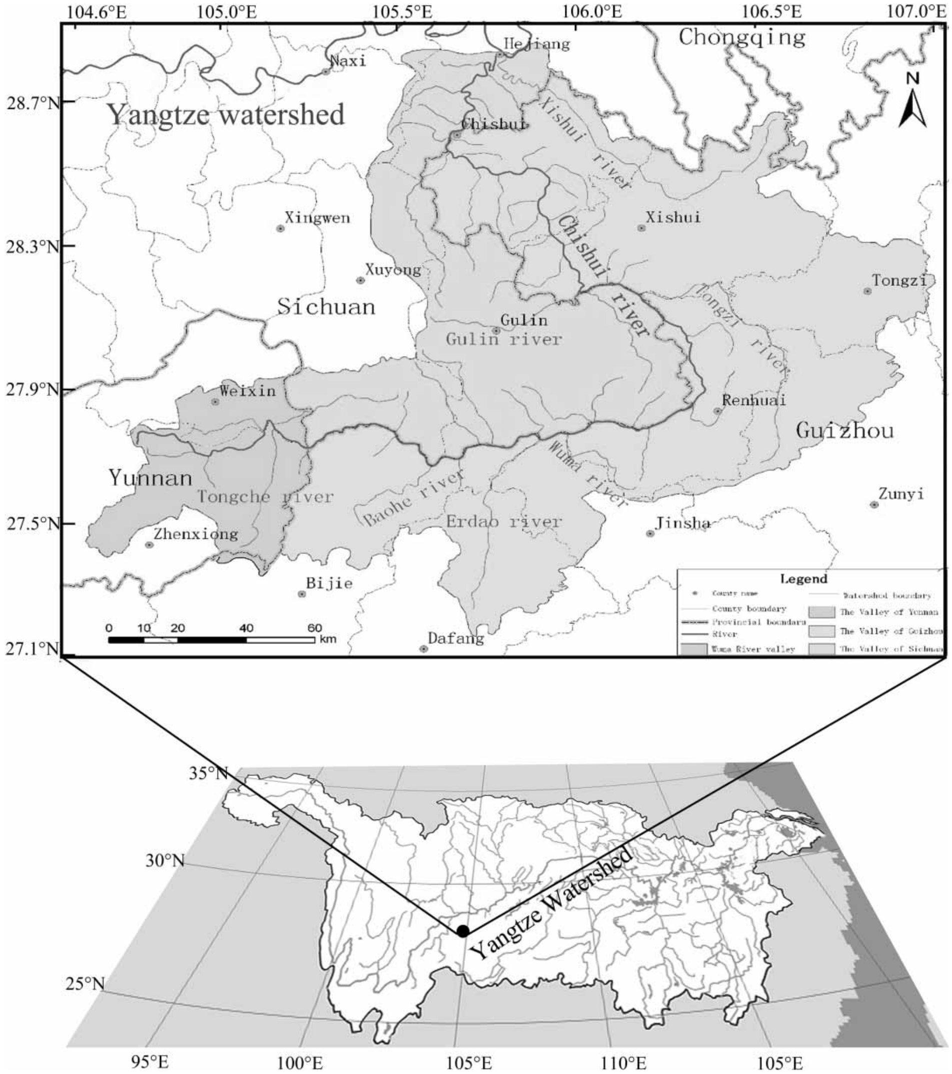

Fig. 1. Overview of the Chishui Watershed.

to its importance as the source of water used in brewing distilled liquors such as the Maotai, and as part of a national Nature Reserve for rare fish species, it has been the only primary tributary of the upper Yangtze not confined by a dam and maintained the characteristic of a natural river (Chi *et al.*, 2017a, 2017b). The regions along the Chishui Watershed have been beset by significant societal and economic inequalities and face an acute conflict between preservation and development, as development in the upper watershed has been heavily constrained by the need to maintain water quality for liquor and eco-tourism industries of the middle and lower watersheds. This is exacerbated by the rapid economic growth of recent years, which has caused fast increases in population and urbanization in the upper watershed, outpacing local infrastructures in transportation, agriculture, and water and environmental management, which has been lacking due to a historical lack of funds. As the situation incurs considerable ecological risks, there is an urgent need to

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formulate an eco-compensation scheme for the watershed, redistribute the benefits of growth between its constituents, and maintain a better balance between preservation and development.

Eco-compensation schemes for watershed regions in China often suffer from shortcomings such as overly simplistic compensation schemes and singular reliance on government funding, which tends to be insufficient in amount and not very sustainable (Chen *et al.*, 2014). The Chishui Watershed faces similar challenges, despite a series of policies issued by local governments (Guizhou Provincial People's Congress Standing Committee, 2011, 2014; Guizhou Provincial Department of Environmental Protection, Finance, Water Resources, 2014; Guizhou Provincial Department of Environmental Protection, 2013, 2014; Guizhou Provincial People's Congress Standing Committee 2011, 2014). In this context, the public–private partnership (PPP) structure can potentially bring in new funding avenues, facilitate complementary use and risk-sharing between funding sources, and encourage stakeholders to participate in the compensation program. In the last two decades, choosing the right structural model for projects in various fields has become an important subject of research, and adopting a suitable model has been recognized as crucial to a project's success (Naoum, 1994; Rwelamila & Meyer, 1999; Zheng & Phang, 2017).

Present research on PPP program model choices has concentrated on two areas. (i) Identifying the influencing indicators on model choices. The proposed indicators included the government's resource capabilities and participation level, ownership and management rights, goals and responsibilities of non-government investors, public benefits, schemes of risk and profit-sharing, life-cycle costs of a program, the field to which the program belongs, and external environment (Sydee & Beder, 2006; Yuan *et al.* 2010; General Office of the State Council of PRC, 2011; Ismail *et al.*, 2011; Ng *et al.*, 2012; Ameyaw & Chan, 2015; Osei-Kyei & Chan, 2015; Liu *et al.*, 2016). (ii) Methodology for choosing PPP program models. The proposed approaches included: treating the program as a decision-making problem to be solved with quantitative simulation, hierarchy analysis and fuzzy set-based decision-making, a Black–Scholes options pricing model, or a two-phase multi-attribute approach; selection based on numerous indicators; a selection process based on model features like ownership, right of management, and extent of cooperation; and a selection process on which selection models can be further developed with hierarchy analysis or similar methods (Crosslin, 1991; Jobin, 2008; Li & Zou, 2011; Su *et al.*, 2012; Bai *et al.*, 2013; Wellens *et al.*, 2013; Xie & Ng, 2013; Girth, 2014; Liu *et al.*, 2014; Hou *et al.*, 2016; Tian *et al.*, 2016).

Any PPP program based on eco-compensation in the Chishui Watershed must find a balance between economic, societal, and ecological benefits, connected to a large number of stakeholders. There is considerable difficulty in selecting a PPP model that covers the many factors representing the stakeholders' preferences. This study sets out to develop a PPP program model selection process for watershed-scale eco-compensation programs in the region, including its indicator system, and quantitative decision-making model. The result can be of value to decision makers wishing to diversify the funding sources and methods of eco-compensation and help improve the abilities of recipients to achieve self-sustained development and innovation.

2. Data sources and PPP program model primary selection

2.1. Data sources

Most data used in this study originate from fieldwork and interviews. We extensively perused the statistical yearbooks, development plans, and policy documents related to the Chishui Watershed published

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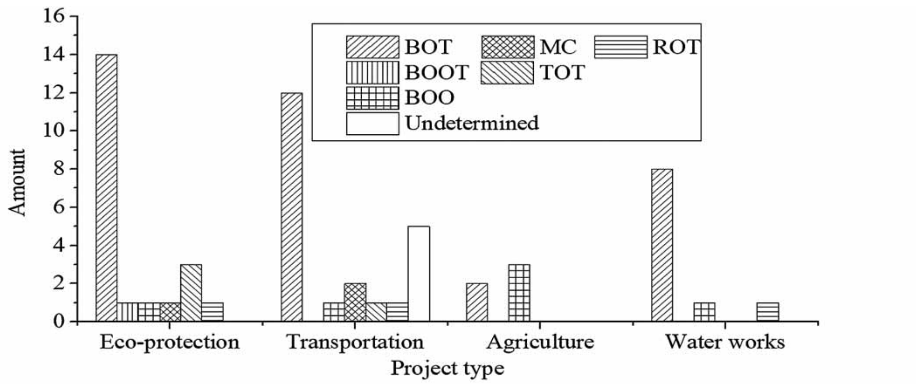
by national, provincial, and county authorities. We conducted fieldwork in regions in the watershed, including Zhenxiong County and Weixin County under Zhaotong prefecture-level city; Qixingguan District, Dafang County, and Jinsha County under Bijie prefecture-level city; Renhuai City, Xishui County, Chishui City, Tongzi County, and Zunyi County under Zunyi prefecture-level city; and Xuyong County and Hejiang County under Luzhou prefecture-level city, and organized several meetings with stakeholder representatives (subjects of ecological compensation: the national government, local governments, water-dependent firms and general populace of the lower watershed, and hydropower developers of the greater Jinsha River region, such as China Three Gorges Corporation; recipients of ecological compensation: the local governments and general populace of the upper watershed).

The data we gathered encompassed: signed or implemented PPP programs in eco-protection, transportation, agriculture, and water works; the stakeholders' potential needs regarding how PPP programs should support local socioeconomic growth and eco-protection; stakeholder demands on amounts and methods of compensation; essential facts on regional resources and environment; basic features of the PPP programs.

2.2. PPP program model primary selection

We gathered information on implemented or signed PPP programs from Zhaotong, Bijie, Zunyi, and Luzhou in the areas of eco-protection, transportation, agriculture, and water works. Figure 2 shows



Project type	Item category	Amount
Eco-protection	Wastewater treatment plants, upgrade of wastewater networks, waste landfill or incineration plants, tourist site infrastructure, wetland parks, and replacement of wood fuel in rural regions	21
Transportation	Expressways and roads, bridges, docks, passenger stations for railways and highways, and road network renovation	22
Agriculture	Trading and service centers for agricultural products, pilot farms, modern industrialization of agriculture, logistical centers for agricultural products, vegetable plantations, and a pilot plantation for traditional Chinese medicine herbs	5
Water works	water plants, water networks, river revitalization, reinforcement of levies, and large reservoirs or dams	10

Fig. 2. PPP program models of the Chishui Watershed.

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statistics information on major programs. From these programs, a short list of feasible PPP models can be chosen, which includes build–operate–transfer (BOT), build–operate–own-transfer (BOOT), build–operate–own (BOO), management contract (MC), transfer-operate-transfer (TOT), and rehabilitate–operate–transfer (ROT) (Table 1).

3. Methods

3.1. PPP program model selection process

The process can be summarized as follows. First, we identified the basic problem of the Chishui Watershed, as the conflict between protection and growth. Through fieldwork, stakeholder interviews, and reviewing documents, we identified the main fields related to eco-compensation programs in the region. Based on basic features of PPP programs and information on the Chishui Watershed, the influencing indicators can be identified and systematically organized. The first screening of feasible program models can then be done with reference to signed or implemented programs in the region, with the purpose of maximizing the public welfare of the basin, and an analytic hierarchy process (AHP)/fuzzy

Table 1. Features of PPP program models.

Model	Definition	Ownership transfer	Applicable program stage	Commerciality
BOT	The private capital designs, builds, manages, and maintains the program. At the end of the contract period, the asset and rights are transferred to the government at no cost.	No	New	Commercial/quasi-commercial
BOOT	The private capital builds the program and has its ownership and management rights in the designated period. At the end of the period, the program is transferred to the government.	Yes	New	Commercial/quasi-commercial
BOO	The private capital finances and builds the facility and has permanent ownership and management rights to it.	No	New	Commercial
MC	The government authorizes the private capital to take over the management and maintenance responsibilities of a preexisting asset in order to improve the public services it provides. The government owns the asset, and pays the firm a management fee.	No	Preexisting	Commercial/quasi-commercial/ non-commercial
TOT	The government transfers the ownership of a preexisting asset to a private capital at a cost. The latter is responsible for its management and maintenance. At the end of the contract period, the asset is transferred back to the government at no cost.	Yes	Preexisting	Commercial/quasi-commercial
ROT	The government transfers the ownership of a preexisting asset to a private capital at a cost. The latter is responsible for its upgrade, management, and maintenance, and recoups the investment via improved efficiency. At the end of the contract period, the asset is transferred back to the government at no cost.	Yes	Preexisting/in development	Commercial/quasi-commercial

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analysis decision-making framework can be developed to determine which model is suitable for which field (Natasha *et al*. 2016; Hadi *et al*., 2016). The program models can be compared to show the main limiting indicators on PPP programs (Figure 3).

3.2. Indicator system

The indicator system is based on the principles of sustainability, representativeness, and practicality. To ensure sustainability, PPP programs based on ecological compensation in the Chishui Watershed should promote both protection and development and give consideration to the interests of all stakeholders. To keep the results representative, we began with a preliminary selection of indicators, drawing from high frequency influencing indicators proposed by previous studies, as well as *Value for Money Evaluation Guidelines of PPP* (Ministry of Finance of PRC, 2016) and *Guidelines of PPP Projects in Traditional Infrastructure* (National Development and Reform Commission of PRC, 2016). Afterwards, the list was refined, with items deleted or added based on stakeholder opinions. Stakeholders of PPP projects based on ecological compensation in the Chishui Watershed mainly include local residents, enterprises, local governments, etc. In the process of soliciting opinions from stakeholders on the indicator system, local residents pay more attention to indicators such as income and employment opportunities. Through discussion of stakeholders, these two indicators are included in the indicator system. Private capital pays more attention to the difficulty of project operation. Local government is more concerned about policy influence. After multiple consultations by stakeholders, these two indicators are considered to be inoperable. Lastly, the principle of practicality dictates all indicators must be based on actually available data, verified through fieldwork.

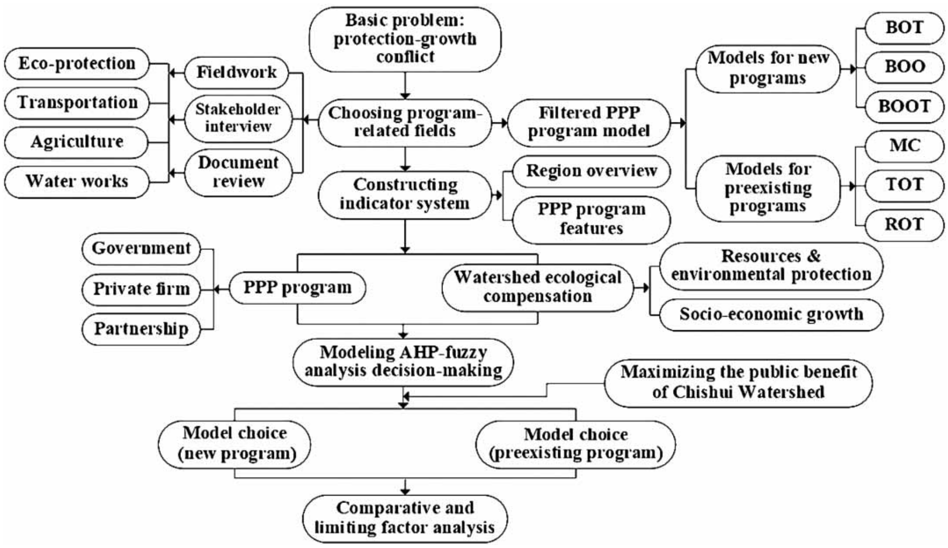

Fig. 3. Basic scheme of the study.

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With the gathered information and principles defined above, we approach the construction of the indicator system from two angles: the makeup of PPP programs and the eco-compensation effects. The former encompasses 11 third-level indicators under the categories of governments, private capital, and their partnership relationship. The latter covers seven third-level indicators under the category of protection effects and socioeconomic impacts (Table 2).

3.3. Decision-making framework

AHP is a method developed by Thomas L. Saaty in the 1970s. It is a technique for hierarchically structured decision-making in a complex system that combines qualitative and quantitative analysis (Mangla *et al.*, 2015; Bouzon *et al.*, 2016; Sylvain *et al.*, 2016; Bian *et al.*, 2017; Sananda *et al.*, 2017). It provides an elegant, broadly applicable, and efficient approach to solving difficult decision problems with multiple goals or principles, or lacking obvious structural features, and has been widely used in the decades since its development for analyzing societal, economic, management, and military problems (Piresa *et al.*, 2011; Kłos & Trebiina, 2014; Socaciu *et al.*, 2016).

Since the problem – PPP model selection for eco-compensation in the Chishui Watershed – is impossible to precisely define, we can base our approach on fuzzy memberships, which allow us to turn qualitative judgments into quantitative decisions through multi-hierarchical computation. Compared to similar approaches, AHP allows us to determine item weights with relatively higher accuracy, and more importantly, use consistency tests to winnow out inconsistencies among expert opinions. This combination of fuzzy mathematics and AHP can thus be used to develop the program model selection process. The main steps are as follows:

(1) Defining decision-making indicators: we start by defining the set of decision indicators (indicators) $U = (u_1, u_2, \ldots u_n)$, where u_i represents second-level indicators (in this case: the government, private capital, partnership, resource and environmental protection, and socioeconomic development), and n is their total number.
(2) Defining the assessment set: the decision assessment set is $V = (v_1, v_2, v_3, v_4, v_5)$, where v_j represents the grade of each indicator based on scores given by experts, and its value can be anything from the set of 'very high, high, normal, low, very low' (Table 3).
(3) Defining the weight set: as required by the AHP method, we had the experts compare every pair of indicators in each level, and give their results on a 1–9 scale (Table 4), and performed a consistency test. The weight of each indicator can be obtained via matrix calculation, and their weight set can be established as a weight vector $W = (w_1, w_2, \ldots w_n)$, where w_i is the weight of the ith factor.
(4) Building the membership matrix: membership functions can be designed based on each indicator's features and then used to calculate each indicator's fuzzy judgment matrix $R = \begin{pmatrix} r_{11} & \cdots & r_{15} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{n5} \end{pmatrix}$, where r_{ij} is the membership of factor u_i to v_j.

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Table 2. Indicator system for PPP program model selection process based on eco-compensation of the Chishui Watershed.

First-level indicator	Second-level indicator	No.	Third-level indicator	Efficacy	Definition
PPP program	Government (A)	1	Early-stage investment	+	Direct and indirect governmental investment in the early stage of a program.
		2	Control over management rights	−	Degree of control the governments have over the management of the program.
		3	Benefits of ownership transfer	+	Benefits governments can gain from transferring the program to private ownership.
		4	Government participation	+	Government participation via financial subsidy, facilitating access to resources, purchasing services, equity, etc.
	Private capital (B)	1	Financing responsibility	+	Responsibility of private capitals in financing the program.
		2	Risks of participation	+	Risks from participating in the program which the private capitals need to account for.
		3	Degree of privatization	+	The extent to which the program ownership has been transferred from the government to private capitals.
	Partnership (C)	1	Asset ownership	+	Ownership of the program by the government or private capitals.
		2	Extent of partnership	++	The extent to which the program has achieved profit and risk-sharing.
		3	Total investment	+	Total sum of investment required for the program to be completed and start operation.
		4	Contract period	+	The effective period of the PPP program contract.
Watershed ecological compensation	Resource and Environmental Protection (D)	1	Water quality impact	+	Program impact on the water quality of the Chishui Watershed.
		2	Water flow impact	+	Program impact on the amount of water supplied to the watershed.
		3	Biodiversity impact	+	Program impact on biodiversity in the watershed.
		4	Forest coverage impact	+	Program impact on the ratio of forest to total land area.
	Socioeconomic Growth (E)	1	Increased population income	+	Program impact on the disposable income of both urban and rural residents in the upper Chishui Watershed.
		2	Job opportunity impact	+	Program impact on job opportunities in the upper Chishui Watershed.
		3	GDP growth	+	Program impact on GDP in the upper Chishui Watershed.

Note: About the efficacy, ' + ' means a benefit indicator; ' − ' means a cost indicator.

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Table 3. Criteria for indicator assessments.

Assessment	Very low	Low	Normal	High	Very high
First- and second-level indicator	0–1	1–2	2–3	3–4	4–5
Third-level indicator	$a_0 - a_1$	$a_1 - a_2$	$a_2 - a_3$	$a_3 - a_4$	$a_4 - a_5$

Note: a_i is the threshold value for each grade. The threshold values of a_i are mainly determined through PPP project database queries, literature research, and expert scoring.

Table 4. Score values of the judgment matrix.

Score	Meaning
1	Indicators i, j are similarly important
3	Factor i is slightly more important than j
5	Factor i is somewhat more important than j
7	Factor i is considerably more important than j
9	Factor i is vastly more important than j
2,4,6,8	Intermediate values between the values above
Reciprocal $(1/w_{ij})$	The result obtained from comparing indicators j and i

Using the threshold values from the assessment criteria as inflection points, the linear membership functions can be established for quantitative indicators as below:

$$r_1(x_i) = \begin{cases} 1, x_i \leq a_0 \\ \dfrac{a_1 - x_i}{a_2 - a_1}, a_0 < x_i \leq a_1 \\ 0, x_i > a_1 \end{cases} \tag{1}$$

$$r_2(x_i) = \begin{cases} 1 - \dfrac{a_1 - x_i}{a_1 - a_0}, a_0 < x_i \leq a_1 \\ \dfrac{a_2 - x_i}{a_2 - a_1}, a_1 < x_i \leq a_2 \\ 0, x_i \leq a_1, x_i > a_2 \end{cases} \tag{2}$$

$$r_3(x_i) = \begin{cases} 1 - \dfrac{a_2 - x_i}{a_2 - a_1}, a_1 < x_i \leq a_2 \\ \dfrac{a_3 - x_i}{a_3 - a_2}, a_2 < x_i \leq a_3 \\ 0, x_i \leq a_1, x_i > a_3 \end{cases} \tag{3}$$

$$r_4(x_i) = \begin{cases} 1 - \dfrac{a_3 - x_i}{a_3 - a_2}, a_2 < x_i \leq a_3 \\ \dfrac{a_4 - x_i}{a_4 - a_3}, a_3 < x_i \leq a_4 \\ 0, x_i \leq a_2, x_i > a_4 \end{cases} \tag{4}$$

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$$r_5(x_i) = \begin{cases} 0, x_i \leq a_3 \\ 1 - \dfrac{a_4 - x_i}{a_4 - a_3}, a_3 < x_i \leq a_4 \\ 1, x_i > a_4 \end{cases} \tag{5}$$

(5) Integrated fuzzy judgment. Considering the numbers of indicators and hierarchical levels, the fuzzy judgment process needs to be performed starting from the lowest level and iterate through each level above, i.e. the membership vector of each subordinate indicator u_{i} is calculated as $B_{\mathrm{i}} = W_{\mathrm{i}} \cdot R_{\mathrm{i}}$, until we obtain the membership matrix of the higher-level indicator set, which is $R = (R_1, R_2, \cdots R_n)^T$, and the membership vector B. The integrated score is then obtained through the assessment criteria.

4. Result analysis

4.1. Indicator weights

If stakeholders participate in the scoring, it is impossible to judge the indicators fairly and objectively because they represent an interest group. To ensure the weights can accurately reflect requirements of the subject, we invited experts from research institutes and universities, and representatives of local governments, firms and general populace with neutral standpoint to fill the comparison matrix with their own scores on a 1–9 scale. Each respondent gave his or her ranks by independent judgment, resulting in 40 valid comparison matrices. The judgment matrix needs to pass the consistency test, and CR is used to indicate the consistency ratio. When $0 < CR < 0.1$, the consistency of the judgment matrix is considered acceptable. If the consistency test is not passed, the expert needs to reuse the 1–9 scale method to score, until the judgment matrix passes the consistency test to obtain the weight of each level of indicators (Table 5).

4.2. Calculation and analysis

4.2.1. PPP program model selection. Using weight values obtained by calculation, scores given by experts, and results of the consistency test, we can determine the membership status of each indicator set for the assessment grades. A judgment matrix can be obtained for each indicator, which combines with the membership matrix and weight set to obtain the membership vector needed by PPP model selection:

$$R = (R_1, R_2, \cdots R_n)^T \tag{6}$$

The membership vector and assessment set are used to determine the integrated decision scores (IDS) and scores for first- and second-level indicators (Table 6).

The following conclusions can be observed from the results.

For new programs, the IDS are ranked as BOT > BOOT > BOO. Similar relationships can be found for all first-level indicators except for ‘watershed eco-compensation’ in the agriculture field. All second-level indicators under ‘PPP program’ display the trend of BOT > BOOT > BOO, except for ‘government’ in the agriculture field. Under the ‘watershed eco-compensation’ category, the ‘resource &

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Table 5. Weights of indicator.

First-level indicator	Weight	Second-level indicator	Weight	No.	Weight
PPP program	1/2	A	1/3	1	0.0455
				2	0.536
				3	0.292
				4	0.127
		B	1/3	1	0.630
				2	0.321
				3	0.0499
		C	1/3	1	0.553
				2	0.254
				3	0.128
				4	0.0654
Watershed ecological compensation	1/2	D	1/2	1	0.287
				2	0.143
				3	0.497
				4	0.0732
		E	1/2	1	0.644
				2	0.309
				3	0.0475

Note: Consistency test results: $CR(A) = 0.049$, $CR(B) = 0.09$, $CR(C) = 0.015$, $CR(D) = 0.005$, $CR(E) = 0.023$.

environmental protection' indicator displays the trend of BOT > BOOT > BOO, and 'socioeconomic growth' displays the trend of BOO > BOT > BOOT.

For preexisting programs, the IDS are ranked as TOT > MC except for the eco-protection field. Among first-level indicators, 'PPP program' and 'watershed eco-compensation' display opposite trends, which can also be seen among second-level indicators.

It must be noted the weighted sum of second-level indicator scores shows a trend consistent with the corresponding first-level indicator score, while the weighted sum of first-level indicator scores shows a trend consistent with the IDS.

If we compare the four fields, we can see the agriculture field has relatively low scores for 'resource & environmental protection' and 'socioeconomic growth'. This can be attributed to the fact that agriculture makes less contribution to growth, particularly to increasing resident income, creating jobs, and growing GDP, yet has a greater impact on water quality and flow. Programs related to transportation perform better by comparison.

On this basis, correlation analysis can be performed on the relationships between IDS and the five second-level indicators. The results (Figure 4) suggest that the IDS are positively correlated to the second-level indicators, with the least correlation with 'resource & environmental protection'. This means the present PPP programs in the Chishui Watershed have yet to achieve their full potential in improving regional eco-protection. The correlations are negative between R&E protection and 'private capital' or 'socioeconomic growth', which should caution us to be careful about the damage that may be caused by the profit-driven nature of private capital and our pursuit of growth. A balanced approach is always necessary.

4.2.2. Comparative analysis. To further understand the suitability of the PPP models, we analyze the status of each third-level indicator and take note of indicators scored 'normal', 'low' or 'very low' (Table 7). The results indicate the following.

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Table 6. Final results of PPP program model selection.

Field	PPP model	Integrated decision Score	First-level indicator score		Second-level indicator score				
					PPP program			WEC	
			PPP program	WEC	Government	PF	Partnership	R&E protection	SE growth
Eco-protection	BOT	3.61	4.51	2.72	4.24	4.83	4.45	3.18	2.26
	BOOT	2.93	3.54	2.35	3.71	3.55	3.37	2.97	2.07
	BOO	2.27	2.57	1.97	3.25	2.88	1.58	1.25	2.53
	MC	2.75	2.67	2.84	3.51	1.00	1.28	4.39	1.08
	TOT	2.65	3.21	2.09	3.86	2.33	3.45	3.11	1.08
Transportation	BOT	3.86	4.65	3.07	4.37	4.80	4.78	2.43	3.70
	BOOT	3.22	3.71	2.73	3.71	3.55	3.88	1.93	3.51
	BOO	2.59	2.60	2.58	3.13	2.88	1.80	0.86	3.94
	MC	2.79	2.62	2.95	3.38	1.00	3.49	4.07	1.83
	TOT	2.89	3.11	2.67	3.99	2.33	3.02	2.64	2.69
Agriculture	BOT	2.91	3.48	2.34	3.45	4.83	2.14	1.79	2.89
	BOOT	2.46	2.94	1.99	2.82	3.55	2.08	1.29	2.69
	BOO	2.33	2.60	2.06	3.13	2.88	1.80	1.00	3.13
	MC	2.11	1.88	2.35	3.33	1.00	1.28	3.43	1.27
	TOT	2.13	2.33	1.94	2.41	2.32	2.24	2.00	1.88
Water works	BOT	3.70	4.60	2.84	3.73	4.83	4.63	2.18	3.51
	BOOT	3.08	3.70	2.50	3.20	3.55	3.82	1.68	3.32
	BOO	2.50	2.62	2.38	3.13	2.88	1.84	1.00	3.75
	MC	2.72	2.71	2.73	3.51	1.00	1.63	3.82	1.64
	TOT	2.77	3.09	2.45	3.99	2.32	2.95	2.39	2.50

Note: The ROT model involves upgrading the already built functional components of a project and is suitable for preexisting or in-development projects. It is not covered by this calculation and has no impact on its result.

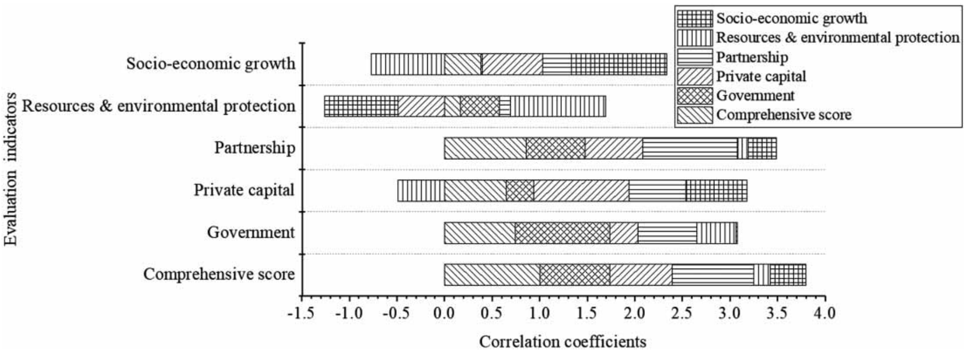

Fig. 4. The analysis of correlation.

For new programs, BOT and BOOT do not produce a significant difference in third-level indicators of the 'government' category. The difference between BOOT and BOO is shown in A3, i.e. BOOT has higher benefits from ownership transfer. Among the 'private capital' category, the three models

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Table 7. Results of third-level indicators for PPP program models.

Field	PPP model	PPP program			Watershed eco-compensation	
		Government A1, A2, A3, A4	Private capital B1, B2, B3	Partnership C1, C2, C3, C4	R&E protection D1, D2, D3, D4	SE growth E1, E2, E3
Eco-protection	BOT	A2(low), A3(normal), A4(normal)	–	C3(low)	D1(normal), D2(normal), D3(normal)	E1(low), E3(low)
	BOOT	A2(low), A3(normal), A4(normal)	B2(normal), B3(normal)	C3(very low)	D1(normal), D2(normal), D3(normal), D4(normal)	E1(low), E2(normal), E3(low)
	BOO	A2(low), A3(very low)	B2(low), B3(very low)	C1(low), C2(low), C3(very low)	D1(very low), D2(low), D3(low), D4(low)	E1(normal), E2(normal), E3(normal)
	MC	A4(normal)	B1(very low), B2(very low), B3(very low)	C2(low), C3(very low), C4(low)	–	E1(very low), E2(low), E3(very low)
	TOT	A1(low), A2(low), A3(low), A4(normal)	B1(low)	C2(normal)	D1(normal)	E1(very low), E2(low), E3(very low)
Transportation	BOT	A1(low), A2(low), A3(normal)	–	C1(low)	D1(normal), D2(normal), D3(normal), D4(low)	–
	BOOT	A1(low), A2(low), A3(normal)	B2(normal), B3(normal)	–	D1(low), D2(low), D3(very low), D4(very low)	–
	BOO	A1(low), A2(low), A3(very low)	B2(low), B3(low)	C2(low), C3(very low)	D1(very low), D2(very low), D3(very low), D4(very low),	–
	MC	A1(very low), A4(normal)	B1(very low), B2(very low), B3(very low)	C1(low), C2(low), C3(very low), C4(low)	D4(normal)	E1(low), E3(low)
	TOT	A2(low), A3(low)	B1(low)	C2(normal), C3(low)	D1(low), D2(normal), D3(normal), D4(low)	E1(normal), E3(normal)

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Agriculture	BOT	A1(low), A2(low), A3(normal)	–	C1(low), C3(very low)	D1(low), D2(low), D3(low), D4(normal)	E1(normal), E3(normal)
	BOOT	A1(low), A2(low), A3(normal)	B2(normal), B3(normal)	C3(very low)	D1(low), D2(low), D3(very low), D4(low)	E1(normal), E3(normal)
	BOO	A1(low), A2(low), A3(very low)	B2(low), B3(very low)	C2(low), C3(very low)	D1(very low), D2(very low), D3(very low), D4(very low)	–
	MC	A1(very low), A4(normal)	B1(very low), B2(very low), B3(very low)	C1(low), C2(low), C3(very low), C4(low)	D3(normal)	E1(very low), E2(low), E3(very low)
	TOT	A2(low), A3(low), A4(very low)	B1(low)	C2(normal)	D1(low), D2(normal), D3(low), D4(normal)	E1(low), E2(low), E3(low)
Water works	BOT	A1(low), A2(low), A3(normal)	–	C1(low)	D1(normal), D2(low), D3(low), D4(low)	–
	BOOT	A1(low), A2(low), A3(normal)	B2(normal), B3(normal)	–	D1(low), D2(very low), D3(low), D4(very low)	–
	BOO	A1(low), A2(low), A3(very low), A4(normal)	B2(low), B3(very low)	C2(low), C3(very low)	D1(very low), D2(very low), D3(very low), D4(very low)	–
	MC	A1(very low), A4(normal)	B1(very low), B2(very low), B3(very low)	C2(low), C3 (normal), C4(low)	D2(normal), D4(normal)	E1(low), E2(normal), E3(low)
	TOT	A2(low), A3(low)	B1(low)	C1(low), C2(normal), C3(very low)	D1(low), D2(low), D3(normal), D4(low)	E1(normal), E2(normal), E3(normal)

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mainly differ in 'risks of participation' and 'privatization'. Among the 'partnership' category, BOOT produces higher public–private cooperation and more investment than BOO. Under the 'R&E protection' category, the three models have differences in all four indicators, meaning the choice has a significant impact on the environment. Under the 'growth' category, BOT and BOO's main differences lie in E1 and E3, as BOO performs better in increasing resident income and GDP.

For preexisting programs, the 'government' indicators have differences in A1 and A4 in the transportation and water works fields, where TOT performs better in 'early-stage investment' and 'government participation'. In agricultural programs, the 'government' indicators have different results in A2, A3, and A4, as MC performs better than TOT in control of management rights, benefits of transfer, and government participation. Under the 'private capital' category, MC and TOT differ in B1, B2, and B3, as TOT can greatly reduce risk and increase program privatization through two ownership transfers. Under the 'partnership' category, C2 and C4 are the main differentiating indicators between MC and TOT in the eco-protection, agriculture, and water works fields. Under the 'R&E protection' category, all four indicators show differences between MC and TOT. MC is shown to allow the government to better supervise private capital, and control potential environmental risks. Under the 'growth' category, the two models differ in E1 and E3, as TOT is better at increasing income and GDP.

4.2.3. Limiting indicators analysis. Third-level indicators graded 'low' or 'very low' (which we call limiting third-level indicators), and their ratio among all grades are recorded (Figure 5). In general, the indicators with the strongest limiting effects are R&E protection, government, and partnership. Among them, A2, A1, C3, D1, D4, D2, and D3 are key indicators that may hinder PPP programs (each with a ratio over 50%). It should be noted that C3 has a 55% ratio of being graded 'very low', while A2 and A1, respectively, have been graded 'low' at the ratios of 80% and 50%. These three indicators – total investment, government control of management rights, and early-stage investment by the government – should have the most notable limiting effects.

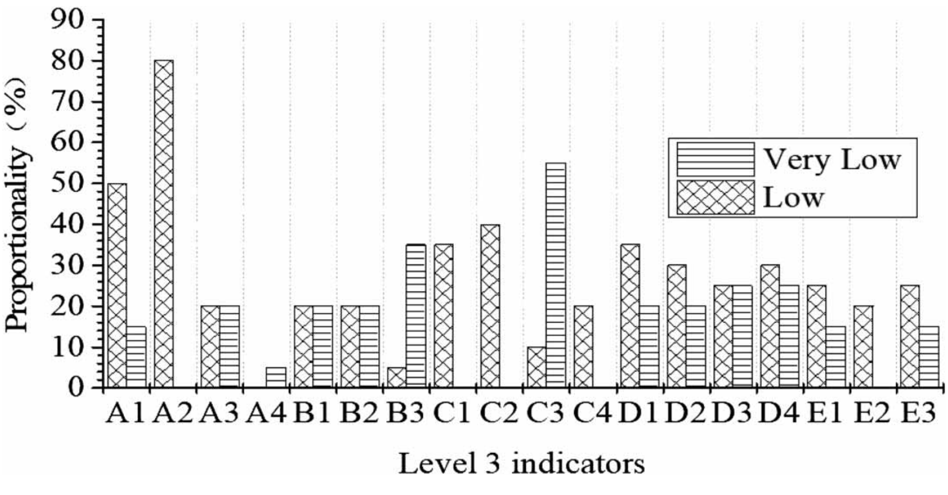

Fig. 5. Ratios of 'low' and 'very low' grades for third-level indicators.

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Following this, we tallied the third-level indicators graded 'low' or 'very low' for the five models (only indicators that appear more than twice are counted), which results in the main limiting indicators for each model (Table 8). We can see that all models are affected by type A indicators; none is strongly affected by type E indicators; and BOO has the most limiting indicators.

Similar analysis can be done for the four fields to find their limiting third-level indicators (again only counting indicators that appear more than twice). It can be seen (Table 9) that A1 is the limiting indicators shared by all four, meaning early-stage investment by the government is extremely important for a program, while the lack of government funds is a common problem in the Chishui Watershed. Agricultural programs are restricted by the highest number of third-level indicators. Therefore, despite being the most important economic sector of the upper Chishui region, programs in the field of agriculture are shown to be impeded by issues like early-stage funding and pollution, while transportation and water works are affected by fewer problems.

5. Discussion

For the key restrictive indicators of PPP projects, targeted preventive measures should be proposed. In the first-level indicator 'PPP project': the A1 indicator is a constrained three-level indicator shared by the four industries, indicating the importance of the government's early investment on the project. In

Table 8. Limiting third-level indicators for PPP program models.

PPP model	Grade	Main limiting third-level indicators and numbers of occurrence
BOT	Low	A1(3), A2(4), C1(3)
	Very low	–
BOOT	Low	A1(3), A2(4), D1(3)
	Very low	–
BOO	Low	A1(3), A2(4), B2(4), C2(4)
	Very low	A3(4), B3(3), C3(4), D1(4), D2(3), D3(3), D4(3)
MC	Low	C2(4)
	Very low	A1(3), B1(4), B2(4), B3(4), C3(3)
TOT	Low	A2(4), A3(4), B1(4), D1(3)
	Very low	–

Table 9. Limiting third-level indicators for each field.

Field	Grade	Main limiting third-level indicators and numbers of occurrence
Eco-protection	Low	A2(4),
	Very low	C3(3)
Transportation	Low	A1(3), A2(4)
	Very low	–
Agriculture	Low	A1(3), A2(4), D1(3)
	Very low	C3(4)
Water works	Low	A1(3), A2(4)
	Very low	–

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practice, this investment includes not only funds but also policies. The government should determine the mode of investment through field research, seminars, etc., and take more measures to increase investment. From the perspective of the A2 indicator, the government's control over management rights is not the larger the better. Of course, the government should not let it go. Based on the identified PPP project model, the enthusiasm of the social capital and supervision role of the government should be combined. The restrictiveness of the C3 indicator indicates that the total investment of the project determines the capital contribution between government and social capital to some extent. The government should increase support for PPP projects through various means such as funds, legislation, policy, and supervision, attracting increased investment from social capital and providing sufficient funds for PPP projects.

In the first-level indicator 'watershed ecological compensation': the restrictiveness of D1, D2, D3, and D4 indicators indicate that the resource and environmental factors have obvious restrictive effects on PPP projects. Related local governments should do resource and environmental carrying capacity demonstration of regions. Besides, the environmental impact assessment of PPP projects should also be done in the early stage of PPP projects. On this basis, targeted risk prevention measures could be proposed. Through whole process ecological and environmental supervision, if the PPP projects damage ecology and environment, targeted ecological and environmental restoration measures should be implemented in a timely manner.

Besides, this study may help inform future PPP programs of eco-compensation in the Chishui Watershed. However, its data sources and modeling can be further improved.

Specifically, first, the data were sourced from operational or already signed PPP programs in four fields from Zhaotong, Bijie, Zunyi, Luzhou, etc. in the watershed, which contained relatively little information on BOOT, MC, and ROT programs. More investigations can be done with information on newer programs.

Second, the indicator system can be improved. For example, some factors, like financing structure, and performance evaluation, can be highly valuable to the assessment but had not been included in this study for lack of data availability. In addition, some indicators should be added to reflect the dynamic change of the quality of resources and environment, so that the PPP project can play a more important role in supporting the ecological and environmental protection of the Chishui Watershed. It is hoped these highly representative data can be incorporated in future versions, as local governments make them available.

Third, the AHP approach in this study utilized weights manually assigned by experts, which introduced an element of subjectivity. Further testing and corrections will be needed when putting the indicator system to practical use.

Fourth, the implementation of the watershed ecological compensation mechanism and the PPP model are closely related to the promotion of governments at all levels in China. Governments play an important role in policy making and implementation. Compared with many other regions of China, the economic and social development of Chishui Watershed is relatively lagging. The private capital in Chishui Watershed is relatively weak. However, the governance level and capacity of local governments in related fields need to be improved, which is reflected in policy operability and policy sustainability. These shortages lead to a series of problems during the operation of PPP program models. The implementation of the PPP projects is undoubtedly market behavior. The market should play a decisive role in the allocation of resources. With the development of the market economy in the Chishui

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Watershed, private capital will play an increasingly important role in the PPP project based on ecological compensation in the Chishui Watershed.

6. Conclusions

This paper proposes a selection process for PPP program models based on the practice of eco-compensation in the Chishui Watershed, which must resolve the acute conflict between protection and growth. Through fieldwork and data gathering, we found the relevant programs to be concentrated in the fields of eco-protection, transportation, agriculture, and waterworks. Based on characteristics of PPP and the watershed, we identified influencing indicators related to either the program itself or local eco-compensation, following the principles of sustainability, representativeness, and practicality. The feasible PPP models were chosen based on existing PPP programs of the region. We then developed an AHP/fuzzy analysis decision-making framework and determined the PPP models suitable for each field that maximizes public benefits.

The results suggest: for new programs, the overall performance is BOT $>$ BOOT $>$ BOO in all four fields; for preexisting ones, TOT generally performs better than MC except in the field of eco-protection. Building on this discovery, the main limiting indicators on PPP programs can be identified by comparing how these models impact third-level indicators graded 'normal', 'low' and 'very low'. The main limiting indicators were found under the second-level categories of resource and environmental protection, government, and partnership. Under these categories, A1, A2, C3, D1, D2, D3, D4 are the key indicators, with, A1, A2, and C3 possessing particularly strong effects.

Limiting third-level indicators were also identified for each specific PPP model and field. Among the models, BOO is limited by the most third-level indicators, at 11. A1 turns out to be the limiting indicator shared by all four fields, which shows the importance of early government investment and is consistent with the Chishui Watershed's common problem – lack of funds at the local governments' disposal. Meanwhile, transportation and waterworks programs have relatively fewer limiting factors and may prove more feasible.

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References

Ameyaw, E. E. & Chan, A. P. C. (2015). Evaluation and ranking of risk indicators in public-private partnership water supply projects in developing countries using fuzzy synthetic evaluation approach. *Expert Systems with Application 42*(12), 5102–5116.

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Bai, Y., Zheng, H. & Ouyang, Z. Y. (2013). Modeling hydrological ecosystem services and tradeoffs: a case study in Baiyangdian Watershed, China. *Environmental Earth Sciences 70*(2), 709–718.
Bian, T., Hu, J. T. & Deng, Y. (2017). Identifying influential nodes in complex networks based on AHP. *Physica A 479*, 422–436.
Bouzon, M., Govindan, K., Rodriguez, C. M. T. & Campos, L. M. S. (2016). Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. *Resources, Conservation and Recycling 108*, 182–197.
Chen, D. S., Li, J., Zhou, Z. X., Liu, Y., Li, T. & Liu, J. Y. (2017). Simulating and mapping the spatial and seasonal effects of future climate and land-use changes on ecosystem services in the Yanhe Watershed, China. *Environmental Science and Pollution Research International 25*(2), 1115–1131.
Chen, Y. Y., Jessel, B., Fu, B. J. & Pittock, J. (2014). *Ecosystem Services and Management Strategy in China*. Springer, Heidelberg.
Chi, S. Y., Qiao, Y. & Han, D. J. (2017a). Development and evaluation of macro invertebrate-based multi-metric indices for the assessment of water quality of Chishui River, China. *Fresenius Environmental Bulletin 26*(1a), 749–760.
Chi, S. Y., Gong, Y. T., Wang, H. J., Zheng, J. X., Hu, j., Hu, J. X. & Dong, F. Y. (2017b). A pilot macroinvertebrate-based multimetric index (MMI-CS) for assessing the ecological status of the Chishui River basin, China. *Ecological Indicators 83*, 84–95.
Crosslin, R. L. (1991). Decision-support methodology for planning and evaluating public-private partnerships. *Journal of Urban Planning and Development 117*(1), 15–31.
General Office of the State Council of PRC (2011). Notice on Adjustments to Three National Nature Reserves incl. Hebei Dahaituo. Available at: http://www.gov.cn/zwgk/2011-12/14/content_2020321.htm (in Chinese).
Girth, A. M. (2014). What drives the partnership decision? Examining structural indicators influencing public-private partnerships for municipal wireless broadband. *International Public Management Journal 17*(3), 344–364.
Guizhou Provincial Department of Environmental Protection (2013). *Provincial People's Government's Reply on the Environmental Protection Plan of Chishui Watershed in Guizhou Province*. Available at: http://govinfo.nlc.cn/gzsfz/zfgb/431203a/201312/t20131217_4477991.html (in Chinese).
Guizhou Provincial Department of Environmental Protection, Finance, Water Resources (2014). *Interim Measures for Ecological Compensation for Water Pollution Prevention in Chishui Watershed, Guizhou Province*. Available at: http://www.gov.cn/xinwen/2014-05/03/content_2670524.htm (in Chinese).
Guizhou Provincial People's Congress Standing Committee (2011). *Regulations on the Protection of the Chishui Watershed in Guizhou*. Available at: http://www.npc.gov.cn/npc/xinwen/dfrd/guizhou/2011-08/02/content_1664537.htm (in Chinese).
Guizhou Provincial People's Congress Standing Committee (2014). *Regulations on Ecological Civilization Construction Promotion of Guizhou Province*. Available at: http://www.gzhjbh.gov.cn:91/zcfg/hbfg/dffg/69233.shtml (in Chinese).
Hadi, V., Houman, L. & Ali, A. (2016). Developing an ethics-based approach to indicators of sustainable agriculture using analytic hierarchy process (AHP). *Ecological Indicators 60*, 644–654.
Hou, Y., Li, B., Muller, F. & Chen, W. (2016). Ecosystem services of human-dominated watersheds and land use influences: a case study from the Dianchi Lake Watershed in China. *Environmental Monitoring and Assessment 188*(1), 652.
Ismail, K., Takim, R. & Nawawi, A. H. (2011). The evaluation criteria of value for money (VFM) of public private partnership (PPP) bids. In: *Proceedings of International Conference on Computer Communication and Management*, Sydney, pp. 349–355.
Jobin, D. A. (2008). Transaction cost-based approach to partnership performance evaluation. *Evaluation 14*(4), 437–465.
Kłos, S. & Trebiina, P. (2014). Using the AHP method to select an ERP system for an SME manufacturing company. *Management and Production Engineering Review 5*(3), 14–22.
Li, J. & Zou, P. X. W. (2011). Fuzzy AHP-based risk assessment methodology for PPP projects. *Journal of Construction Engineering and Management-ASCE 137*(12), 1205–1209.
Liu, J. C., Yu, X. B. & Cheah, C. Y. J. (2014). Evaluation of restrictive competition in PPP projects using real option approach. *International Journal of Project Management 32*(3), 473–481.
Liu, T. T., Wang, Y. & Wilkinson, S. (2016). Identifying critical indicators affecting the effectiveness and efficiency of tendering processes in public-private partnerships (PPPs): a comparative analysis of Australia and China. *International Journal of Project Management 34*(4), 701–716.
Mangla, S. K., Kumar, P. & Barua, M. K. (2015). Risk analysis in green supply chain using fuzzy AHP approach: a case study. *Resources, Conservation and Recycling 104*, 375–390.

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Ministry of Finance of PRC (2016). *Value for money evaluation guidelines of PPP*. Available at: http://jjs.mof.gov.cn/mofhome/jinrongsi/zhengwuxinxi/zhengcefabu/201512/t20151228_1634669.html (in Chinese).
Naoum, S. G. (1994). Critical analysis of time and cost of management and traditional contracts. *Journal of Construction Engineering and Management, ASCE 120*(4), 687–705.
Natasha, K., Syahrul, N. K. & Mohamad, R. B. (2016). Ranking the indicators of building performance and the users' risk via analytical hierarchy process (AHP): case of Malaysia. *Ecological Indicators 71*, 567–576.
National Development and Reform Commission of PRC (2016). *Guidelines of PPP Projects in Traditional Infrastructure*. Available at: http://www.ndrc.gov.cn/zcfb/zcfbtz/201610/t20161027_824138.html (in Chinese).
Ng, S. T., Wong, Y. M. W. & Wong, J. M. W. (2012). Indicators influencing the success of PPP at feasibility stage – a tripartite comparison study in Hong Kong. *Habitat International 36*(4), 423–432.
Osei-Kyei, R. & Chan, A. P. C. (2015). Review of studies on the critical success indicators for public-private partnership (PPP) projects from 1990 to 2013. *International Journal of Project Management 33*(6), 1335–1346.
Piresa, A., Chang, N. B. & Martinho, G. (2011). An AHP-based fuzzy interval TOPSIS assessment for sustainable expansion of the solid waste management system in Setúbal Peninsula, Portugal. *Resources, Conservation and Recycling 56*(1), 7–21.
Rwelamila, P. D. & Meyer, C. (1999). Appropriate or default project procurement systems? *Cost Engineering 41*(9), 40–44.
Sananda, K., Deepak, K. & Arun, M. (2017). Landuse change impact on sub-watersheds prioritization by analytical hierarchy process (AHP). *Ecological Informatics 42*, 100–113.
Socaciu, L., Giurgiu, O., Banyai, D. & Simion, M. (2016). PCM selection using AHP method to maintain thermal comfort of the vehicle occupants. *Energy Procedia 85*, 489–497.
Su, C. H., Fu, B. J., He, C. S. & Lü, Y. H. (2012). Variation of ecosystem services and human activities: a case study in the Yanhe Watershed of China. *ACTA Oecologica 44*, 46–57.
Sydee, J. & Beder, S. (2006). The right way to go? Earth Sanctuaries and market-based conservation. *Capitalism Nature Socialism 17*(1), 83–98.
Sylvain, K., Jérémy, R., William, D., Voisin, A. & Traon, Y. L. (2016). A state-of-the-art survey & testbed of fuzzy AHP (FAHP) applications. *Expert Systems with Applications 65*, 398–422.
Tian, Y. C., Wang, S. J., Bai, X., Luo, G. & Xu, Y. (2016). Trade-offs among ecosystem services in a typical Karst watershed, SW China. *Science of the Total Environment 566*, 1297–1308.
Wellens, J., Nitcheu, M., Traore, F. & Tychon, B. (2013). A public-private partnership experience in the management of an irrigation scheme using decision-support tools in Burkina Faso. *Agricultural Water Management 116*, 1–11.
Xie, J. Z. & Ng, S. T. (2013). Multi-objective Bayesian network model for public-private partnership decision support. *Journal of Construction Engineering and Management 139*(9), 1069–1081.
Yuan, J. F., Skibniewski, M. J., Li, Q. M. & Shan, J. (2010). The driving factors of China's public-private-partnership projects in metropolitan transportation system: public sector's viewpoint. *Journal of Civil Engineering and Management 6*(1), 5–18.
Zheng, C. & Phang, S. Y. (2017). Urban rail transit PPPs: lessons from East Asian cities. *Transportation Research Part A: Policy and Practice 105*, 106–122.

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