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Performance Measurement Model for Farmland Water Conservancy Projects

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Abstract

A systematic and scientifically grounded model must be developed for measuring performance in farmland water conservancy projects in order to achieve the desired performance objectives. This study addressed the unique characteristics of such projects by proposing a performance evaluation model based on the Balanced Scorecard (BSC) framework. The model was developed through comprehensive questionnaire surveys and statistical analysis. It includes four key dimensions: stakeholder satisfaction, benefit performance, management and maintenance performance, and process management performance. A total of 15 evaluation criteria were established. The results demonstrate that the model has strong reliability and validity, confirming its effectiveness for performance assessment in farmland water conservancy projects.

Keywords

Farmland water conservancy projects, Performance measurement, Balanced Score card.

1. Introduction

Farmland water conservancy facilities are critical public assets in rural China, directly influencing agricultural development, rural governance, and farmers' incomes. Developing a systematic and scientifically grounded performance measurement model for farmland water conservancy projects is therefore of significant theoretical and practical importance. While project performance measurement has attracted considerable attention in academic circles, research specifically targeting the performance of farmland water conservancy projects exhibits several notable limitations: (1) Existing measurement models often lack rigorous theoretical foundations, with evaluation systems frequently characterized by subjectivity and arbitrariness. (2) Evaluation indicators are predominantly lagging and static, failing to account for the long-term developmental potential of these projects. (3) Quantitative methodologies are underutilized, hindering the accurate representation of the developmental status of such projects. To address these shortcomings, this study integrates theoretical exploration and empirical analysis to construct a performance measurement model tailored to farmland water conservancy projects in China.

2. Research on the Performance of Farmland Water Conservancy Projects

2.1. Connotation of Farmland Water Conservancy Project Performance

The definition of performance can be categorized into three main approaches: (1) Behavioral Process Theory: This perspective emphasizes performance as a behavior process intricately linked to objectives, rather than merely as an outcome. (2) Outcome Theory: This viewpoint defines performance as the resulting output, with a focus on the effectiveness of outcomes. (3) Stakeholder Theory: According to this approach, performance encompasses processes, outcomes, and the satisfaction of stakeholders. This study defines project performance as encompassing both the behavioral processes undertaken to achieve objectives and the results derived from these processes.

2.2. Research on Performance Evaluation of Farmland Water Conservancy Projects

Kirchsteiger et al. [2] conducted extensive empirical analyses of farmland water conservancy project performance, exploring social, environmental, and economic benefits, as well as management aspects. Their work applied tools such as the Analytic Hierarchy Process (AHP) to comprehensively evaluate project performance. Aliasghar et al. [3] highlighted the critical role of management systems in influencing the construction performance of farmland water conservancy projects. Similarly, Lerman Zvi et al. [4] demonstrated that farmland irrigation and the construction of water conservancy projects significantly contributed to agricultural productivity and farmers' income. Wang et al. [5] utilizing the Social-Ecological System (SES) framework, analyzed factors influencing the governance of farmland water conservancy facilities in rural China.

Various methodologies have been employed by scholars to evaluate the performance of farmland water conservancy projects. Zhou [6] developed a performance evaluation index system for small-scale farmland water conservancy projects, utilizing a multi-index comprehensive evaluation model based on weighted summation. By applying the Analytic Network Process to determine index weights, Zhou demonstrated that property rights reform could significantly enhance governance efficiency. Chen et al. [7] employed the Grey Relational Analysis method to determine the weights of performance indicators, establishing a mixed indicator system model for evaluating small-scale farmland water conservancy projects. Li et al. [8] applied the Analytic Hierarchy Process (AHP) to evaluate project performance through a summative perspective.

2.3. Balanced Score Card Model

Project performance serves as a critical standard for evaluating the success of projects. Previous studies have identified time, quality, and cost as the "iron triangle" of project performance evaluation. To enable more comprehensive and rational performance measurement, scholars have expanded evaluation methods, with the Balanced Scorecard (BSC) emerging as a widely utilized tool (Fig. 1).

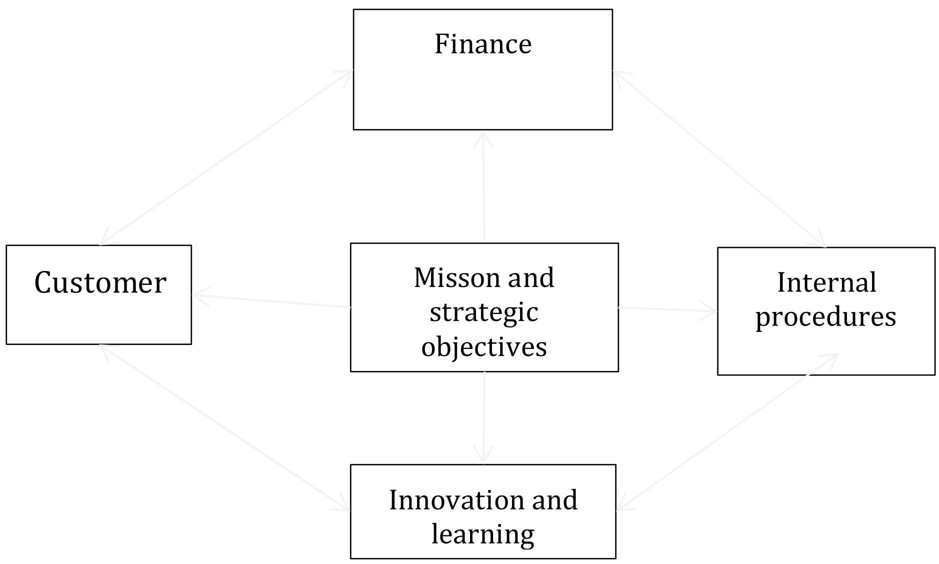

Fig. 1 BSC model

3. Theoretical Analysis of Farmland Water Conservancy Project Performance

3.1. Characteristics of Performance Evaluation for Farmland Water Conservancy Projects

As rural public goods, farmland water conservancy projects aim to provide high-quality public products to farmers. The public nature of these projects necessitates balancing financial performance with the externalities associated with public goods, including public welfare and equity. Consequently, performance evaluation for these projects must account for both financial and non-financial metrics, as well as short-term and long-term benefits, aligning with the principles of the BSC. Farmland water conservancy projects involve multiple stakeholders, with the achievement of operational and management objectives depending on their collaboration. Clearly defining the demands and goals of each stakeholder enables the establishment of strategic objectives, facilitating the alignment of all participants toward achieving organizational goals. Accordingly, the BSC framework can be effectively applied to identify the dimensions of performance measurement for farmland water conservancy projects.

3.2. Dimensions of Farmland Water Conservancy Project Performance Based on the BSC

The development of performance dimensions for farmland water conservancy projects requires a clear understanding of stakeholder demands and overarching strategic objectives.

The customer dimension of the BSC evaluates perceptions of the products and services provided, typically reflected in customer satisfaction. For farmland water conservancy projects, which involve diverse stakeholders, the interests of the government, consulting entities, construction teams, and supervisors directly influence project outcomes alongside water users' satisfaction. Consequently, this dimension was adjusted to represent stakeholder satisfaction in the context of this study. The financial dimension in traditional BSC models focuses on metrics such as income, profit, market share, and shareholder value, emphasizing profitability. However, as farmland water conservancy projects are public goods initiated by the government for rural water users, they do not generate significant financial returns. Instead, these projects deliver social and environmental benefits, such as improved rural living conditions, increased agricultural income, and enhanced ecological sustainability. For this reason, the financial dimension was modified to represent benefits in this study. The internal process dimension in the BSC evaluates improvements in operational management to enhance service delivery and competitiveness. For farmland water conservancy projects, this corresponds to supervising and managing operational capacities and implementation effectiveness to ensure quality and efficiency. Thus, this dimension was reframed as process management in the proposed framework. The innovation and learning dimension in the BSC reflects an organization's development prospects, including innovation and employee growth. For farmland water conservancy projects, this is analogous to the management and maintenance efforts necessary after project completion, highlighting the potential for long-term sustainability. Accordingly, this dimension was adapted to management and maintenance in this study. Based on these adjustments, a BSC model tailored to farmland water conservancy projects was developed, as illustrated in Fig. 2.

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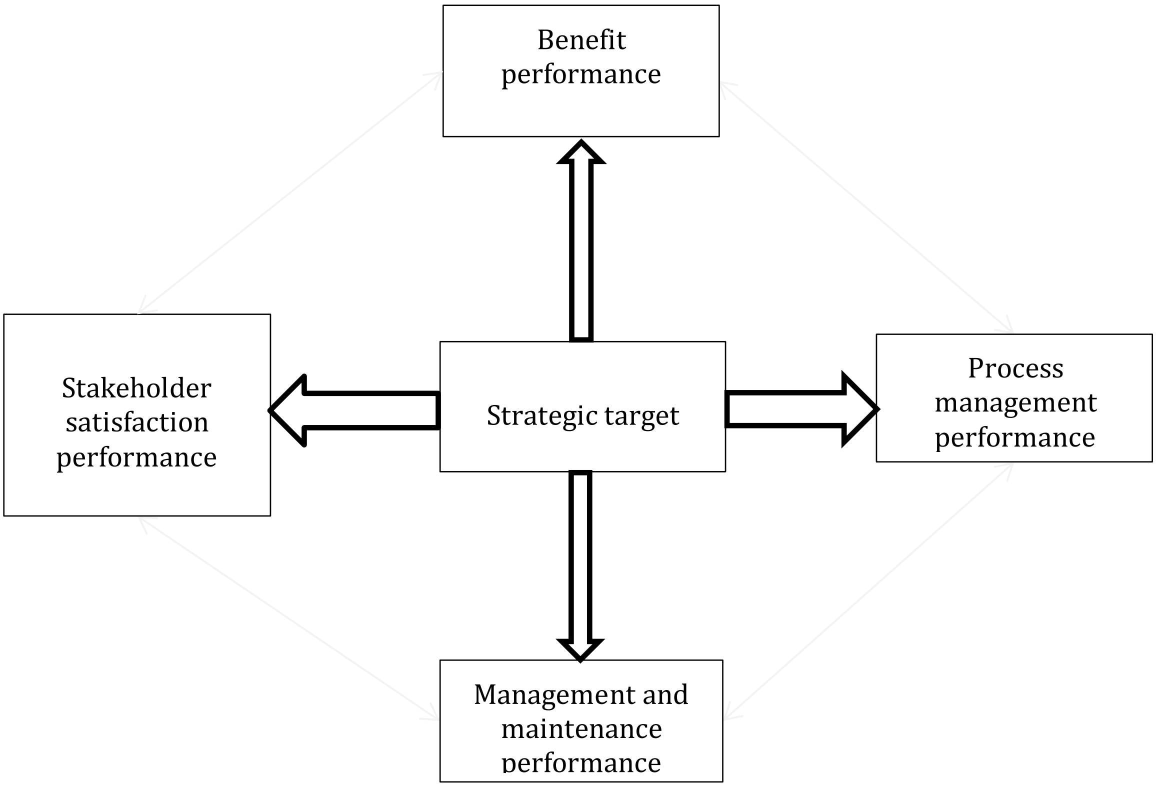

Fig. 2 BSC model for farmland water conservancy projects.

4. Farmland Water Conservancy Project Performance Measurement

4.1. Development of the Farmland Water Conservancy Project Performance Scale

The performance of farmland water conservancy projects was categorized into four key dimensions: stakeholder satisfaction, benefit performance, process management performance, and management and maintenance performance. Stakeholder satisfaction represents the degree of approval and contentment among all participants involved in the project. Benefit performance reflects the project's impact on water users as a government-provided public service, including its contributions to environmental and social benefits. Process management performance evaluates the operational efficiency and financial management during the project's implementation phase. Management and maintenance performance assesses the project's sustainability and the long-term advantages achieved post-completion. Drawing from prior studies on farmland water conservancy project performance and aligning with the research objectives, a preliminary performance measurement scale was developed. This process involved group discussions and expert consultations. The resulting performance measurement items are presented in Table 1.

Table 1 Performance measurement items for farmland water conservancy projects

Variable	No.	Measurement Item
Stakeholder satisfaction	Y1	The project has received support and recognition from farmers.
	Y2	Overall satisfaction among project participants is high.
	Y3	Few conflicts or disputes occurred during project construction.
Benefit performance	Y4	The project enhances local agricultural production levels.
	Y5	The project contributes to environmental protection.

	Y6	The project reduces local water disputes.
	Y7	The project improves the efficiency of local water resource utilization.
Management and maintenance performance	Y8	The project ensures transparency in fund management.
	Y9	The project has clear responsibilities and rights for management and maintenance.
	Y10	Farmers actively participate in project management and maintenance.
	Y11	Regular inspections are conducted post-operation.
Process management performance	Y12	The project demonstrates a high level of operational management.
	Y13	The project timeline was adhered to.
	Y14	The project maintains high standards of quality and safety management.
	Y15	Fund usage aligns with the allocated budget.

4.2. Empirical Survey Process

(1) Preliminary survey

The survey process consisted of two phases: a preliminary survey and a formal survey. The preliminary survey aimed to refine and optimize the initial questionnaire and assess its validity through a small-scale distribution. A total of 60 questionnaires were distributed during the preliminary survey, yielding 53 valid responses. Reliability analysis of the preliminary survey data assessed the consistency and stability of the sample. The Corrected Item-Total Correlation (CITC) and Cronbach's Alpha values were employed as evaluation criteria. A CITC exceeding 0.6 and a Cronbach's Alpha value greater than 0.7 were considered acceptable. The CITC values for stakeholder satisfaction, benefit performance, process management performance, and management and maintenance performance all exceeded 0.6, while Cronbach's Alpha values for these dimensions surpassed 0.7. These results confirmed the reliability of the questionnaire in the formal survey.

(2) Formal survey

Following the completion of two rounds of preliminary surveys, a formal survey was conducted. A total of 450 questionnaires were distributed, with 420 returned and 405 deemed valid, resulting in an effective response rate of 90%. Both online and offline methods were employed to maximize participation. Notably, 50.9% had over five years of experience in farmland water conservancy projects or related research, ensuring their expertise and familiarity with the subject. Participants included representatives from diverse stakeholder groups, such as government agencies, farmer water user associations, and individual water users. Furthermore, 48.8% of respondents had been involved in six or more farmland water conservancy projects or related studies/contracts. These characteristics underscored the representativeness and validity of the sample data.

4.3. Reliability Test

Reliability testing was conducted to assess the internal consistency of the scale. The results, summarized in Table 2, indicated a Cronbach's Alpha of 0.869 for farmland water conservancy project performance, surpassing the minimum threshold of 0.7. This demonstrated the reliability of the scale for evaluating performance across all dimensions.

Table 2 Reliability analysis of each variable scale

Variable	Latent variable	Item	Reliability
Performance of farmland water conservancy projects (Cronbach's Alpha=0.869)	Stakeholder satisfaction	Y11	0.706
		Y12	
		Y13	
	Benefit performance	Y21	0.707
		Y22	
		Y23	
		Y24	
	Management and maintenance performance	Y31	0.701
		Y32	
		Y33	
		Y34	
	Process management performance	Y41	0.725
		Y42	
		Y43	
		Y44	

4.4. Validity Analysis

Validity analysis was conducted to evaluate whether the questionnaire's measurement items accurately and effectively captured the intended variables. This analysis encompassed content validity and construct validity. Content validity assessed whether the questionnaire's content was logically structured, concise, easily understandable, and representative of the target constructs. Construct validity evaluated the extent to which the measured characteristics corresponded to the actual constructs being assessed. To ensure robust content validity, the study utilized established scales and refined the initial questionnaire through a preliminary survey, resulting in the final version. Structural validity was examined through confirmatory factor analysis (CFA), as the questionnaire was adapted from classic scales validated in prior studies. The CFA results, as presented in Table 3, demonstrated a Chi-square to degrees of freedom ratio (CMIN/DF) of 2.606, which falls within the excellent range (<3). The Root Mean Square Error of Approximation (RMSEA) value was 0.063, indicating a good fit (<0.08). Additionally, the IFI, TLI, and CFI values all exceeded 0.9, indicating excellent model fit. These findings confirmed that the measurement scales and observed variables effectively explained the performance of farmland water conservancy projects.

Table 3 Goodness-of-fit indicators for CFA

Indicator	Reference standard	CFA results
CMIN/DF	1-3: Excellent; 3-5: Good	2.606
RESEM	<0.05: Excellent; <0.08: Good	0.063
IFI	>0.9: Excellent; >0.8: Good	0.924
TLI	>0.9: Excellent; >0.8: Good	0.904
CFI	>0.9: Excellent; >0.8: Good	0.923

Following confirmation of the model's strong fit indices, convergent validity and composite reliability of the scale dimensions were evaluated. Convergent validity was assessed by calculating the standardized factor loadings of each measurement item within their respective dimensions, followed by the computation of average variance extracted (AVE) and composite reliability (CR) values using their respective formulas. According to established criteria, AVE values should exceed 0.5, and CR values should exceed 0.7 to demonstrate acceptable convergent validity and composite reliability. The results, as illustrated in Fig. 3 and Table 4, indicated that all dimensions of the performance scale for farmland water conservancy projects met the criteria, with AVE values exceeding 0.5 and CR values exceeding 0.7. Thus, the performance scale demonstrated strong convergent validity and composite reliability across all dimensions.

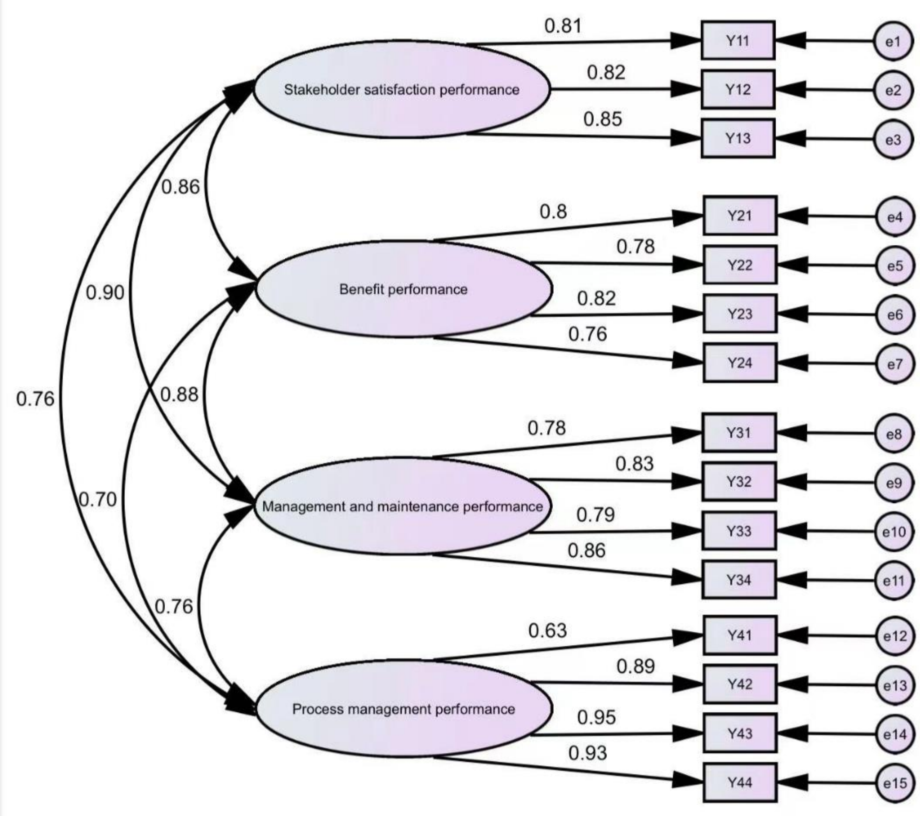

Fig. 3 CFA of dependent variables

Table 4 CFA of dependent variables

Path relationship			Standardized factor loading	AVE	CR
Y11	<---	Stakeholder satisfaction performance	0.811	0.686	0.868
Y12	<---	Stakeholder satisfaction performance	0.822		
Y13	<---	Stakeholder satisfaction performance	0.851		
Y21	<---	Benefit performance	0.799	0.627	0.870
Y22	<---	Benefit performance	0.780		
Y23	<---	Benefit performance	0.824		
Y24	<---	Benefit performance	0.762		

Y31	<---	Management and maintenance performance	0.775	0.664	0.887
Y32	<---	Management and maintenance performance	0.830		
Y33	<---	Management and maintenance performance	0.794		
Y34	<---	Management and maintenance performance	0.857		
Y41	<---	Process management performance	0.632	0.735	0.916
Y42	<---	Process management performance	0.889		
Y43	<---	Process management performance	0.946		
Y44	<---	Process management performance	0.925		

The results of the discriminant validity test are presented in Table 5. The standardized correlation coefficients between the dimensions of farmland water conservancy project performance were all smaller than the square roots of the AVE values for their respective dimensions. These results confirmed that the dimensions exhibited good discriminant validity.

Table 5 Discriminant validity test results for dependent variable dimensions

Variable	Stakeholder satisfaction performance	Benefit performance	Management and maintenance performance	Process management performance
Stakeholder satisfaction performance	0.686			
Benefit performance	0.503	0.627		
Management and maintenance performance	0.562	0.486	0.664	
Process management performance	0.369	0.300	0.348	0.735
Square Root of AVE	0.828	0.792	0.815	0.857

5. Conclusions and Outlook

This study examined the applicability of the BSC model for categorizing the dimensions of farmland water conservancy project performance. A performance measurement model based on the BSC framework was developed, tailored to the specific characteristics of farmland water conservancy projects. Through a comprehensive questionnaire survey and statistical analysis, a formalized performance measurement model was constructed, comprising four dimensions: stakeholder satisfaction performance, benefit performance, management and maintenance performance, and process management performance, encompassing a total of 15 measurement items.

The theoretical contributions of this study are twofold. First, the dimensional categorization of farmland water conservancy project performance was revisited through the perspective of the BSC model, integrating insights from recent academic advancements. These categorizations were subsequently validated within the context of practical scenarios in China, resulting in a reliable tool for assessing the performance of farmland water conservancy projects. This tool provides a foundation for future theoretical exploration and empirical analysis.

The findings of this study also have significant implications for the management of farmland water conservancy projects. The proposed performance measurement model can serve as a diagnostic framework to identify areas requiring improvement in performance management and to highlight specific accomplishments of these projects. Additionally, the model facilitates benchmarking by enabling comparisons between assessed projects and ideal or benchmark projects. Such comparisons can reveal deficiencies and, thus, lay foundation for the adoption of enhanced management practices to improve project performance.

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