Developing Key Performance Indicators for Public-Private Partnership Projects: Questionnaire Survey and Analysis

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Abstract: Public-private partnerships (PPPs) are increasing in popularity. Major challenges in the development of PPPs have resulted from the global financial crisis. However, with respect to their monetary value, PPPs are still an attractive option for public sector projects. Performance management and measurement, in which Key Performance Indicators (KPIs) are the core elements, viewed as effective methods to help PPPs deliver value for money. This article describes in greater detail a KPI conceptual model composed of 5 performance packages and 48 indicators developed by the authors in previous studies. A structured questionnaire survey explored PPP stakeholders perceptions of 48 project performance indicators (PIs) to identify actual KPIs for performance management and measurement in PPPs. Although the survey results show that all PIs are important, performance packages contribute differently to the overall project performance. A confirmatory factor analysis (CFA) was used to test whether the proposed conceptual model fit the observed set of collected data in a predictable way, and to further consolidate the KPIs. The improved KPI model uses 41 PIs, which indicate that performance improvement within PPP projects is strongly influenced by reasonable procurement, design and planning in the public sector, effective process control in the private sector, and the ultimate satisfaction of both the public and private sectors. These 41 KPIs can be used to identify strengths and weaknesses of PPP projects and improve effective performance management and measurement in PPPs. **DOI: 10.1061/(ASCE)ME.1943-5479.0000113.** © *2012 American Society of Civil Engineers.*

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Introduction

Public-private partnerships (PPPs) have been adopted extensively by governments and are viewed as useful vehicles to facilitate development of public infrastructure around the globe (Ke et al. 2009; Tang et al. 2010). Private sector use of PPPs has been related to facilities development, including designing, financing, construction, ownership, and/or operation of a public sector utility or service (Akintoye et al. 2003). The objective of PPPs is to effectively transfer risk to the private partners, reducing public sector administrative costs, solving the problem of public sector budgeting constraints, providing higher quality public products and services, and saving time in delivering the projects. (Yuan et al. 2010)

However, the global financial crisis (GFC) of 2008 had a strong impact on the development of PPPs. Private finance for PPP projects became much more expensive and market capacity was substantially reduced, leading some commentators to claim that the PPP model was dead (Burger et al. 2009; Kappeler and Nemoz 2010). However, the rationale behind PPP projects has not changed. They remain attractive to the public sector, as historically they have provided strong value for the money (VfM), delivering high-quality outcomes, ontime and onbudget. Therefore, PPPs are also attractive to private sector contractors and service providers. Furthermore, despite the current problems with financing them, well-structured PPP projects remain fundamentally good credit risks and, hence, remain attractive to lending and investment prospects (KPMG 2010; Regan 2011). The challenge for the PPP market is to ensure that projects can be financed under current market conditions and that they still can deliver VfM. A large number of studies have mentioned that VfM is very important in PPP projects (Li et al. 2005; Cheung et al. 2005; Regan et al. 2011). Therefore, achieving VfM through improved efficiency, effectiveness, economy, and partnerships is a productive way to address problems resulting from the GFC. The delivery of VfM should rely on long-term project performance at a high level, which would sustainably benefit the expanded development of PPPs (Cheung et al. 2005). As established by the authors' prior research, an effective Performance Measurement and Management (PMM) system contributes significantly to performance improvement in PPP projects and increased VfM (Yuan et al. 2008; Yuan et al. 2009).

Project measurement and management has been introduced as an effective tool for management of construction projects (Kagioglou et al. 2001). In prior studies, the authors identified a

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series of performance objectives (POs) for PMM in PPP projects. Performance objectives are the basis for PMM, the process of determining how successful organizations or individuals have been in attaining these objectives (Solomon and Young 2007). On the basis the defined POs, a conceptual model was established and 48 performance indicators (PIs) were identified (Yuan et al. 2008; Yuan et al. 2009). PIs are data measures used to assess and evaluate the performance of a PPP operation (Kagioglou et al. 2001). Accurate analysis of performance can be achieved only after the KPIs are determined and monitored. In the present study, the 48 indicators were further consolidated through a survey of stakeholders to identify key performance indicators (KPIs).

The research objectives of this study were: (1) to assess the relative significance of PIs using stakeholder survey data to identify KPIs; (2) to test whether the proposed conceptual model has correctly identified PIs based on stakeholder survey data; and (3) to better define relationships among PIs in the conceptual model.

The paper begins with a literature review in the related fields followed by a presentation of the research approaches used in the study, and further refinement of the proposed conceptual model of PIs in PPP projects and the theoretical relationships in the model. A confirmatory factor analysis (CFA) was used to test and improve the conceptual model, identifying KPIs and clarifying their relationships.

Literature Review

Literature on Public-Private Partnerships

Increasing private participation in public infrastructure development suggests that studies of PPPs are important both academia and industry. Features of PPPs such as high risks, long durations, complicated procedures and multiple stakeholders command the attention of researchers in engineering project management.

Several studies have conducted systematic reviews of relevant PPP research to ascertain the coverage and foci of PPP-related research topics and the contributions of these studies. The most common conclusion among these researchers is that studies of on PPPs are experiencing a tremendous change (Yuan et al. 2009; Ke et al. 2009; Tang et al. 2010).

Risk-based decision methods (Grimsey and Lewis 2002; Ke et al. 2010), procurement methods (Lam and Chow 1999; Kumaraswamy and Morris 2002), concession-related issues (Shen and Wu 2005; Ng et al. 2007), financial problems (Chang and Chen 2001; Xenidis and Angelides 2005), and success factors for PPPs (Li et al. 2005; Zhang 2005) are primary topics of ongoing research in the field (Al-Sharif and Kaka 2004; Yuan et al. 2009; Ke et al. 2009; Tang et al. 2010). Public-private partnerships have been adopted in many regions and by many types of public infrastructure development projects. Studies in recent years have focused on how to address issues such as stakeholder relationships (El-Gohary et al. 2006; Chan et al. 2010), performance improvement (Koppenjan and Enserink 2009; Yuan et al. 2010), governance (Brinkerhoff and Brinkerhoff 2011), and strategic infrastructure development (Kwak 2009). Ke et al. (2009) and Tang et al. (2010) suggest that more advanced methods should be applied in PPP-related studies to resolve newly emerging problems related to project performance. Moreover, Yuan et al. (2009) propose more effective administration of PPP project and achievement of intended objectives through micromanagement and stage-specific analyses (Noble and Jones 2006).

Changing circumstances within the external environment, such as the GFC, have created new problems in PPPs that can be resolved by using new management methods. As proposed by Yuan et al. (2009) and Hodge (2009), PMM can provide PPPs with an integrated solution to facilitate sustained VfM, while responding effectively to the challenges resulting from to changes in the macroeconomic environment and new project requirements.

Literature on Performance Measurement and Management

Performance measurement and management provides not only a new basis for PPP research, but also a series of methodologies to assist the public and private sectors in making decisions and managing PPP projects (Pavlov 2010). Performance management and measurement, now used as a management control tool, is an effective and integrated method that can increase organizational profits at the company level (Luu et al. 2008), and reduce overhead costs, quality, and safety risks at the project level (Yu et al. 2007). Other researchers have found that tangible benefits, such as stakeholder satisfaction (Dainty et al. 2003) and sustainable development (Ugwu and Haupt 2007), can also be achieved through PMM. Indeed, some have also shown that Performance management and measurement increases project team communication and collaboration while facilitating the implementation of strategic objectives (Yu et al. 2007; Pavlov 2010).

At the project level, PMM is used to estimate a performance score based on the monitoring of PIs, perform an analysis and assessment using this score, and to continuously update and complement PIs. The core function of PMM is to identify, measure, and manage appropriate KPIs (Yu et al. 2007). Thus, prior studies have been more focused on KPIs at the project level. In addition, Yu et al. (2007) proposed KPIs as the basis for better implementation of PMM at the company level. Public-private partnership projects are very different from traditional construction project, and few studies have attempted to identify KPIs in PPP projects. In PPPs, a special purpose vehicle (SPV) should determine whether the project can be successfully achieved and be fully responsible for its planning, construction, and operation. In this case, KPIs are applied as metrics to evaluate factors vital to project success (Yuan et al. 2009), and consequently should be used as part of the PMM to be measure the success of the SPV in meeting the designated meets objectives.

Although many studies have explored PPPs, the literature implies that little effort has been directed toward the application of PMMs and KPIs for measuring performancein in PPP projects. Although 48 PIs have been identified through prior studies (Yuan et al. 2008; Yuan et al. 2009), the relative significance of PIs must be determined through data collection from stakeholders to identify the KPIs. Furthermore, the relationships among identified KPIs should also be clarified to determine which KPIs contribute most significantly to project success.

Research Methodology

Based on theoretical relationships within their proposed conceptual model, the authors developed an indicator system to measure project performance and to identify KPIs in PPP projects. A survey using a stratified random sampling method was conducted to more extensively investigate the PIs of a PPP project during its life cycle. Statistical analyses were performed, using the SPSS 17.0 software package, by multiple methods including Cronbach's alphas, mean value, and grouping discussion to validate the survey and evaluate stakeholders' perceptions of performance indicators. A confirmatory factor analysis (CFA) was performed using the LISREAL 8.70 software to test the correlation of the theoretical model with the survey data, and to consolidate the number of performance indicators by identifying KPIs and clarifying the relationships

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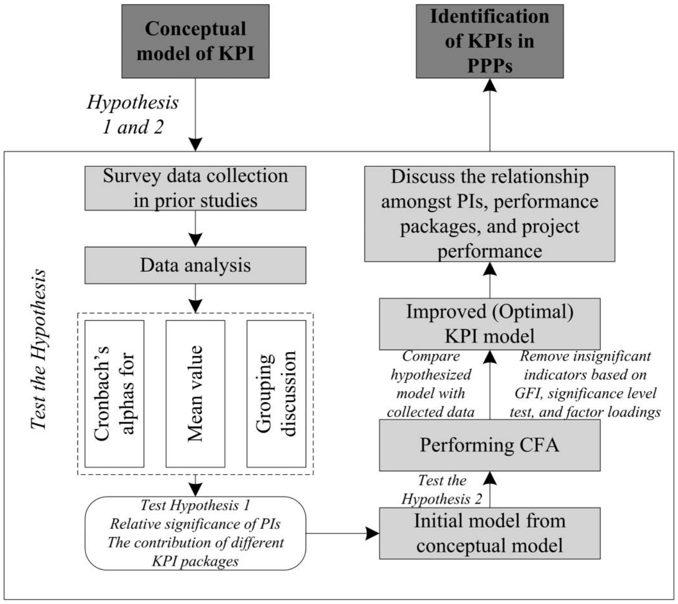

Fig. 1. The methodology adopted in this study

among the indicators. The organization of methodology adopted in the research is shown in Fig. 1.

Performance Indicators for Public-Private Partnerships

Description of the Proposed Conceptual Model

The proposed conceptual model depends on identification of PIs according to POs (Yuan et al. 2009). Toor and Ogunlana (2009) described performance measurement by establishing KPIs as objective criteria to measure project success. PIs, as characterized by Yuan et al. (2009), measure achievement of POs defined by PPP stakeholders.

Fig. 2 presents the conceptual model for PIs (Yuan et al. 2009), which can be further consolidated into KPIs. There are five packages in the model: KPI_1-physical characteristics of projects; KPI_2-requirements of stakeholders from the perspective of financing and marketing; KPI_3-requirements of stakeholders from the perspective of innovation and learning; KPI_4-requirements of stakeholders from the perspective of stakeholders; and KPI_5-project process, in which KPI_2, KPI_3, and KPI_4 can be viewed as a big package representing the requirements of stakeholders. The model includes both static and dynamic indicators, and reflects the expectations and requirements of stakeholders. By adopting the proposed model, the stakeholders not only stress the quality, time, and costs of PPP projects, but also impose high expectations on public service and improvement provided by PPPs.

In package 1, the physical characteristics of PPP projects, considered as project specifications, influence performance of at an early stage. These have a strong impact on the decision-making process during project initialization and planning (e.g., concessionaire selection, concession agreement, and risk allocation), and on the prospects for project success based on the influence of economic, legal, and political circumstances in project host country. In packages 2, 3, and 4, financial and marketing indicators, innovation and learning indicators, and stakeholder indicators are included. These three packages reflect specific stakeholder requirements from the perspective of economy, innovation, culture, and benefit to the stakeholders. Indicators in package 5 aim at improving project performance of PPPs through effective process control to achieve stakeholder POs.

The PIs can be used to effectively describe the attributes of a system. They define 'how good' a system is, in objectively measurable terms (Solomon and Young 2007). The indicator values should be defined by stakeholders and be quantifiable, so that they can be arranged along a scale of measure, and complex enough to contain many elementary attributes.

Hypothesized Relationships in the Conceptual Model

Conceptual framework (Fig. 2) is a representation of PPP project implementation, and serves as the foundation for systematic PMM based on KPIs. PPPs are focused on capturing the product requirements, customer satisfaction, efficiency, business success, future potential of the projects, and performance change. Given that PPPs can achieve better quality than traditional construction activities (NAO 2001; Li et al. 2005; Bloomfield 2006) through successful process control, focus on VfM, and innovation (Aziz 2007), new

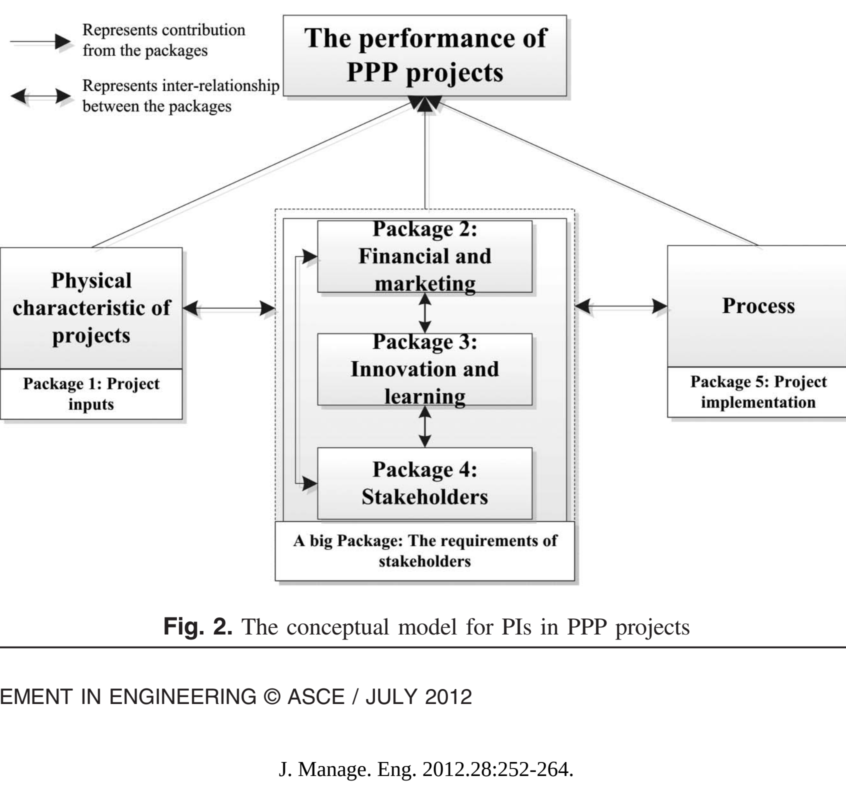

Fig. 2. The conceptual model for PIs in PPP projects

indicators must be considered in proposed models for project PMM. Compared to traditional construction activities, the factors that influence the performance of PPP projects are more complex, addressing benefits for different stakeholders to achieve acceptable VfM. Despite the simplistic nature of PMM as depicted in prior research by the iron triangle (Cooke-Davies 2002), many scholars have agreed that performance measurement can no longer be restricted to the traditional indicators which include time, cost, and quality (Low and Chuan 2006).

Based on these relationships, three hypotheses can be concluded.

- All stakeholders have the same opinions on the PIs in PPP. The PPP stakeholders were divided into four types by Yuan et al. (2009), in a study revealing that different stakeholders have different expectations of PPP projects, which leads to different perceptions of POs based on their different roles in the projects. However, all stakeholders should work together to help a project achieve VfM; therefore, the core PIs or KPIs should be shared among different stakeholders. The indicators that are considered significant by all stakeholders would be KPIs for PPP projects.
- All performance packages contribute to the performance of PPP projects, and the Classification of performance packages is correct. As shown in Fig. 2, all packages contribute to the performance of PPP projects from different perspectives. Although their contributions and pathways are different, they all influence project performance. On the other hand, the classification of these packages within the proposed model specifically reflects the characteristics of PPPs, which should be supported by data from the survey. Additionally, the survey data should provide an empirical evaluation of the arrangement of indicators into the different packages.

Cause and effect relationships among different packages may also exist. Greater awareness of those relationships will help both the public and private sectors to better understand how project performance evolves and how it can be measured in PPPs. This paper is focused on Hypotheses 1 and 2, however future studies will explore the interaction relationships.

Survey on Performance Indicators in Public-Private Partnerships

Questionnaire Survey

A structured survey of researchers, professionals, and stakeholders was conducted from January to March 2008. A detailed description of the survey questionnaire and results of the first and second parts were described by Yuan et al. (2009, 2010). The third part of the survey questionnaire, focused on the investigation of PIs within PPPs, is further described in this paper. In order to identify the relative significance of PIs, Likert-style rating questions, using a five-point scale, were used to elicit respondents' opinions about the importance of each objective. Generally, the level of agreement or disagreement was measured. The scale intervals are interpreted as follows: (1) can be ignored or not important; (2) maybe important; (3) important; (4) very important; and (5) most important. A total of 1,083 questionnaires were distributed and 141 respondents returned completed questionnaires (Yuan et al. 2009). The returned questionnaires were from different organizations/institutions in a number of countries and regions. The survey respondents' roles and experiences are described by Yuan et al. (2009). The effective return rate was 13.02%. Compared to acceptable rates in other studies of PPPs, including 12% in Li et al. (2005), 9.4% in Salman et al. (2007), 11.4% in Jin and Zhang (2011), and 36% in Chan et al. (2011), the survey response rate is not high, but is acceptable for social science research of this nature and scale (De Vaus 2001).

Consistency of Survey Data

A reliability analysis was conducted to test the internal consistency of the survey variable data. Cronbach's Alphas are 0.954 (F-statistic $= 36.067$, sig. $= 0.000$) for all PIs. It is much higher than the 0.70 recommended in Nunnally's (1978) guideline and Zhang's (2006) similar research, which suggest that, in the early stages of research on predictive tests or hypothesized measures of a construct, reliability of 0.70 or higher should suffice. A Cronbach's value was derived for each factor. A value exceeding 0.9; between 0.9 and 0.7; and lower than 0.35 indicates high, acceptable, and low reliability, respectively. In prior research (Yuan et al. 2009, 2010), respondents were divided into 4 groups based on their roles in PPPs from the stakeholder perspective to investigate their opinions on POs in PPPs. The survey results in this paper were generated from the third part in the same questionnaire. Although the research results indicate that the opinions of various groups on POs are different (Yuan et al. 2009), the opinions of different stakeholder groups on PIs are similar based on the value of Cronbach's Alphas, which confirms Hypothesis 1 and provides a basis for development of further studies.

Ranking of Performance Indicators

As listed in Table 1, the mean response rating values for the 48 PIs offered to respondents range from a maximum of 3.986 (PI_{13}, Commitment and responsibility between public and private sector) to a minimum of 3.014 (PI_1, Type of construction). No indicator mean value scores fell into the 'extremely important' (> 4.50) and 'not important' (< 1.5) categories, which indicates that all of these 48 PIs are considered important and can be used to monitor the project performance.

Based on the survey results (Table 2), the mean values of 31 indicators are higher than 3.50. These 31 indicators come from all of the five packages, with 10 indicators from KPI_1, 6 indicators from KPI_2, only 2 indicators from KPI_3, 4 indicators from KPI_4, and 9 indicators from KPI_5. These results suggest that stakeholders pay greater attention to decision-making in early stages and process control activities, as 19 indicators are from KPI_1 and KPI_5, implying that the need for effectiveness and efficiency is considered important among diverse stakeholder groups. In addition, the mean values for 6 of the 9 indicators in KPI_2 are greater than 3.50, suggesting that economic issues are also very important to the performance of PPP projects. All stakeholder indicators (KPI_4) are among the 31 values greater than 3.50, a sign that good partnerships among stakeholders would positively influence the performance of PPP projects. Moreover, only 2 indicators from KPI_3 fall among the 31 most highly rated indicators, which demonstrates that public and private sectors prefer more mature technology for such large infrastructure projects (Li et al. 2005).

Focusing on the 10 most highly ranked indicators (Table 2), the improvement of project performance in PPPs strongly depends on cooperation and support among different stakeholders (PI_{13} and PI_{32}) and reasonable management capability within both the public and private sectors (PI_{15}, PI_{48}, and PI_{30}), including risk management, regulation and governance, and financial management. Traditional project goals (schedule, PI_{47}; quality, PI_{35}; and cost, PI_{46}) are all important indicators among the 10, most highly rated which means that stakeholders emphasize process control in PPPs as they do in traditional construction projects. Additionally, knowledge of PPPs in both the public and private sectors (PI_5 and PI_6) is extremely important to the success of PPP projects because many difficulties result from inexperienced participants. Understanding

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Table 1. PIs in the PPP Projects and Their Scores and Rankings

Package		PIs	Mean	SD	Rank
KPI_1	PI_1	Type of construction	3.014	1.046	48
	PI_2	Level of design complexity	3.238	0.957	42
	PI_3	Level of construction complexity	3.343	0.979	39
	PI_4	Level of technological advancement	3.231	0.984	43
	PI_5	Concessionaire's knowledge of PPPs	3.853	1.068	7
	PI_6	Government's knowledge of PPPs	3.825	1.044	8
	PI_7	Competitive tender procedure	3.532	1.040	28
	PI_8	Standard PPP contract with enough flexibility	3.622	1.042	21
	PI_9	General public/social support	3.462	1.067	34
	PI_{10}	Stable and favorable macroeconomic conditions	3.559	1.052	25
	PI_{11}	Stable and favorable legal environment	3.755	0.966	14
	PI_{12}	Stable and favorable political environment	3.622	1.060	22
	PI_{13}	Commitment and responsibility between public and private sector	3.986	0.971	1
	PI_{14}	Project technical feasibility, constructability, and maintainability	3.790	1.034	11
	PI_{15}	Appropriate risk allocation, risk sharing, and risk transfer	3.965	1.024	2
KPI_2	PI_{16}	Sound financial analysis	3.790	1.040	12
	PI_{17}	Sustainable profitability	3.727	1.001	17
	PI_{18}	Increased marketability	3.490	0.926	32
	PI_{19}	Financial ability of whole shareholders	3.559	0.901	26
	PI_{20}	Perfect tariff/tolls or price adjustment mechanism for the project	3.539	0.925	27
	PI_{21}	Financing cost	3.308	1.002	41
	PI_{22}	Realistic schedule of investment and revenue	3.511	1.027	30
	PI_{23}	Insurance coverage	3.168	0.880	45
	PI_{24}	Construction and concession period	3.615	1.006	23
KPI_3	PI_{25}	Investment in research and development of new technology	3.189	1.107	44
	PI_{26}	Establishment of learning organization	3.112	0.994	46
	PI_{27}	Employee training	3.413	0.988	36
	PI_{28}	Technology innovation (e.g., designing, construction, planning, etc.)	3.511	1.013	31
	PI_{29}	Technology transfer	3.357	0.891	38
	PI_{30}	Financial innovation (i.e., creative financial package)	3.825	1.044	9
KPI_4	PI_{31}	Public client's satisfaction	3.685	1.064	19
	PI_{32}	General public/Social satisfaction	3.916	1.091	4
	PI_{33}	Good relationship among the concessionaire, subcontractors, and suppliers	3.594	0.841	24
	PI_{34}	Good relationships within project team	3.706	0.948	18
KPI_5	PI_{35}	High quality control	3.909	1.068	5
	PI_{36}	Safety management	3.776	1.024	13
	PI_{37}	Health control	3.378	0.955	37
	PI_{38}	Environmental protection	3.532	0.925	29
	PI_{39}	Effective risk management system	3.748	0.968	15
	PI_{40}	Facility management	3.462	0.862	35
	PI_{41}	Stress/Conflict management	3.343	0.950	40
	PI_{42}	Resource utilization (material and equipment)	3.664	0.911	20
	PI_{43}	Contract management	3.112	0.505	47
	PI_{44}	Prominent technical management and skill	3.490	0.871	33
	PI_{45}	Interface management between organization and stages	3.734	1.027	16
	PI_{46}	Cost management (during construction and operation periods)	3.867	0.929	6
	PI_{47}	Time management (during construction and operation periods)	3.811	0.927	10
	PI_{48}	Good governance	3.944	0.970	3

the PPP is key to dealing with complex problems and provides a basis for collaboration (El-Gohary et al. 2006).

The important information discovered through the survey is that PPP projects depend on successful partnership. As shown in Table 2, all participants influence project performance. Both public and private collaborators, and the general public are primary stakeholders, as identified by Yuan et al. (2010). They all impact the performance of PPP projects according to the survey results presented in Table 2. Therefore, stakeholders should collaborate to improve performance in PPPs.

Grouping of Survey Results

As mentioned in the discussion of the survey instrument, all PIs are assigned to one of five packages in the proposed conceptual model

Table 2. PIs (Mean Value > 3.50) and Related Stakeholders

Rank	No.	Mean	Package	Related stakeholders	Rank	No.	Mean	Package	Related stakeholders
1	PI_{13}	3.986	1	Public and private sectors	17	PI_{17}	3.727	2	Private sector
2	PI_{15}	3.965	1	Public and private sectors	18	PI_{34}	3.706	4	Private sector
3	PI_{48}	3.944	5	Public sector	19	PI_{31}	3.685	4	Public sector
4	PI_{32}	3.916	4	General public	20	PI_{42}	3.664	5	Private sector
5	PI_{35}	3.909	5	Private sector	21	PI_{8}	3.622	1	Public sector
6	PI_{46}	3.867	5	Private sector	22	PI_{12}	3.622	1	Public sector
7	PI_{5}	3.853	1	Private sector	23	PI_{24}	3.615	2	Public and private sectors
8	PI_{6}	3.825	1	Public sector	24	PI_{33}	3.594	4	Private sector
9	PI_{30}	3.825	3	Private sector	25	PI_{10}	3.559	1	Public sector
10	PI_{47}	3.811	5	Private sector	26	PI_{19}	3.559	2	Private sector
11	PI_{14}	3.790	1	Public and private sectors	27	PI_{20}	3.539	2	Private sector
12	PI_{16}	3.790	2	Private sector	28	PI_{7}	3.532	1	Public sector
13	PI_{36}	3.776	5	Private sector	29	PI_{38}	3.532	5	Private sector
14	PI_{11}	3.755	1	Public sector	30	PI_{22}	3.511	2	Private sector
15	PI_{39}	3.748	5	Private sector	31	PI_{28}	3.511	3	Private sector
16	PI_{45}	3.734	5	Public and private sectors					

of KPIs. In the questionnaire survey, indicators from each of the packages were investigated. Thus, a discussion of the survey results with respect to the different packages is necessary. The rankings of PIs within the different KPI packages are shown in Table 3. Some important findings can be summarized based on the results of the survey.

- KPI_1: The KPIs in this package should include indicators that reflect the influence of decision-making (PI_{13}, PI_{15}, PI_{14}, PI_8, and PI_7), external environment (PI_{10}, PI_{11}, and PI_{12}), and the ability of public and private sectors (PI_5 and PI_6), based on the survey results.
- KPI_2: The contributions of this package to project performance are optimized cash flow of PPP projects, reduced financial risk, a healthy project environment, and adequate profits for private sector partners. The core of this package is the cost of project elements (e.g., tariff, water rate, and energy change costs) that relate closely with PI_{17}, PI_{18}, PI_{19}, PI_{20}, PI_{22}, and PI_{24}.
- KPI_3: Innovative technologies, creative management, and financing skills contribute substantially to project performance because PPPs are very large and complicated, integrating many processes. Financial innovation (PI_{30}), technology innovation (PI_{28}), and training programs (PI_{27}) are the most important indicators in this package.
- KPI_4: The score of PI_{34}, "Good relationship in project team," is higher than that of PI_{31}, "Public client's satisfaction," which indicates that the public and private sectors both realize that the promotion of project performance should rely on favorable teamwork. Therefore, the score of PI_{33} is also high. These results suggest that KPIs should measure satisfaction from multiple perspectives.
- KPI_5: The most highly emphasized indicators in this package are: PPP governance by public sector participants through strict regulation and administration during the process to avoid significant defects when the project is transferred (PI_{48}); reduction of uncertainty and risk through management of quality, safety, and process risk (PI_{35}; PI_{36}, and PI_{39}); and sustainable development, including sustainable viability (PI_{45} and PI_{41}), effective resource utilization (PI_{42}), and health-safety-environment (HSE) (PI_{38} and PI_{37}). It was surprising that PI_{43} (contract management) obtained the lowest score in this package. When compared with the survey

Table 3. Ranking in KPI Packages

KPI_1 package			KPI_2 package			KPI_3 package			KPI_4 package			KPI_5 package		
Rank	PI	Mean	Rank	PI	Mean	Rank	PI	Mean	Rank	PI	Mean	Rank	PI	Mean
1	PI_{13}	3.986	1	PI_{16}	3.790	1	PI_{30}	3.825	1	PI_{32}	3.916	1	PI_{48}	3.944
2	PI_{15}	3.965	2	PI_{17}	3.727	2	PI_{28}	3.511	2	PI_{34}	3.706	2	PI_{35}	3.909
3	PI_{5}	3.853	3	PI_{24}	3.615	3	PI_{27}	3.413	3	PI_{31}	3.685	3	PI_{46}	3.867
4	PI_{6}	3.825	4	PI_{19}	3.559	4	PI_{29}	3.357	4	PI_{33}	3.594	4	PI_{47}	3.811
5	PI_{14}	3.790	5	PI_{20}	3.539	5	PI_{25}	3.189				5	PI_{36}	3.776
6	PI_{11}	3.755	6	PI_{22}	3.511	6	PI_{26}	3.112				6	PI_{39}	3.748
7	PI_{8}	3.622	7	PI_{18}	3.490							7	PI_{45}	3.734
8	PI_{12}	3.622	8	PI_{21}	3.308							8	PI_{42}	3.664
9	PI_{10}	3.559	9	PI_{23}	3.168							9	PI_{38}	3.532
10	PI_{7}	3.532										10	PI_{44}	3.490
11	PI_{9}	3.462										11	PI_{40}	3.462
12	PI_{3}	3.343										12	PI_{37}	3.378
13	PI_{2}	3.238										13	PI_{41}	3.343
14	PI_{4}	3.231										14	PI_{43}	3.112
15	PI_{1}	3.014												

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responses about the contract design element in the KPI_1 package, contract design ($PI_8 = 3.622 > PI_{43} = 3.112$) is greater importance, which suggests that contract management relies more on the completeness and correctness of contracts signed during the early stage.

Confirmatory Factor Analysis of Survey Data

As suggested by Hypothesis 2, all performance packages and indicators contribute to PPP project performance as shown in Fig. 3 (Conceptual model, Fig. 2, is transformed to a hypothesized model as presented by Fig. 3). A confirmatory factor analysis (CFA) was used to test whether this PI model fit the observed set of empirical data in the predicted way. Gorsuch (1983) proposed the CFA as a powerful tool for explicit hypothesis testing of factor analytic problems.

In statistics, CFA is a special form of factor analysis and a confirmatory technique—it is theory driven (Schreiber et al. 2006). Therefore, the planning of the analysis is driven by the theoretical relationships among the observed and unobserved variables (In Fig. 2, the performance and PIs are observed variables, and the 5 packages are unobserved variables). It is used in this case to test whether measures of a construct are consistent with the authors' understanding of the nature of PPP project PIs.

When a CFA is conducted, a hypothesized model (Fig. 3) is used to estimate a population covariance matrix that is compared with an observed covariance matrix. Thus, the proposed model of KPIs is tested using CFA to eliminate insignificant indicators. Furthermore, indicators with comparatively low factor loadings (contribution to the performance) can be removed to achieve the optimal model, through which real KPIs can be ultimately identified.

An optimal statistical model can propose a priori and specified number of indicators and item-loading patterns. The adequacy

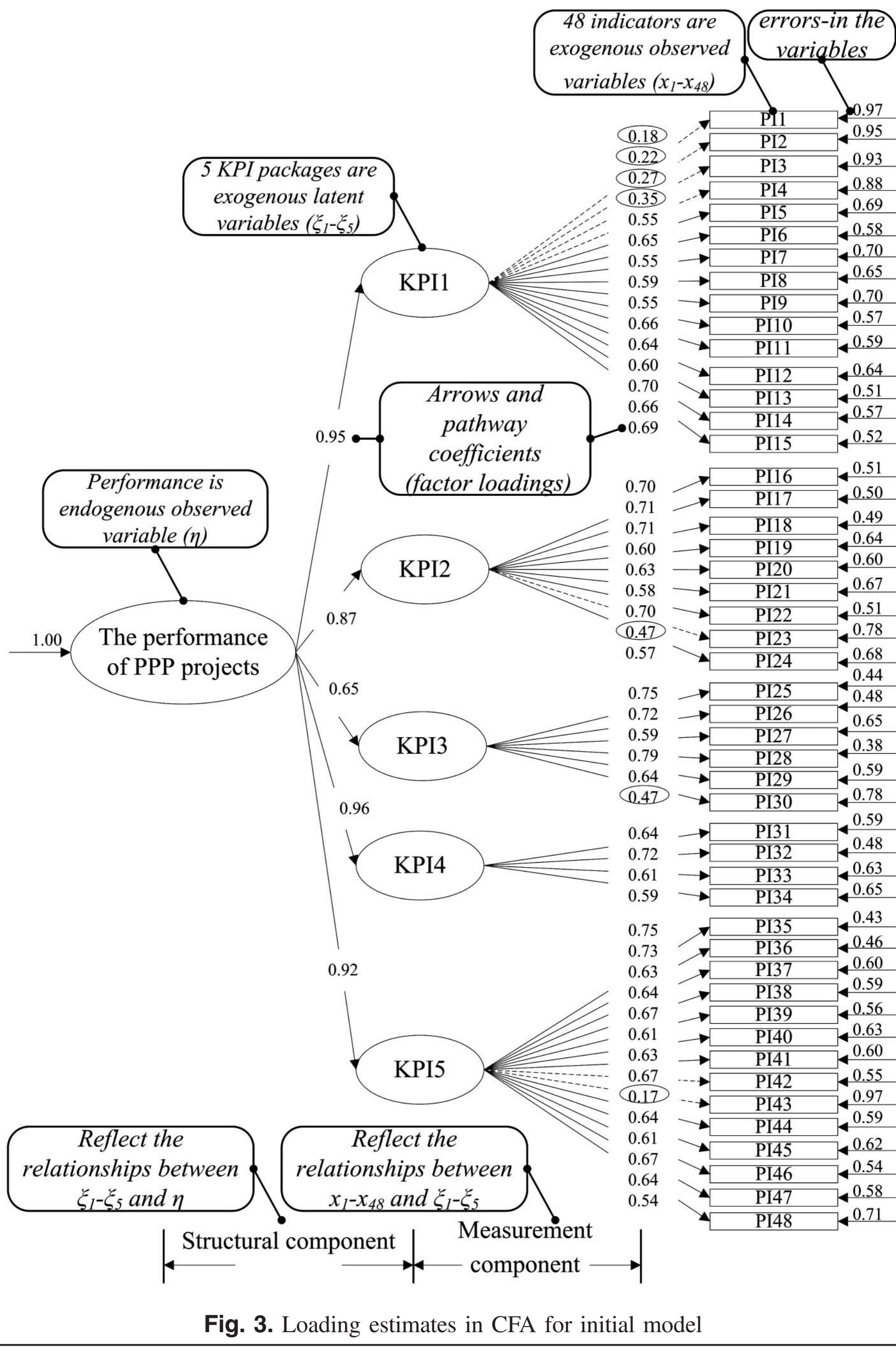

Fig. 3. Loading estimates in CFA for initial model

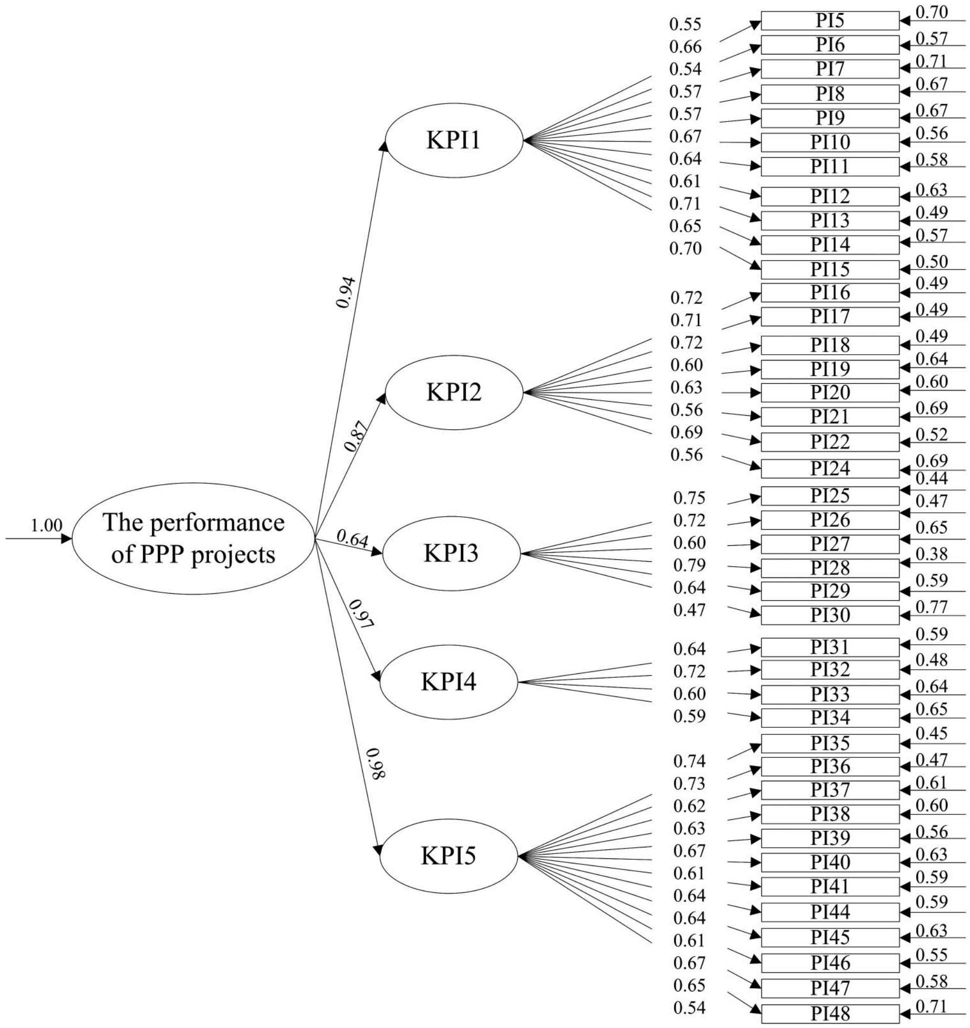

Fig. 4. Loading estimates in CFA for improved model

of the model is determined by comparing it to an actual data set. Additionally, the optimal model (Fig. 4) is systematically compared with the initial model (Fig. 3), which provides a direct test of the hypothesized superiority of the optimal model. Using CFA, the adequacy of a model is evaluated using a number of goodness-of-fit indices (GFIs), which reflect the correlation between the hypothesized statistical model and the actual data set (Sanders et al. 2005). Common GFIs include the chi-square ($\chi 2$) statistic, comparative fit index (CFI), and the root mean square error of approximation (RMSEA). Moreover, some estimation of parameters (factor loadings and errors) could be problematic, even if the overall model fit is good. Therefore, significance level tests on parameters, including the standard error (SE) and *t*-test, are necessary. In this case, these tests allow the model to be improved and reestimated if some parameters are not significant. Consequently, the improved model can be compared to the initial model using GFI and significance level tests if some indicators are eliminated. A summary of the recommended benchmarks for GFI and significance level tests in adopted in this study is presented in Table 4. The main steps performing CFA are shown in Fig. 1.

Table 4. Recommended Values for GFI and Significance Level Tests

GFI	Recommended values
$\chi 2$	The lower, the better; $1 <= \chi^2/Df <= 5$
CFI	$>= 0.90$
RMSEA	$<= 0.05$: good model fit $<= 0.1$: acceptable
Significance level tests	
SE	$0.008 \sim 0.36$
t value	> 1.96 (0.05 significance level)

Performing CFA to Analyze Data

This study expanded on previous analyses of survey results, using CFA to test the proposed KPI model. The variables and the errors among the variables are presented in Fig. 3. The arrows and pathway coefficients (factor loadings) in the figure indicate the causal effect statistically and in terms of the contributions of the performance packages and indicators to project performance in the proposed model. The measurement and structural components are also shown in Fig. 3, demonstrating that the model directly reflects the relationships between project performance, packages, and indicators.

The software LISTEL 8.70 was used to evaluate whether the constructs were measured with satisfactory accuracy and to analyze the hypothesized initial KPI model and the relationships among KPIs and packages CFA was performed to test the initial KPI model, producing a parameter estimation and GFI of the intial

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model as shown in Fig. 3 and Table 5. In Table 5, the parameter estimation is described by LAMBDA-X and THETA-DELTA. LAMBDA-X indicates the estimation of the pathway coefficients between performance indicators and performance packages including estimated parameter value, SE, and t-value. THETA-DELTA contains the estimated error of each KPI including estimated error value, SE, and t-value. The estimates of pathway coefficients between performance packages and project performance are presented in Fig. 3. The initial model (Fig. 3, Table 5, initial model) includes all assumed indicators and relationships, and shows a good model fit ($\chi^2 = 2475.85$, $D_f = 1075$, CFI $= 0.91$, RMSEA $= 0.098$). Fig. 3 highlights the factor loadings of the PIs associated with each package. However, not all factor loadings are statistically significant ($t > 1.96$). PI_1, PI_2, PI_3, PI_4, and PI_{42} are not significant based on the results of the significance level tests. Based on Fig. 3 and Table 5, all 5 packages were significant and had a positive correlations with project performance. All indicators except for 5 that were found to be insignificant correlated positively with their corresponding packages (KPI_1–KPI_5). The factor loadings between 5 packages and project PIs within corresponding packages are shown in Fig. 3 and Table 5. Most of the factor loadings are greater than 0.50, which is considered adequate for estimation, except for $KPI_1 \rightarrow PI_1(0.18)$, $PI_2(0.22)$, $PI_3(0.27)$, $PI_4(0.35)$; $KPI_2 \rightarrow PI_{23}(0.47)$; $KPI_3 \rightarrow PI_{30}(0.47)$; $KPI_5 \rightarrow PI_{43}(0.17)$.

In order to achieve the optimal model, 5 insignificant indicators and 2 other indicators (PI_{23}, PI_{43}) with factor loadings lower than 0.50 were deleted from the new models. PI_{30}, with a factor loading of 0.47, was ranked ninth based on the questionnaire survey results, and was retained in the model. The probable reason for the low factor loading of PI30 is its relatively high standard deviation (SD) in the survey. Based on the initial CFA analysis, a new model (Fig. 4) was established and CFA was used again to test the new model.

As shown in Fig. 4 and Table 6, the improved model excludes indicators PI_1, PI_2, PI_3, PI_4, PI_{23}, PI_{42}, and PI_{43} that were included in the initial model, resulting in a better fit ($\chi^2 = 2,290.58$, $D_f = 774$, CFI $= 0.92$, RMSEA $= 0.058$) than the initial model. All factor loadings and package. loadings were statistically significant ($t > 1.96$). The factor loadings, shown in Fig. 4 and Table 6, are almost all greater than 0.50, which indicates that the relationships in the model are significant.

Based on the CFA results for the initial model, the proposed initial KPI model correlated relatively well with observed data (RMSEA $= 0.098 > 0.08$). The five packages, indicators, and their assumed relationships were confirmed by the correlation with empirical data. The performance of PPP projects can be described in terms of 5 perspectives, which include physical characteristics of the projects, financing and marketing, innovation and learning, stakeholders, and the overall development process. The relatively high RMSEA value results primarily from the insignificance of some parameters and their low factor loadings in the pathway analysis. Consequently, 7 indicators were deleted to produce an optimal model. Testing of the optimized model indicated a very good fit between the improved model and observed data (RMSEA $= 0.058 < 0.08$). The optimized model can be used to describe the relationships between project performance, the 5 packages, and the indicators, and provides an accurate model of KPIs in PPPs.

Discussion

Measurement Component of CFA Framework

The latent variable describing the physical characteristics perspective is measured by PI_5–PI_{15}. Although all indicators in this

Table 5. Parameter Estimates, t-Value Tests, and GFI in CFA for Initial Model

LISREL Estimates (maximum likelihood)	LAMBDA-X			THETA-DELTA		
PIs	Loading estimates	Standard error	t	Error estimates	Standard error	t
PI_1	0.18	0.13	0.66	0.97	0.11	8.40
PI_2	0.22	0.13	1.66	0.95	0.11	8.39
PI_3	0.27	0.15	1.78	0.93	0.11	8.37
PI_4	0.35	0.18	1.92	0.88	0.11	8.32
PI_5	0.55	0.27	2.06	0.69	0.09	8.10
PI_6	0.65	0.31	2.09	0.69	0.07	7.90
PI_7	0.55	0.27	2.06	0.58	0.09	8.11
PI_8	0.59	0.28	2.08	0.70	0.08	8.04
PI_9	0.55	0.27	2.06	0.65	0.09	8.11
PI_{10}	0.66	0.31	2.09	0.70	0.07	7.86
PI_{11}	0.64	0.31	2.09	0.57	0.07	7.92
PI_{12}	0.60	0.29	2.08	0.59	0.08	8.01
PI_{13}	0.70	0.33	2.11	0.64	0.07	7.71
PI_{14}	0.66	0.31	2.10	0.51	0.07	7.86
PI_{15}	0.69	0.33	2.10	0.57	0.07	7.76
PI_{16}	0.70	0.09	7.79	0.51	0.07	7.47
PI_{17}	0.71	0.09	7.79	0.50	0.07	7.45
PI_{18}	0.71	0.09	7.85	0.49	0.07	7.42
PI_{19}	0.60	0.09	6.65	0.64	0.07	7.88
PI_{20}	0.63	0.09	7.02	0.60	0.08	7.77
PI_{21}	0.58	0.09	6.42	0.67	0.08	7.94
PI_{22}	0.70	0.09	7.73	0.51	0.08	7.48
PI_{23}	0.47	0.09	5.21	0.78	0.07	8.16
PI_{24}	0.57	0.09	6.30	0.68	0.10	7.97
PI_{25}	0.75	0.09	6.70	0.44	0.09	6.63
PI_{26}	0.72	0.09	8.18	0.48	0.07	6.91
PI_{27}	0.59	0.09	6.70	0.65	0.07	7.68
PI_{28}	0.79	0.09	8.90	0.58	0.08	6.12
PI_{29}	0.64	0.09	7.22	0.59	0.06	7.47
PI_{30}	0.47	0.09	5.30	0.78	0.08	8.03
PI_{31}	0.64	0.10	7.20	0.59	0.10	7.59
PI_{32}	0.72	0.10	7.20	0.48	0.09	7.04
PI_{33}	0.61	0.10	6.27	0.63	0.07	7.75
PI_{34}	0.59	0.10	6.16	0.85	0.07	7.80
PI_{35}	0.75	0.08	8.97	0.43	0.08	7.58
PI_{36}	0.73	0.08	7.60	0.46	0.06	7.67
PI_{37}	0.63	0.08	7.69	0.60	0.08	8.00
PI_{38}	0.64	0.08	8.04	0.59	0.10	7.98
PI_{39}	0.67	0.08	7.28	0.56	0.08	7.92
PI_{40}	0.61	0.08	7.63	0.63	0.07	8.05
PI_{41}	0.63	0.08	8.08	0.60	0.08	7.99
PI_{42}	0.67	0.08	1.95	0.55	0.06	7.91
PI_{43}	0.17	0.08	7.68	0.97	0.06	8.41
PI_{44}	0.64	0.08	7.34	0.59	0.12	7.98
PI_{45}	0.61	0.08	8.17	0.62	0.07	8.04
PI_{46}	0.67	0.08	7.34	0.54	0.08	7.89
PI_{47}	0.64	0.08	7.77	0.58	0.07	7.97
PI_{48}	0.54	0.08	6.37	0.71	0.09	8.17

Note: $\chi^2 = 2,475.85$; $D_f = 1,075$; CFI $= 0.91$; RMSEA $= 0.098$.

Table 6. Parameter Estimates, *t*-Value Tests, and GFI in CFA for Improved Model

LISREL Estimation (maximum likelihood)	LAMBDA-X			THETA-DELTA		
PIs	Loading estimation	Standard error	*t*	Error estimation	Standard error	*t*
PI_5	0.55	0.06	10.17	0.70	0.05	15.18
PI_6	0.66	0.06	11.14	0.57	0.04	14.71
PI_7	0.54	0.06	9.76	0.71	0.05	15.21
PI_8	0.57	0.06	10.19	0.67	0.04	15.09
PI_9	0.57	0.06	10.16	0.67	0.04	15.10
PI_{10}	0.67	0.06	11.25	0.56	0.04	14.64
PI_{11}	0.64	0.06	11.02	0.58	0.04	14.77
PI_{12}	0.61	0.06	10.65	0.63	0.04	14.94
PI_{13}	0.71	0.06	11.71	0.49	0.03	14.31
PI_{14}	0.65	0.06	11.10	0.57	0.04	14.73
PI_{15}	0.70	0.06	11.63	0.50	0.04	14.37
PI_{16}	0.72	0.05	10.22	0.49	0.04	13.78
PI_{17}	0.71	0.05	14.98	0.49	0.04	13.84
PI_{18}	0.72	0.05	15.05	0.49	0.04	13.80
PI_{19}	0.60	0.05	12.62	0.64	0.04	14.74
PI_{20}	0.63	0.05	13.29	0.60	0.04	14.54
PI_{21}	0.56	0.05	11.82	0.69	0.05	14.93
PI_{22}	0.69	0.05	14.55	0.52	0.04	14.06
PI_{24}	0.56	0.05	11.72	0.69	0.05	14.95
PI_{25}	0.75	0.05	16.70	0.44	0.04	12.43
PI_{26}	0.72	0.05	15.32	0.47	0.04	12.90
PI_{27}	0.60	0.05	12.54	0.65	0.04	14.38
PI_{28}	0.79	0.05	16.60	0.38	0.03	11.47
PI_{29}	0.64	0.05	13.54	0.59	0.04	13.98
PI_{30}	0.47	0.05	9.95	0.77	0.05	15.05
PI_{31}	0.64	0.05	13.41	0.59	0.04	14.30
PI_{32}	0.72	0.05	13.64	0.48	0.04	13.25
PI_{33}	0.60	0.05	11.73	0.64	0.04	14.63
PI_{34}	0.59	0.05	11.59	0.65	0.04	14.69
PI_{35}	0.74	0.05	10.77	0.45	0.03	14.23
PI_{36}	0.73	0.04	16.35	0.47	0.03	14.31
PI_{37}	0.62	0.05	13.77	0.61	0.04	14.98
PI_{38}	0.63	0.05	13.99	0.60	0.04	14.94
PI_{39}	0.67	0.05	14.86	0.56	0.04	14.75
PI_{40}	0.61	0.05	13.40	0.63	0.04	15.05
PI_{41}	0.64	0.05	14.15	0.59	0.04	14.91
PI_{44}	0.64	0.05	14.10	0.59	0.04	14.92
PI_{45}	0.61	0.05	13.49	0.63	0.04	15.03
PI_{46}	0.67	0.04	14.97	0.55	0.04	14.73
PI_{47}	0.65	0.05	14.43	0.58	0.04	14.85
PI_{48}	0.54	0.05	11.90	0.71	0.05	15.26

Note: $\chi^2 = 2290.58$, $D_f = 874$, CFI = 0.92, RMSEA = 0.058.

package have a similar influence, the most significant impact results from $PI_{13}(0.71)$ and $PI_{15}(0.70)$. These two indicators received the highest scores in the questionnaire survey. They indicate that the most important factors in project planning and decision-making depend on the cooperation between the public and private sectors. The CFA results also indicated that the contributions of external factors [$PI_7(0.54)$, $PI_9(0.57)$, $PI_{10}(0.67)$, $PI_{11}(0.64)$, $PI_{12}(0.61)$] would be greater than those of internal factors [$PI_5(0.55)$, $PI_6(0.66)$, $PI_8(0.57)$, and $PI_{14}(0.65)$] during the planning and decision-making stage.

The latent variable representing the financing and marketing perspective is measured by PI_{16}–PI_{22}, and PI_{24}. The greatest influences resulted from $PI_{16}(0.72)$, $PI_{17}(0.72)$, and $PI_{15}(0.71)$. With sound financial analysis, long-term development of PPP projects can achieved sustainable profits and increased market ability, strengthening overall project performance.

The latent variable describing the innovation and learning perspective is measured by PI_{23}–PI_{30}. The most significant influences on project performance resulted from technology innovation (PI_{28}, 0.79) and investment in new technology (PI_{25}, 0.75). PI_{30} influenced innovation the least (0.47); however, because this indicator also impacts financing and marketing, it remains an important indicator of project performance.

The latent variable characterizing the stakeholder perspective is measured by PI_{31}–PI_{34}. The approval of the General public and social satisfaction are the most important indicators in the stakeholder package (PI_{32}, 0.72), which indicates that the success of PPP projects relies on the support of society and the general public.

The latent variable representing the process perspective is measured by PI_{35}–PI_{41}, and PI_{44}–PI_{48}. The greatest influences resulted from quality (PI_{35}, 0.74), followed by safety (PI_{36}, 0.73). Other important indicators included risk management (PI_{39}, 0.67), cost (PI_{46}, 0.67), and time (PI_{47}, 0.65). These results suggest that traditional PIs (PI_{35}, PI_{36}, PI_{46}, and PI_{47}) continue to play very important roles in PPP project performance, and that risk-related issues should receive greater attention. The CFA results also indicated that the private sector contributions are important to process control during the implementation of PPP projects.

Structural Component of CFA Framework

The structural components of the initial and optimized models are presented in Fig. 3 and Table 5. All of the 5 packages were found to be significant in both the initial and optimized models. Therefore, the proposed classification into 5 packages has been verified. Based on the results from analysis of the optimized model, the most substantial influence on project performance was correlated with KPI_5 (process, 0.98). The packages representing stakeholder satisfaction (KPI_3, 0.97) and physical characteristics (KPI_1, 0.94) also indicated very strong influences on project performance. The least influence on project performance resulted from the package signifying innovation and learning (KPI_3, 0.64). As stated previously, stakeholders prefer improved financial management, process management, or decision-making capabilities rather than an improved level of technology in a large scale infrastructure project.

Potential Use of Identified KPIs

In Figs. 3 and 4, the relationships between project performance, performance packages, and PIs are clearly presented. The most important result of the statistical analyses was the deletion of 7 PIs from the initial model because of low factor loadings and statistical insignificance, which further consolidated the number of PIs. According to the CFA of the 41 KPIs included in the optimized model, the improvement of performance in PPP projects is strongly dependant on reasonable procurement, careful design and planning by the public sector, effective process control by the private sector, and the ultimate satisfaction of both the public and private sectors. Furthermore, adopting appropriate financial and technical methods is crucial to the success of PPPs.

The identified KPIs are useful tools for effective PMM in PPPs. Potential use of these KPIs can be summarized as follows:

- The stages at which each package of KPIs would be most useful: As mentioned in the description of the conceptual model,

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indicators in KPI_1 were considered as the inputs to the projects, which can influence performance from the early stages to the stage of project transfer. Hence, indicators in KPI_1 should be included in PMM throughout the execution of the project. Additionally, indicators KPI_2, KPI_3, and KPI_4 reflect stakeholders' requirements from three different perspectives, and the indicators in KPI_5 reflect the process viewpoint. Therefore, indicators in KPI_2–KPI_5 should be added at the stages of construction and operation, when the indicators in packages KPI_2–KPI_5 can be used to more precisely measure performance characteristics of indicators in KPI_1. KPI_1 can be used to measure overall project performance, as this package reflects an overview of the indicators in KPI_2–KPI_5.

- Measurement of project performance: Several different measurement methods can be applied to evaluate project performance using the identified KPIs. The benchmarking method can be used with KPIs and their criteria. Evaluations based on benchmarking typically compare actual and estimated performance through KPIs. Therefore, the appropriate KPIs must be determined in order to measure performance or calculate the effects of any given change in the conduct of PPP projects, a means to identify the strengths and weaknesses of PPP projects. The criteria of KPIs in various types of PPP projects could be different. When the KPIs are used in practical projects, more detailed criteria should be customized to the application.
- The use frequency of KPIs to measure performance: KPIs can be used throughout the execution of a PPP project; therefore, the use frequency is determined by the results of the performance measurements. If the results indicate acceptable performance, frequent measurement may not be necessary. Public-private partnership projects would suffer some loss of performance quality because of uncertainty during the phases of planning, design, procurement, construction, and early stages of operation, suggesting a rationale for more frequent measurement using KPIs.

Conclusion

This paper presents survey results on PIs for PPP projects, and uses the CFA model to test the relationships between PIs, performance packages, and project performance to identify 41 KPIs.The conceptual model of KPIs presented in the authors' prior work (Yuan et al. 2009, 2010) was further developed by analysis of the hypothesized relationships among indicators measuring PPP project' performance. A questionnaire survey was conducted to investigate stakeholder opinions on 48 PIs that influence performance of a PPP project during its life cycle. Before analyzing the survey results, reliability analysis was conducted to test the internal consistency of the survey variable data, conforming that opinions of different stakeholders on PIs are consistent (Hypothesis 1). The survey results demonstrated that although all of the 48 PIs are important and can be used to monitor project performance the significances of the indicators from the five packages vary. According to the statistical analysis, the stakeholders assign greater value to decision-making in the early stages of development and in cojunction with process control during project implementation. The results of the survey also indicated that successful partnerships among project stakeholders positively influences the performance of PPP projects, and that improvement of project performance in PPPs strongly depends on cooperation and support among various stakeholders. In addition, low mean values for learning and innovation indicators indicated that public and private sectors prefer more mature technology for construction and operation of PPP projects.

The CFA method was also used to test whether the hypothesized model correlates with data collected from the survey. The results of the CFA on the initial model showed a comparatively good model fit, which indicated that all performance packages contribute to the performance quality of PPP projects, and that the classification of KPIs within the performance packages is accurate (Hypothesis 2). Based on these results, an improved model was developed with 7 indicators removed as a result of insignificance and low factor loadings. Results of the CFA on the optimized model supported a strong correlation with and observed data. Thus, the 41 indicators in the optimized model can be viewed as KPIs for PPPs. According to the CFA results for the the optimized model, the most important criteria for improving performance in PPP projects are reasonable procurement, design, and planning by public sector partners, and effective process control by private sector partners. Additionally, the satisfaction of both the public and private sectors and use of appropriate financial and technological methods are also crucial to PMM in PPPs.

The 41 KPIs offer a useful tool for distinguishing strengths and weaknesses for effective performance management and measurement in PPPs. Moreover, these CFA results provide a basis for improved project performance and more effectively meet the requirements of stakeholders to obtain long-term and sustainable development through PPP projects. Although this research on KPIs promotes improved understanding of PMM in PPP projects, there are some limitations of the study. First, the number of KPIs remains large despite efforts to consolidate the list, therefore future studies should focus on further reducing the number of KPIs through mathematic modeling and practical application of the 41 KPIs in actual PPP projects Second, the cause and effect relationships between the different KPI packages should be clarified through future research of though the relationships between PIs, performance packages, and project performance described in this paper. The clarification of these relationships between different KPIs will promote enhanced industry understanding of how to more effectively measure and improve performance of PPP projects, suggesting that further studies Should also explore how these KPIs can be most effectively applied.

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