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From Design to Operations: A Process Management Life Cycle Performance Measurement System for Public-Private Partnerships

Abstract

Public-Private Partnerships (PPPs) have become a critical vehicle for delivering infrastructure worldwide. Yet, the use of such a procurement strategy has received considerable criticism, as they have been prone to experiencing time/cost overruns and during their operation poorly managed. A key issue contributing to the poor performance of PPPs is the paucity of an effective and comprehensive performance measurement system. There has been a tendency for the performance of PPPs to be measured based on their *ex-post* criteria of time, cost and quality. Such criteria do not accommodate the complexities and lifecycle of an asset. In addressing this problem, the methodology of sequential triangulation is used to develop and examine the effectiveness of a 'Process Management Life-Cycle Performance Measurement System'. The research provides public authorities and private-sector entities embarking on PPPs with a robust mechanism to effectively measure, control and manage their projects' life-cycle performances, ensuring the assets are 'future proofed'.

Keywords: PPPs, Infrastructure asset, Performance measurement, Future proofing, Australia

1. Introduction

Public-Private Partnerships (PPPs) have become a critical vehicle for delivering infrastructure worldwide. In Australia, PPPs have been used to deliver both economic (e.g., roads, bridges and tunnels) and social infrastructure (e.g., hospital, stadium and school) (Duffield and Clifton, 2008). The Victorian State Government have used PPPs to procure 15 public schools, and in

Western Australia (WA) to deliver a hospital, stadium and a prison to be functional before 2018 (Victoria Department of Treasury and Finance, 2015; WA Department of Treasury, 2015). In the United Kingdom (UK), there have been a total of 24 infrastructure projects delivered via PPPs since 2012, which include public housings, schools, roads, social care centres and hospitals (HM Treasury, 2013). PPPs have been and continue to form an integral part of many Governments' strategies for infrastructure procurement. Yet, they have been plagued with controversy, particularly in Australia and the UK, as they have been prone to experiencing schedule (i.e., pre-construction) and construction cost overruns and not delivering expected value during their operations and maintenance phases (Love *et al.*, 2017).

A number of factors have contributed to the poor performance of PPPs (Hodge and Greeve, 2004). However, the absence of an evaluation mechanism to manage their performance has contributed to their inability to deliver satisfactory outcomes to stakeholders and the community (Regan *et al.*, 2015). Accordingly, this has led Liu *et al.* (2015a) to suggest that the lack of an effective performance measurement system (PMS) in such projects may act as a trigger to produce sub-optimal service quality for an asset. The Australian PPP industry and markets are acknowledged as being mature (Hodge, 2004). Despite this maturity, most of the procured PPPs have not undergone any form of comprehensive performance evaluation in terms of what has been delivered (Hodge and Greve, 2007; Regan *et al.*, 2011). For instance, ineffective and incomplete measurement has been identified as a determinant of unsatisfactory performance of in several PPPs, such as: (1) *Latrobe Regional Hospital* and *Deer Park Women Prison* (Australia); (2) *Ashfield Prison* and *Knowsley Park School* (UK); and (3) *Golden Ears Bridge* in Canada (House of Commons, 2003; Roth, 2004; Garvin *et al.*, 2011; Harris *et al.*, 2014; Whitfield, 2017).

There is a widespread consensus that performance measurement is fundamental for business success (Bititci *et al.*, 2012). In fact, measuring project performance is a core activity of PPP contract management (European Investment Bank – EIB, 2011a). Performance measurement is a process of quantifying and reporting the effectiveness and efficiency of the action performed towards influencing organisational objectives (Neely *et al.*, 2005; Berg and Marques, 2011). Nonetheless, PPP performance measurement has received limited attention in the normative literature, especially within the context of social infrastructure assets (Liu *et al.*, 2016). Rather than examining the advantages and disadvantages of PPPs, Yong (2010) suggested that there is a need for empirical research about how to structure and ensure a higher performance to achieve the predetermined policy goals and objectives. Against this contextual backdrop, this paper aims to empirically develop a robust PMS that can be used throughout a PPP life cycle so that they can be ‘future proofed’. The paper commences with a review of the performance measurement and PPP literature and then using the findings obtained for adopting sequential triangulation approach develops a ‘Process Management Life Cycle Performance Measurement System’.

2. Performance Measurement

The origins of performance measurement can be traced back to the 13th century; during the period when double entry bookkeeping played a dominant role (Johnson, 1972). In the 1950s, early globalization contributed to development of performance measurement and productivity management with an emphasis being placed on financial-based measures (Keegan *et al.*, 1989). This cost-based measurement, which was within the framework of management accounting, was widely used across the manufacturing, production and engineering industries during the 1970s and 1980s (Johnson, 1981).

A distinct shift in economic thinking emerged from the 1960s to the 1980s led to a shift away from supply to demand led factors such as quality, time, flexibility and customer satisfaction (Slack, 1983). This resulted in performance measurement becoming a multi-dimensional construct laying the building blocks for Kaplan and Norton's (1992) *Balanced Scorecard* and Neely *et al.*'s (2001) *Performance Prism*. Thereafter, a number of studies have been undertaken that have contributed to development of PMS or empirical examination of their impacts on public or private-sector organisations (Greatbanks and Tapp, 2007; Pavlov and Bourne, 2011; Baker and Bourne, 2014; Nudurupati *et al.*, 2015). As a result of such research, the theoretical construct of performance measurement has matured into a robust system that aims to: (1) identify an organisations' success, customer satisfaction, and where problems exist and improvements can be made; (2) understanding an organisations' processes and determine what they do and do not know; (3) ensure the effective decision-making; and (4) indicate whether the expected outcomes have been met (Gunasekaran and Kobu, 2007; Franco-Santos *et al.*, 2012).

3. Future Challenges of Performance Measurement Research

Despite its rise to prominence, performance measurement is being confronted with an array of new challenges, which have substantially impacted the effectiveness and efficiency of the PMS used by organisations (Pavlov and Bowman, 2015). This view is supported by Melnyk *et al.* (2014), who suggested that the increasingly dynamic business environment has resulted in a need for new performance measures and/or metrics. A review of extant performance measurement confirms this view with additional challenges resulting from: (1) prediction of future performance; (2) complicated and dynamic business environment (e.g., culture or networks); (3) open innovation; (4) knowledge work; and (5) sustainability (Bititci *et al.*, 2012; Harkness and Bourne, 2015). Limited empirical research, however, has been undertaken to

identify how to solve the aforementioned issues within a PMS.

PPPs possess a sophisticated development process and a stakeholder network, which are typically bound together by a long-term contractual arrangement and therefore have number of drawbacks, such as: (1) the propensity for contracts to be renegotiated; (2) the difficulty in writing such complex contracts; the more complete they are the higher the transaction costs; (3) incorporating mechanisms for inflation and changes in economic conditions that are beyond the control of the parties; and (4) difficulties in monitoring and rewarding service ensure assets are delivered effectively and efficiently to meet key stakeholders' expectations and predetermined strategic goals; this result in a dynamic business environment (Yong, 2010).

4. PPPs and Performance Measurement

A variety of definitions of PPPs can be found in the normative literature. The EIB (2004) defines PPPs as “the relationships formed between private sector and public bodies often with the aim of introducing private sector resources and/or expertise in order to provide and deliver public sector assets and services” (p.2). Similarly, The Public Private Infrastructure Advisory Facility (PPIAF) defines a PPP as involving “the private sector in aspects of the provision of infrastructure assets or of new or existing infrastructure services that have traditionally been provided by government”. In addition, a life-cycle of a PPP can be categorised by three phases, (1): *Initiation and Planning* (e.g., selection and definition, PPP option assessment, organization and pre-tendering work); (2) *Procurement* (e.g., bidding, contract and financial close); and (3) *Partnership* (e.g., design and construction, operation, facility maintenance and handover) (EIB, 2011a).

PPPs can take a variety of forms such as Design-Build-Operate-Maintain (DBOM), Design-

Build-Finance-Maintain (DBFM), Design-Build-Finance-Operate-Maintain (DBFOM) (NSW Treasury, 2011). They can also be categorised based on their payment mechanism; availability- and demand-based models. The availability-based PPP is a regime whereby the government retains demand risk with the main form of revenue for a *Special Purpose Vehicle* (SPV) being a regular service payment derived from an asset based on a standard of performance that is being delivered. Contrastingly, for demand-based PPPs, demand risk is transferred to private entities, which operate built assets for the purpose of generating profits. Here revenues of the assets are yielded by charging third parties (i.e., end-users) rather than receiving service payments from the public sector. The procurement of social infrastructure such as hospitals, especially in Australia, have been typically delivered using an availability-based regime under the auspices of DBOM/DBFM/DBFOM contracts.

Six common themes emerge from an analysis of the PPP literature (Kwak *et al.*, 2009; Liu *et al.*, 2015a): (1) roles/responsibilities of government; (2) concessionaire selection; (3) risk identification and allocation; (4) cost/time efficiency; (5) project finance; and (6) critical success factors (CSFs). There has, however, been a paucity of research that has attempted to identify how to comprehensively measure the performance of PPPs even though it is pivotal for ensuring Value for Money (VfM) for public clients throughout their life-cycle (Liu *et al.*, 2014). Research on the use of PMS in PPPs has been limited as not many have not yet completed their operational phase and thus key performance indicators (KPI) have not been developed. A major possible reason for lack of research on PMSs of PPPs, especially social infrastructure projects, is that most social PPPs have just been in operations. Thus, PPP performance measurement focused on the operation/maintenance phase is just starting to become an issue in practice.

PMS have not been forthcoming as there has been a tendency to only focus on time, cost and

quality (TCQ) in construction (Raiseback *et al.*, 2010; Love *et al.*, 2015). Nevertheless, with increasing demand for assets to add value during operations and maintenance and meet the needs to respond to ‘climate change’, their development has become a necessity. Table 1 presents a summary of key studies that have examined PPP performance measurement.

<Insert Table 1. Key research on PPP performance measurement>

Such studies have attempted to evaluate whether PPPs are capable of benefiting the input (cost) or output (time) of infrastructure projects. However, limited attention are being paid to PPP performance measurement from a “process” perspective, which is concerning with the project’s life-cycle deliverables (e.g., initiation and planning, construction, operation and maintenance) (Yuan *et al.*, 2009; Liu *et al.*, 2015a). Nevertheless, a delivery process synergized with public and private sectors enables PPPs to be unique and have an extremely dynamic business environment (Akintoye *et al.*, 2003; Yong, 2010). According to Love *et al.* (2015), a measurement approach that neglects to consider a “process perspective” will be unable to comprehensively capture the inherent complexities of PPPs.

5. Research Approach

Performance measurement can marry the ontology and epistemology of interpretivism, as practitioners’ experience and insights can be considered when developing a new PMS (Neely *et al.*, 1997). To develop and test a PMS for PPPs, sequential triangulation (inductive-deductive) was adopted (Love *et al.*, 2002), which involved initially undertaking a qualitative study using exploratory interviews followed by questionnaire quantitatively analysed applying *Confirmatory Factor Analysis* (CFA).

Qualitative Study: Exploratory Interviews

Research relying on interpretivism can either be quantitative or qualitative (Love *et al.*, 2002). Thus, exploratory interviews with key stakeholders of PPPs were initially conducted to understand current practice in performance measurement of PPPs. Interviewees' expert judgements were solicited to develop a 'Process Management Life Cycle PMS'. Meeting this objective through the use of interviews requires a sample size of 15 to 35 participants purposefully selected, who have specialized knowledge in the topic (Kumar, 1989).

A total of 25 in-depth interviews with senior practitioners who had been involved with the delivery of PPPs were undertaken over an eight month period (Table 2). The interviews lasted from 60 to 90 minutes and were digitally recorded. Manuscripts were transcribed verbatim and then presented to each interviewee to verify their accuracy, correct errors or inaccuracies and provide clarification to comments that were made.

<Insert Table 2. Information of samples of interviews>

The interview questions focused on: (1) current PPP performance measurement; (2) the shortcomings of performance measurement of PPPs; and (3) direction for amelioration. At the beginning of each interview, an interviewee was asked to select a completed or on-going social PPP project with which they had been or were currently involved. The textual narratives compiled were analysed by using *NVivo 10* software package, which combines efficient management of non-numerical and unstructured data with powerful processes of indexing and theorising. The development and reassessment of themes as the analysis progressed accords with calls to avoid confining data to predetermined sets of categories (Silverman, 2006). Kvale (1996) suggests that *ad hoc* methods for generating meaning enable the researchers to access

“a variety of common-sense approaches to interview text using an interplay of techniques such as noting patterns, seeing plausibility, making comparisons etc. (p.204).”

Quantitative Study: Questionnaire Survey and CFA

A questionnaire survey was adapted to examine the feasibility of the conceptual PMS derived from the interviews. The conceptual framework is integrated with measurement perspectives as well as their relevant key performance indicators (KPIs). Using the questionnaire survey the following hypotheses were tested:

- $F^1 - H_0$: The measurement perspectives are *not significant* for measuring social PPPs.
 $F^1 - H_1$: The measurement perspectives are significant for measuring social PPPs.
- $F^2 - H_0$: The KPIs are *not significant* for measuring social PPPs.
 $F^2 - H_1$: The KPIs are significant for measuring social PPPs.

The questionnaire comprised of the following sections: (1) Background Information (i.e., respondents' experience, roles during PPP delivery and projects involved); (2) Performance Measurement Perspectives; and (3) KPIs used within each phase of a PPP project. As there had been a limited number of social infrastructure PPPs procured in Australia, purposive sampling was adopted to distribute the questionnaires (Foreman, 1991; Jin, 2010). Moreover, respondents from the public and private sectors were required to be knowledgeable of all aspects of a PPP lifecycle. As web-based survey tools are efficient for data collation and management (Nulty, 2008), the questionnaires were distributed to the selected respondents via *SurveyMonkey*.

Using a 5-point Likert scale respondents were asked to draw upon their experience and knowledge to identify the significance of the performance measures and KPIs that had been

derived. The data was analysed by using CFA, which is within the scheme of *Structural Equation Modelling* (SEM). It is a multivariate process formulated to examine how well the variables being measured represent their construct(s). The process to conduct the analysis was adapted from Yuan *et al.* (2012), which is presented in Figure 1. Notably, insignificant items observed were eliminated from the conceptual PMS according to the ‘factor loadings’ (i.e., coefficients) of the CFA structural models.

<Figure 1. Data analysis process (adapted from Yuan *et al.* (2012))>

CFA is a theory-driven technique, relying on a pre-constructed knowledge. It aims to confirm theoretical relationships rather than to explore the linkages between the observed items (Schreiber *et al.*, 2006). In particular, CFA is suitable for examining the feasibility of a conceptual model developed from a qualitative study or an in-depth literature review (Yuan *et al.*, 2012). The configuration of CFA is formed according to the theoretical interrelationships between observed and unobserved variables. Mathematically, CFA can be represented as:

$$y_i = \nu + \Lambda\eta_i + \varepsilon_i \quad (\text{Eq.1})$$

where ν is a vector of intercepts; Λ stands for a matrix of factor loadings; η_i represents factor values; and ε_i denotes the vector of residual values. CFA has been widely used in a variety of types of research and considered to be a robust tool for the hypothesis testing undertaken for factor analytical problems (Yuan *et al.*, 2012).

6. Understanding Current Practice in Performance Measurement of PPPs

Information derived from the interviews indicated that performance measurement of a PPP

project is comprised of two parts: (1) an evaluation for design and construction; and (2) a measurement for asset operation. Put simply, as noted by the interviewees, design and construction in PPPs are primarily evaluated by using TCQ, which are referred to as the ‘Iron Triangle’ in project management. Contrastingly, measurements for operations of a built asset is dependent on a series of KPIs, which are determined and agreed between stakeholders. A summary of the key findings derived from the interviews is presented in Figure 2.

<Insert Figure 2. Current practice in performance measurement in PPPs>

7. Deficiencies of Current PMS within PPPs

Existing performance measurement that are applied to social infrastructure PPPs were deemed to be myopic as they focus on TCQ. As a result, there is a tendency for long-term needs of stakeholders to be overshadowed, particularly in the case of schools or hospitals (KPMG, 2008). This was acknowledged by a design manager who stated:

“Delivering a PPP on time and on budget is very important, but there may be a need for measures to capture some intangible factors, for example, innovation in design. This is actually what the private sector should bring to a public project, but the approach we are using cannot reflect it.”

Reflecting on the use of TCQ as a measure, a senior financial advisor proffered that the VfM assessment considered by the *Public Sector Comparator* (PSC) offers a mechanism for *ex-ante* evaluation which intends to provide the business case for PPPs and then enable potential non-financial benefits to be considered. However, it was made explicit that no mechanism was in place to measure whether nor not value and non-financial benefits were being attained. This

issue has been repeatedly identified as a failing of PPPs, with an *ex-post* evaluation simply being a review of the final product rather than an assessment of the project's entire performance (EIB, 2011b; Haponava and Al-Jibouri, 2012). A financial advisor interviewed stated that the lack of performance measures of non-financial benefits in *ex-ante* evaluation adversely impacts decision making and hinders the realisation of VfM.

There were insufficient measures for systematically evaluating the 'intangible' issues that are critical to successful design/construction of the projects, for example, innovation, asset sustainability and key stakeholder expectation. The public sector not only relies on private-sector entities to financially invest in infrastructure, but also draws on its expertise to engender innovation and develop a sustainable asset that is able to meet and possibly exceed stakeholders' needs.

Attention is drawn to Grimsey and Lewis's (2004) definition of VfM, which defines that "the optimum combination of whole-of-life-cycle costs, risks, completion time and quality in order to meet public requirements" (p.1); here emphasis is placed not only on time and quality, but ensuring minimal maintenance and sustainability during operations as well as public expectations. According to Grimsey and Lewis (2005) and EIB (2011b), too much emphasis is placed on the financial benefits that can be acquired from PPP projects; more importance needs to be placed on non-financial measures that examine social benefits to the community. Previous research supports this view, as PPPs have tended to act as drivers of non-financial benefits (i.e., in terms of asset design, choice of construction methods, material selection multi-functionality and contextual fit), therefore can significantly contribute to lowering the cost and risks or improving the physical outcomes (Himmel and Siemiatycki, 2017; Van den Hurk and Hueskes, 2017).

An effective and efficient PMS can provide a PPP with the drive and direction towards the achievement of its strategic goals and the basis for decision-making. Within a PPP, key areas of focus (i.e., critical success factors) are defined and used to identify the needs of key stakeholders. In fact, KPIs are a mechanism for ensuring the needs of stakeholders have been satisfied. The interviewees (n=23) stated that KPIs are only specific to the operation in PPPs, though it was acknowledged that they should be distributed to other key areas such as initiation, design, construction and facility maintenance (FM). This is because KPIs can indicate the key areas needed to be improved, though they were deemed to be 'static' and unable to respond to changing conditions of the operation of the built asset.

An effective PMS must reflect the context where the relevant organisation operates; yet it would appear that this issue has not been adequately considered. Within the State of WA, a significant number of PPPs are now in operation. The KPIs being used were devised prior to the construction stage of the project. Therefore, the sustainability of such operational KPIs was deemed questionable by some interviewees. The interviewees defined the sustainability of KPIs in PPPs by their ability to be relevant and accommodate changes to an asset over its life. For example, PPP procurement director stated that "some private prisons in Australia are still currently under the KPIs that were designed in the 1990s though the capacities of the assets have been modified."

This experienced professional considered the operational KPIs of PPPs to be unsustainable to accommodate the change within the local business environment. A number of issues other than KPI sustainability emerged during the interviews with the two procurement advisors. For instance, limited attention was being given by public sector to measure project's performance during its inception stages (e.g., business case, planning and procurement). This can contribute

to substantial delays and budget overruns being experienced. For example, the Victorian Comprehensive Cancer Centre in Melbourne, Australia, took more than 25 months to reach financial close (Victoria Department of Treasury and Finance, 2012). Further, the process of measuring an asset's impacts on the public (i.e., local communities) had not been considered and most likely would not be, as this would require a modification to the contractual conditions that were in place. Also, the scope of operational KPIs is limited, being unable to indicate whether the long-term success of the project has been achieved. In recognising these, an operation manager suggested:

“The KPIs for operations of PPPs are too narrow. The indicators about long-term impacts of the procured assets/facility on the public (i.e., local communities/regions) are being overlooked, though they are very important. The government will have to carefully consider how to design them.”

The views that were derived from the interviews about the practice in PPP performance measurement above can be summarised as follows: (1) traditional TCQ is unable to capture CSFs and uncertainties that exist in PPPs; (2) the financial-based assessment for VfM cannot completely reflect potential non-financial benefits provided by PPPs; (3) operational KPIs are not applicable to reflect whether or not all key stakeholders' expectation have been met within a long-term period; (4) no formal mechanism is available for refining the launched KPIs; (5) gaps are in systematically measuring the preliminary outputs of PPP projects; and, (6) the social impacts of the assets are substantially ignored.

8. Improving Performance Measurement System of PPPs

While acknowledging performance measurement is an imperative and there is a need for

amelioration, interviewees were pessimistic that such an initiative would be implemented. Inertia of this nature appeared to stem from political unwillingness, structural rigidity hampered by contractual conditions and the absence of technological innovation. In WA, for example, the economic environment has changed as a result of the falling price of iron ore, oil and a reduction in the Goods and Services Tax. A rapid fall in revenue to the State's budget has resulted in a reduction of infrastructure spending and therefore PPPs have become a valuable proposition for new infrastructure investment. A procurement director of the state government suggested "now it's possibly the right time to address performance measurement in PPPs so we can look at future proofing our assets".

Process-based Measurement with Life-Cycle Learning Mechanism and VfM

Most interview respondents (n=18) proffered that the PMS devised for PPPs need to address a life-cycle perspective so as to be able to accommodate inherent uncertainties (e.g., those relating to documentation, financing, taxation and technical details) that can materialise from the *pre-construction* phases of a project. In stark contrast, the procurement director of state government and an experienced financial advisor considered that a life-cycle approach for measuring PPPs was cumbersome to implement due to the complexity associated with the stakeholder network and a project's longevity. However, innovative ideas to overcome such hurdles were promulgated. A leading procurement consultant suggested that a process-based evaluation is ideal for addressing a life-cycle perspective to measuring PPPs.

A process-oriented approach is akin to the use of 'stage gates' and focuses on measuring the deliverable (i.e., tangible and intangible deliverables or outputs) of each project phase using a sequence of KPIs. This approach was reiterated by an architect, suggesting that "PPPs should be measured against the whole development processes of the projects rather than the finally-

procured assets.” The whole process of a PPP is complex and uncertain due to their long-term contractual arrangements (up to 25 years). In addressing this issue, a procurement advisor interviewed suggested that a robust learning mechanism is required to support a comprehensive performance measurement in PPPs. He stated:

“It is necessary for constantly refining the performance measures through an implementation of a learning mechanism, because the asset, macro environments and technology are subject to changing conditions over the project’s life-cycle. This mechanism must be useful and robust for helping the client and SPVs to effectively and efficiently absorb the lessons learned from external and internal environments to identify what actions should be taken for improving outputs and renewing/updating existing KPIs to enhance the effectiveness of the project’s PMS. And, a balanced abatement regime considering both public and private sectors’ benefits might be requested as well for supporting a life-cycle evaluation of PPPs.”

Interviewees who advocated a life-cycle performance measurement indicated that a realistic VfM assessment, which can be integrated with tangible and intangible issues was required to underpin this approach. Thus, it may be essential to place a strategic emphasis on the creation of VfM with its evaluation for both quantitative and qualitative outputs. Thus, a consideration of the contribution of a PPP to the local community will be required. For example, in the case of a school, its ability to enhance educational quality, and for a hospital to improve local/regional healthcare level. As stated by many interviewees (n=14), VfM is referred to as whether or not the built asset can be continuously valued throughout its lifecycle.

Stakeholder-Oriented Performance Measures

A process-based performance measurement during a project's lifecycle needs to reflect the deliverables produced from each project phase. Bearing these considerations, then "what type of performance measures should be devised in a life-cycle PMS for PPPs?" It has been acknowledged that a complex stakeholder network acts as one of the defining features of PPPs. The majority of the interviewees (n=19) stated that a stakeholder orientation was a rational strategy for designing performance measures. The stakeholder-oriented measures should not only examine satisfaction, but also expectations and commitments. The public, who are customarily asset end-users or consumers, is a pivotal component of the stakeholder network. Therefore, their needs must be married with the measures of a PMS. Furthermore, a contract management adviser reinforced the requirements to enable employees to be satisfied throughout the asset's operational phase, especially the impact that changing technology and functional use can have morale and productivity.

A number of interviewees (n=13) also considered that measuring the performance of PPPs is challenging as both public- and private-sector organisations needed to be considered. Therefore, the fundamental capabilities of the involved organisations should be addressed as the measures in the project's performance measurement (e.g., the private-sector entity's financial infrastructure, skilled workforce, structure of service team and internal learning mechanism). They stated that these issues are useful for key stakeholders in a PPP to identify what problems are pertaining in the project and what actions will have to be taken for future.

<Insert Figure 3. Recommendations for improving current PPP performance measurement>

In summary, a sequence of recommendations are proposed from the interviewees for

ameliorating PPP performance measurement. These include an implementation of a process-based measurement, which is supported by the stakeholder-oriented measures as well as a life-cycle learning mechanism and VfM assessment. Figure 3 illustrates how these perspectives are able to contribute to addressing the problems that are innate within the current practice of PPP performance measurement.

9. Process Management Life-Cycle Framework and Relevant KPIs

From the interview findings, a process-oriented framework that is integrated with stakeholder-oriented measures for evaluating performance of PPP project was developed (Figure 4). The framework is comprised of a total of five measurement perspectives: (1) stakeholder expectation measures; (2) stakeholder commitment measures; (3) project delivery process; (4) project strategic goal (i.e., life-cycle VfM); and (5) foundations of the involved organisations (i.e., capabilities of public authority and private SPV). Learning and process-based measurement mechanisms underpin this framework. The developed framework, denoted in Figure 3, is contextualised according to a PPP's lifecycle and presented in Figure 5.

<Insert Figure 4. Process Management Life-Cycle Framework (adapted from Neely *et al.* (2001))>

<Insert Figure 5. Process Management Life-Cycle PMS for PPPs>

A sequence of KPIs can be derived according to the measurement perspectives of the proposed PMS (e.g., key stakeholder expectation, project strategic goal, delivery process and key stakeholder expectation) (Appendix 1). Life-cycle VfM in terms of 'future proofing' of the built asset has been identified as a strategy of PPPs from the exploratory interviews. VfM is

conventionally defined as ‘the optimum combination between the project’s whole life cost and quality’ (Office of Government Commerce, 2002). Nevertheless, it was implied from the interviews that a life-cycle approach to enabling V/M refers to not only the cost and quality of a project, but also an asset’s long-term ability to continue to be value into the future (i.e., future proofing). Thus, KPIs relevant to the ‘facet’ of ‘Strategic Goal’ in Appendix 1 (KPI_{F2-1} to KPI_{F2-3}) are underpinned by this concept.

Furthermore, the key stakeholders of a PPP throughout the project’s life-cycle include public client, concessionaire, subcontractor(s), creditors (i.e. banks), shareholders, suppliers and end-users of the built asset (EIB, 2011a). As a consequence, KPIs relevant to the stakeholder’s expectation and commitment encompass public client’s expectation on innovative design and construction and sub-contractors’/suppliers’ performance (e.g., KPI_{F1-1} to KPI_{F1-12} and KPI_{F5-1} to KPI_{F5-12}). Notably, skilled employees, for example, procurement/legal/financial advisors, engineers and facility management (FM) professionals were identified as key stakeholders of a PPP; thus, KPIs with their expectations/commitments (i.e., KPI_{F1-2}, KPI_{F1-4}, KPI_{F1-6}, KPI_{F5-3}, KPI_{F5-5} and KPI_{F5-10}) were proposed. Bourne *et al.* (2003) supports this point of view and has argued that employees are key stakeholders within the organisation as their performance is correlated to the organisational performance.

Additionally, a sequence of process KPIs was derived. The indicators devised to measure the effectiveness of delivery process of PPPs need to capture the works to be completed in each phase of the projects (Liu *et al.*, 2015a). Essentially, a number of interconnected tasks can be identified throughout PPP development process, for example, evaluation for macroeconomic conditions, risk analysis/allocation, selection of concessionaire, finance close, asset’s design, construction and operations/maintenance. Hence, KPIs under the process perspective of the

developed PMS relate to the works listed above.

Interface management (IM) is derived as the KPIs that have been emphasised across all phases of the life-cycle of a PPP project (KPI_{F3-9}, KPI_{F3-13} and KPI_{F3-24}). IM is the management of communication, coordination, and responsibility across a common boundary between two organizations, phases or physical entities which are interdependent. PPPs are the projects that incorporate complex phases and are synergised by public authority and multiple private entities. The importance of IM in PPPs has been acknowledged by academia and practitioners (Chan *et al.*, 2005). Moreover, the organisational foundations of the public authority and private-sector entity involved with PPPs have been considered by interviewees above to be a focus of performance measurement of the projects. Therefore, a total of 15 relevant KPIs were identified (KPI_{F4-1} to KPI_{F4-15}), such as skilled workforce, technological innovation, training and learning mechanism/system and knowledge management ability.

10. Testing the Process Management Life-Cycle PMS

To test the feasibility of the developed the Process Management Life Cycle PMS, a CFA with the questionnaire-survey data was performed. A pilot survey was undertaken with 28 senior professionals within the Australian PPP industry in order to pre-examine the effectiveness of the research instrument. The responsive rate of the pre-survey achieved 89% (25 out of 28), which comprised of: (a) public sector: procurement consultants (6) and financial advisors (5); (b) private sector: architects (3), project managers (5), operation managers (3) and FM managers (3).

After the pilot survey, 368 questionnaires were distributed to practitioners from the public and private sectors across Australia. A total of 141 responses had been received, 6 of which had to

be discarded because of incompleteness. As a result, 135 valid datasets were used for quantitative analysis and the sample information is indicated by Table 3. While 63 respondents (47%) were associated with the public authorities, the remaining 72 (53%) served for the private-sector entities within PPP projects. Ideally, CFA, which is under SEM, relies on a larger sample size; however, numerous studies have run CFA under a sample smaller than 200 (Chinda and Mohamed, 2008; Aibinu *et al.*, 2011; Rajeh, 2014). As identified by Bagozzi and Yi (2012) and Molwus (2013), a sample size ranging from 100 to 200 is acceptable for SEM.

<Insert Table 3. Questionnaire survey samples>

The reliability of the research instrument was then tested by using *Cronbach's α* . A α value that is greater than 0.70 indicates a reliable measurement of a construct (Scott, 1981). The corrected item-total statistics were used with the α value throughout the reliability tests to identify what items would have to be discarded in subsequent modelling. The items being observed in a research instrument must be discarded if the values of their corrected item-total statistics cannot exceed 0.30 (Nunnally and Bernstein, 1994).

According to α values derived from the entered dataset, a total of 4 items (e.g., KPI_{F1-1}, KPI_{F3-2}, KPI_{F3-14} and KPI_{F5-4}) had to be excluded from the Process Management Life-Cycle PMS, because their corrected item-total statistics were below the threshold value of 0.30. Again, the reliability test had been performed after eliminating aforementioned items. The results show that modified instrument has a higher α value of 0.97 and the increased item-total statistics ranging from 0.36 to 0.81. The empirical evidences indicate a high degree of internal consistency, suggesting that the questionnaire was reliable (Tabachnick and Fidell, 1996).

A CFA was run after *Cronbach's* α value tests. As mentioned above, CFA possesses the theory-oriented nature regarding observed and unobserved variables. Thus, based on the developed Process Management Life-Cycle PMS (Figures 4 and 5), the measurement perspectives and their relevant KPIs addressed as the observed variables, while the deliverables/outputs of each project phase of PPPs are viewed as the unobserved variables.

A hypothesised model of CFA (Figure 6) was initially formulated to estimate a covariance matrix of the survey population, which is used for comparing with an observed covariance matrix. In other words, this model was constructed for a purpose of examining whether or not the observe items (for example, measurement perspectives and KPIs) were significant to be implemented for measuring PPPs. Noteworthy, the items with comparatively low factor loadings (i.e., coefficients) that were under 0.40 were eliminated to modify the initial model and develop an optimal one.

The CFA-hypothesised model is capable of capturing the Process Management Life- Cycle PMS, in which the process-based KPIs are under five measurement perspectives assumed to be causally significant to PPP performance. The path arrows and the coefficients in Figure 5 are deemed to be the causal effects in terms of the contributions of the observed items to the outputs/deliverables of each phase and entire project life-cycle performance. Based on Figure 6, the factor loadings of all performance measurement perspectives (e.g., P1: Key Stakeholder Expectation; P2: Project Strategic Goal; P3: Project Delivery Process; P4: Organisational Foundations; and P5: Key Stakeholder Commitment) that are emphasised by the developed PMS (Figures 4 and 5) are 0.78, 0.82, 0.77, 0.75 and 0.76. These coefficients are under 5% significance level, indicating that the perspectives proposed are significant to evaluate the performance of PPP projects.

<Insert Figure 6. Initially-hypothesised model of CFA>

A series of important implications are able to be derived from the empirical evidence relating to KPIs. For instance, in the pre-construction phases (Phase 1: Initiation and Planning; Phase 2: Procurement), the coefficients of most KPIs are larger than 0.50 and are significant at 5% significance level. This implies that the majority of the observed KPIs are valuable for measuring PPPs. However, such four KPIs as P305 (KPI_{F3-5}), P307 (KPI_{F3-7}), P312 (KPI_{F3-12}) and P408 (KPI_{F4-8}), were identified to be statistically insignificant, due to their comparatively low factor loadings, that is., 0.40, 0.16, 0.34 and 0.42, respectively.

The procurements of PPPs across Australia are underpinned by the auspices of well-designed national guidelines and process to enabling VjM is obtained (Infrastructure Australia, 2008). Therefore, the Australian state governments and an array of private entities have acquired considerable experience in delivering PPP projects. There exists a high degree of familiarity with resolving the issues with financing options, design of an appropriate concession period, governance of tendering and financial close. This may explain why the KPIs of PPP's for the finance option (KPI_{F3-5}), concession period (KPI_{F3-7}), financial close efficiency (KPI_{F3-12}) and the government's ability in governing procurement phase (KPI_{F4-8}) were considered to be insignificant by the respondents.

The empirical evidence generated by CFA also indicate that the coefficients of most KPIs under the *Partnership* phase (i.e., Phase 3) of PPPs exceed 0.50, except P109 (KPI_{F1-9}), P321 (KPI_{F3-21}) and P512 (KPI_{F5-12}), which have factor loading values of 0.25, 0.41 and 0.33, respectively. When the research was conducted, it was suggested that the effects of building product suppliers can be ignored when measuring a PPP's performance. A possible reason for this situation was

due to the stability of the Australian construction materials market. Due to a decline in demand from China for minerals such as iron ore, material prices have fallen. The private consortia of PPPs have rarely faced challenges of unavailability/shortage of essential raw building materials during the delivery of their projects. This view is supported by the data issue by the *Australian Bureau of Statistics* (ABS) (2016), which indicates that the building material market in Australia is stable.

In Figure 6, profitability is identified as an insignificant KPI. As addressed above, the delivery of social infrastructure PPPs, particularly such projects as hospitals, prisons and schools, is normally under the availability-based model. In this instance, private entities rely on service payment received regularly from the government (i.e., monthly or quarterly) for maintaining the availability of the facilities rather than the profits yielded by the operations of the assets. The public and private sectors in social PPPs are concerned with effective and efficient delivery of the projects with quality outputs/outcomes, rather than an enhancement of revenues generated by the assets (Yong, 2010). Hence, project profitability as a KPI is not as important in Australian PPPs as in the projects in some other countries where the demand-based PPP regime plays a major role.

<Insert Figure 7. Optimally-revised model of CFA>

An optimally-revised model was constructed after removing a set of insignificant KPIs (e.g., KPI_{F1-9} , KPI_{F3-5} , KPI_{F3-7} , KPI_{F3-12} , KPI_{F3-21} , KPI_{F4-8} , and KPI_{F5-11}) (Figure 7). As illustrated it, the factor-loading values of all observed items (i.e., five performance measurement perspectives and 60 KPIs) in the CFA optimal model are larger than 0.50 and are significantly correlated to the project performance of PPPs at 5% significance level.

Theoretically, an examination of the fit of CFA model depends on three Goodness-of-Fit Indexes (GFIs), including *Chi-squared* (χ^2) statistic, *Comparative Fit Index* (CFI) and *Root Mean Square Error of Approximation* (RMSEA). Goodness-of-Fit Indexes are widely being used to indicate how well the structural model fits observations (Sanders *et al.*, 2006). Table 4 provides the benchmark values of such GFIs. The constructed structural model is deemed to be ‘fitted’ if its GFIs are within the intervals of the benchmark values.

<Insert Table 4. GFIs benchmark values for examining the CFA model>

The GFIs of the CFA optimal model (Figure 7) are 2.32 (*Chi-squared* statistic), 0.92 (CFI) and 0.076 (RMSEA), which indicate a good model fit. Therefore, the proposed measurement perspectives are all significant; 60 out of 71 derived KPIs passed the quantitative tests. These findings rejected the null hypotheses of the questionnaire survey that were proposed from the interviews and confirmed the feasibility of the developed Process Management Life-Cycle PMS (Appendix 2 for the refined KPI dataset).

11. Discussion

A Process Management Life-Cycle PMS of PPPs has been quantitatively tested above through the use of CFA. Due to its characteristics, the developed system is capable of enabling PPPs to realise long-term success by substantially improving the deliverables of each project phase. The learning mechanism and process- and stakeholder-oriented measurement perspectives of the Process Management Life-Cycle PMS not only enhances the suitability and applicability of the KPIs, but also positively affect the project’s planning, design, construction, operation and facility maintenance. These can contribute to improving the sustainability of an asset and increase end-user’s satisfaction, enabling PPPs to provide V_fM over the long-term period.

The empirical results of the strategic goal factor loading values for the KPIs are high throughout a projects' life-cycle (Phases 1 to 3), ranging from 0.75 to 0.77 (Figure 7). Based on this finding, it is reliable to argue that the concept of future proofing needs to be addressed in performance measurement of PPPs. This complies with the view of Love *et al.* (2015), who have suggested that future proofing is critical for the long-term sustainability of infrastructure procurement.

As noted in Figure 5, additional factor loadings of the three phases of PPP projects were 0.96 (Initiation and Planning), 0.95 (Procurement) and 0.91 (Partnership). These values indicate that the outputs of all major PPP phases are significantly correlated to the successful delivery of projects. The coefficients of Phases 1 and 2 are larger than that of Phase 3. The traditional approach to project evaluation has identified the partnership phase of a PPP as the most significant for contributing to a project's success (Yong, 2010; EIB, 2011a). The findings from this research, however, suggest that the quality of the deliverables of pre-construction works (e.g., business case, VfM assessment, bidding and contract negotiation) are just as important. Thus, performance measurement of PPPs should be wider in scope and cover all phases of a project's lifecycle, rather than simply focusing on construction and operations. The empirical evidence derived from CFA confirms that the perspective developed from the interviews may enable improved performance measurement and management through a PPP lifecycle that encapsulates stakeholder-focused measures. Moreover, the proposed approach is underpinned by a learning mechanism that can enable the client and SPV to enact continuous improvement as the project progresses each phase of its life-cycle.

12. Conclusions

It has been widely acknowledged that there is paucity of effective PMS, which has contributed to the poor performance of PPPs. In addressing this issue, a total of 25 exploratory interviews

with experienced professionals were undertaken to understand the current practice of performance measurement of PPPs. It was revealed that existing PPP performance measurement is referred to as the product-oriented evaluation focusing on construction TCQ as well as the operational outputs of the asset. In addition, there was a lack of a formal mechanism for measuring pre-construction activities such as the business case, tendering/bidding and contract negotiation.

From interview findings, a Process Management Life-Cycle PMS was developed and tested by using CFA via a questionnaire survey. The analysis of the survey findings indicates that the developed framework accurately reflected practitioners' aspirations for future performance measurement for PPPs. The Process Management Life-Cycle PMS accommodates the nuances of the dynamic business environment within which infrastructure is procured. It incorporates performance measures to support a process and stakeholder-orientation as well as a life-cycle learning mechanism.

The research presented in this paper not only contributes to body of knowledge of PPPs, but also supports the development of performance measurement for organisations operating in a complex network. The Process Management Life-Cycle PMS can provide governments and private-sector entities that are embarking on PPPs with a robust tool to enhance the outputs and outcomes of their assets' development, production and operation. Future research, however, is required to accommodate a balanced abatement mechanism, which should form an explicit function of the proposed PMS so that it can be utilized in practice. In particular, emphasis will need to be placed on developing incentives so that the SPV are able to understand, control and minimize availability and performance risks, and therefore enhance V_fM for the public sector client. With payment mechanisms being effectively calibrated and service delivery monitored

and measured using the framework provided by the Process Management Life-Cycle PMS, the likelihood of PPP contracts providing long-term value to all stakeholders will be engendered.

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