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A Life-Cycle Model for Evaluating Social Infrastructure Public-Private Partnerships

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Numbers #...BE-127-2013, RD-09-14 and ENG-68-14...

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Date: ………………………...

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Author's Relevant Publications

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

ABS: Australian Bureau of Statistics

ADF (Test): Augmented Dickey-Fuller (Test)

ASX: Australian Stock Exchange

BIM: Building Information Modelling

BOO: Build-Own-Operate

BOOT: Build-Own-Operate-Transfer

BSC: Balanced Scorecard

CAFM: Computer Aided Facility Management

CE: Co-integration Equation

CFA: Confirmatory Factor Analysis

CFI: Comparative Fit Index

CICRP: Computer Integrated Construction Research Programme

CI(s): Core (Performance) Indicator(s)

CMMS: Computer Maintenance Management System

COBie: Construction-Operations Building Information Exchange

CSFs: Critical Success Factors

D&C: Design and Construction

DB: Design-Build

DBFM: Design-Build-Finance-Maintain

DBFOM: Design-Build-Finance-Operate-Maintain

DBO: Design-Build-Operate

EOI: Expression of Interest

FM: Facility Maintenance/Management

FPE: Final Prediction Error

GFC: Global Financial Crisis

GFIs: Goodness-of-Fit Indexes

GIRF: Generalised Impulse Response Function

GNP/GDP: Gross National/Domestic Product

GST: Goods and Services Tax

IFC: Industry Foundation Class

KPIs: Key Performance Indicators

LCC: Life-Cycle Costing

LOD: Level of Development

NPV: Net Present Value

NSW: New South Wales

OPPIs: Output Producer Price Indexes

PFI: Private Finance Initiative

PM: Performance Measurement

PMBOK: Project Management Body of Knowledge

PMF: Performance Measurement Framework

PMS(s): Performance Measurement System(s)

PPIAF: Public Private Infrastructure Advisory Facility

PPPs: Public-Private Partnerships

PSC: Public Sector Comparator

RBA: Reserve Bank of Australia

RFID: Radio Frequency Identification

RFP: Request for Proposal

RMSEA: Root Mean Square Error of Approximation

RVC: Relative Variance Contribution

SC: Schwarz (Information) Criterion

SEM: Structural Equation Modelling

SMART: Strategic Measurement and Reporting Technique

SPSS: Statistical Product and Service Solutions

SPV(s): Special Purpose Vehicle(s)

SVAR: Structural Vector Autoregression

SWOT: Strengths, Weaknesses, Opportunities and Threats

TCQ: Time, Cost and Quality

UK: United Kingdom

USA: United States of America

VAR: Vector Autoregression

VDC(s): Variance Decomposition(s)

VEC: Vector Error Correction (Model)

VEC-D: Vector Error Correction Model with a Dummy Variable

V*f*M: Value for Money

WA: Western Australia

ABSTRACT

Many governments across the world have been facing challenges from infrastructure development, owing to their limited budgets and taxpayers' increasing demands for enhanced efficiency and quality in the provision of public services. This has led to an involvement of private sector in delivering infrastructure projects. Governments have expected that the private entities would benefit the delivery of the public projects by enhancing the effectiveness and efficiency through an introduction of a sound and robust financing mechanism and expertise in innovation and management. Normally, the associations between the public and private sectors in infrastructure procurement are referred to as Public-Private Partnerships (PPPs).

The use of PPPs, however, has been plagued with controversy over the last decade, especially in Australia, because some of the projects have experienced substantial schedule and budget overruns. The reports published by the public authorities of the Australian government have indicated the unsatisfactory outputs and outcomes of a series of PPP projects. In essence, an effective performance measurement/evaluation is critical to the success of PPPs. Theoretically, the prerequisite of a successful performance measurement approach must be capable of reflecting the context in which it is applied. PPPs are complex construction projects with a sophisticated delivery process and stakeholder network. Nevertheless, the conventional *ex-post* evaluation that is invariably adopted for PPPs is simplistically focused on meeting the predetermined schedules, budgets and quality criteria, and fails in completely capturing the inherent complexities and uncertainties of the projects. Therefore, this research aims to empirically develop a life-cycle model for PPPs with a purpose of comprehensively and effectively evaluating the performances of the projects.

To satisfy the primary aim aforementioned, the 'triangulation approach' was used and, therefore, the research was undertaken in three distinct phases. In phase one, an in-depth literature review was conducted in order to identify a significant knowledge 'gap' of PPPs, and then an exploratory study that depended upon 25 interviews was undertaken to interpret and gain an understanding of the practices in performance measurement of PPPs. As a consequence of the interviews, a conceptual framework was proposed, consisting of a sequence of process-based and stakeholder-oriented core (performance) indicators (CIs), which are underpinned by Building Information Modelling (BIM).

In phase two, the feasibility and practicability of the conceptual framework were examined by two detailed case studies, which were rigorously selected, designed and determined according to the outputs of the exploratory interviews. After this, the phase-three study was initiated with an aim of quantitatively testing the hypotheses identified from the prior qualitative studies (i.e., exploratory interviews and case studies). Such hypotheses examined whether the proposed framework is significant to be used for measuring the performance of PPPs. Questionnaire survey acted as a dominant instrument in this phase and, therefore, Confirmatory Factor Analysis was applied to statistically analyse the collected data. To enhance the applicability of the research, a series of macroeconomic key performance indicators (KPIs) were derived conceptually and empirically validated by using a vector error correction model that is integrated with a dummy variable.

Based on the empirical findings derived from the qualitative and quantitative studies, a life-cycle performance measurement system (PMS) was developed for PPP projects. The developed PMS is technologically supported by BIM and thus a demonstration regarding how PPPs can be 'future-proofed' by BIM through the 'lens' of life-cycle performance measurement was presented. Additionally, recommendations for future research are also displayed in the conclusions. Owing to a strong linkage with 'real-world' projects, this research is practical and can provide the governments and private-sector entities that will embark on PPPs with a robust tool in measuring the performances of their future projects.

Keywords: PPPs, life-cycle performance evaluation, social infrastructure, Australia

CHAPTER 1 INTRODUCTION

1.1 Background

In many countries across the world, the pressure of public debt reduction and an intensive quest for enhanced effectiveness and efficiency in the delivery of essential public services have encouraged the governments to involve private organisations into a variety of infrastructure procurements since the 1990s (Regan *et al.*, 2011a). The associations between the public and private sectors, which are normally referred to as Public-Private Partnerships (PPPs), is formed as an integral part of the strategy of infrastructure procurement by the Australian governments (Duffield and Clifton, 2008; Raisbeck *et al.*, 2010). The choice of a PPP is, by its nature, a project financial mechanism and is considered to be a 'win-win' option, due to its medium-term fiscal revenue solution, not only in regard to limited public budgets, but also in the benefits of prudent management, control of risk and corruption reduction (Heller, 2005).

The concepts underlying PPPs, over the past decade, have been widely applied in procuring both economic and social infrastructures (Yong, 2010; Regan *et al.*, 2011a). The *Regional Plan* issued by the Queensland Department of Infrastructure and Planning (2009) defines social infrastructure as "the community facilities/properties, services and networks that help individuals, families, groups and communities meet their social needs and maximise their potential for development, and enhance community wellbeing" (p.130). It includes, but is not limited to, hospitals, prisons, public housings, schools and stadiums, and so on (Yong, 2010; Queensland Department of Local Government and Planning, 2011). A critical reason for the popularity of PPP in infrastructure procurement is because it has been perceived as a method with superior 'cost' and 'time' efficiencies over other traditional procurement approaches. Nonetheless, the use of PPPs is currently plagued with controversy, especially in Australia and the United Kingdom (UK), as many of the projects have been subject to substantial budget and schedule overruns (Hodge and Greve, 2009). According to the report of Infrastructure Partnerships Australia (2007) and the comparative study conducted by Raisbeck *et al.* (2010), approximately 12% of the Australian PPPs had faced significant cost overruns and more than 13% of procured PPPs in Australia had experienced time overruns. Additionally, a large percentage of Australian PPPs were associated with unsatisfactory performances in operations (i.e., 19%), which were resulting from ineffective, inefficient and incomplete estimation and performance evaluations (Li and Hensher, 2010; Department of Infrastructure and Transport, 2012).

Despite the aforementioned problematic issues, Australian state governments continue to express their keen interest towards PPPs, because of the increasingly limited public budgets available for infrastructure development and the conceptual rationale behind PPPs. For instance, in the state of Victoria, PPPs have been determined as the main strategy to deliver 15 new government schools that are expected to be operational before 2018 (Victoria Department of Treasury and Finance, 2015). In addition, the State Government of Western Australia (WA) has been using PPPs to procure its new Perth Stadium, as well as regional hospitals and schools to be functional in the upcoming decade (WA Department of Treasury, 2015).

The private financing of public infrastructure projects, however, has been facing an increasingly intensive challenge, owing to the public sector's increasing demand for Value for Money (V*f*M), as well as the higher production costs of procuring the assets (e.g., finance, design, construction, operation and maintenance costs) and reduced market capacity that has been evident since the 2008 Global Financial Crisis (GFC) (Kappeler and Nemoz, 2010; Yuan *et al.*, 2012). According to the UK's Office of Government Commerce (2002), V*f*M is "the optimum combination of whole life cost and quality to meet the user's requirement" (p.6). Fundamentally, V*f*M focuses on overall outcomes achieved, covering a wide range of issues within qualitative and quantitative contexts such as whole life costs, service quality, maintainability, social benefits and sustainability (Partnerships Victoria, 2001; Department of Treasury and Finance, 2007). As a result, the public and private sectors are now attempting to identify a promising way to enhance the effectiveness and efficiency of PPP delivery; therefore, the debate about these special procurement relationships has moved beyond ideological arguments of their advantages and disadvantages to focusing on how they can be structured to achieve the expected benefits and then, eventually, realise predefined public policy goals (Regan *et al.*, 2011a). "To achieve the potential benefits that can be provided by PPPs they must be designed to deliver performance improvements within a framework that shares costs and risks between the public and private sectors" (Yong, 2010, p.3).

Performance improvement centres on organisational measurement, which has been considered to be extremely critical to business success (Gunasesekaran and Kobu, 2007), particularly at either the project or corporate level (Love and Holt, 2000; Qureshi *et al.*, 2009). Notably, performance measurement/evaluation is important for the construction sector and has been identified as an effective and efficient tool for managing construction projects (Kagioglou *et al.*, 2001; Bassioni *et al.*, 2004).

PPPs are complex construction projects, by nature. The PPP markets in Australia and the UK are deemed as being sophisticated and mature (Hodge, 2004). Despite their maturity in implementing PPPs, ineffective and incomplete performance evaluation continues to be identified as a major factor that has contributed to unsatisfactory operational performance (for example, inefficiency, inadequate staffing and poor support services) during the delivery of the Latrobe Regional Hospital and Deer Park Women's Prison in Victoria, Australia and the Ashfield Prison in the UK (House of Commons 2003; Roth 2004; Harris *et al.*, 2014). According to Yuan *et al.* (2009), an absence of effective and complete performance measurement in a PPP project acts as a trigger for producing below optimum service quality of the infrastructure asset. Yuan *et al.* (2012) also are proponents of this point of view and argue that effective performance measurement "contributes significantly to performance improvement in PPP projects and increased V*f*M" (p.252).

The majority of PPPs, however, have not undergone a comprehensive form of performance evaluation, in terms of what has been delivered, because of the high complexity of the projects' delivery processes and stakeholder networks (Hodge 2005; Regan *et al.*, 2011b). In essence, a complete evaluation is one of the critical success factors (CSFs) of PPPs, but very limited attention has been paid to this important field (Hodge and Greve 2007; Yuan *et al.*, 2012). There is widespread consensus that evaluating and monitoring performance are a core activity of contract and project management, which is a vital part of PPP policy in most developed countries, especially in Australia and the UK (Chinyio and Gameson 2009; European Investment Bank, 2011a). Against this contextual backdrop, it is necessary and significant to conduct an investigation into "how to measure the performance of PPPs comprehensively and effectively throughout the projects' life-cycles", and this research attempts to answer that question within the context of Australian social infrastructure PPPs.

1.2 Research Aim and Objectives

To answer the research question proposed at the end of the last section, it is essential to identify a rational direction to effectively and efficiently evaluate the whole-of-life performance of PPPs. Thus, the aim of this research is to develop a life-cycle model for evaluating the performance of PPPs. Specific objectives include:

- identify a conceptual performance measurement framework (PMF) within the context of social infrastructure PPPs;
- derive and determine the performance measurement perspectives and relevant core indicators (i.e., key performance indicators – KPIs) on the basis of the proposed PMF to develop a PPP life-cycle performance measurement system (PMS);
- test and refine the developed PMS empirically; and
- develop a life-cycle model for performance evaluation of PPPs.

In summary, this research will contribute to the normative literature through the development of a performance evaluation model for social infrastructure PPPs within the qualitative and quantitative contexts. As limited work has been conducted for the PPP performance measurement/evaluation (this will be demonstrated in Chapter 2), the output of this research is significant, not only theoretically, but also practically.

1.3 Research Significance

State governments in Australia spend more than AU$50 billion per annum on capital works (Commonwealth of Australia, 2014). However, budget and schedule overruns are common in infrastructure projects, and a major contributing factor is the delivery process that is implemented (Love *et al.*, 2008; Regan *et al.*, 2011a). PPPs are deemed as an effective and efficient approach toward infrastructure delivery in terms of V*f*M, as well as time and cost performance (Raisbeck *et al.*, 2010). However, this special form of procurement is currently under huge stress, and this is because problems resulting from ineffective and incomplete evaluation, for example, unsatisfactory operational performance and budget and schedule overruns, were associated with some of the procured projects (Davidson, 2011; Clayton UTZ, 2013). Yet, performance measurement/evaluation of PPPs has not been identified as a main research scheme in the literature and has received limited attention from practitioners (Kwak *et al.*, 2009; Yuan *et al.*, 2012).

This research will bridge this ‘gap’ and focus on life-cycle performance evaluation of PPPs. It specifically emphasises how the public and private sectors can effectively and comprehensively evaluate their PPPs, throughout the whole lifetime of the projects, to ensure V*f*M. As suggested by Hodge and Greve (2009), governments need to review the approach they have used to evaluate their infrastructure projects, in order to deal with the problematic issues raised by the projects’ development processes (i.e., life-cycles). Put simply, there is a need for a performance evaluation model capable of substantially addressing the dynamic nature of an infrastructure project’s life-cycle (Yuan *et al.*, 2009). Such an innovative model would provide the decision-makers of both the public sectors and the potential private consortia that will embark on PPPs with a more realistic and dynamic insight into the performance of the projects. In addition, an evaluation of PPPs should cover an assessment of the macroeconomic environment in which the projects will operate (Cheung *et al.*, 2012). In addressing this critical issue, a macroeconomic assessment has been proposed and it serves as an essential component of the life-cycle model developed in this research. Therefore, this is the first research incorporating macroeconomic analysis into the performance measurement/evaluation of PPP projects.

The model to be developed in this research is a practical system, because it is designed with an emphasis on overcoming the limitations of the current practice in performance measurement of PPPs and it possesses a sound foundation that is established by BIM. Hence, this life-cycle model is useful for PPP project managers and/or evaluation practitioners to monitor and improve their projects’ performances over their life-cycles. Essentially, it offers the impetus for ‘real-time’ performance control and improved quality of serves.

1.4 Research Methodology

This research, similar to most of other studies, commenced with an in-depth review of the literature. This phase confirmed that performance measurement of PPPs has not been identified as a main topic of research, even though it is critical to the success of the projects. The limited prior studies undertaken for PPP performance evaluation are primarily based on economic infrastructure projects, and no specific attention had been paid to social infrastructures. Accordingly, a focussed empirical study is needed to fill this knowledge gap.

To contribute to the literature of PPP performance evaluation, an understanding of the approaches being used to measure PPPs was required. Hence, this research was initiated with an exploratory study that depended on key-informant interviews. On the basis of the findings that were derived from the interviews, a conceptual framework was proposed, which was examined by two case studies of Australian social infrastructure PPPs. The case studies relied on semi-structured interviews and documentary sources, aiming to empirically testing the feasibility and applicability of the developed framework.

After the case studies, the conceptual framework was further quantitatively tested by performing a questionnaire survey and econometric modelling. Initially, a pilot survey was conducted with experienced industry practitioners in the regions of Perth, Sydney and Melbourne to determine the effectiveness of the research instrument. Only minor alternation to the research instrument was needed. The main survey was distributed to project managers, construction managers, project advisors, architects, financial managers, operation managers, and asset and facility managers. These practitioners were purposively selected for this research because they were involved with a series of social infrastructure PPP projects within Australia, the UK and the USA, and thus were deemed to be knowledgeable about the performance evaluation of PPPs over a project's life-cycle. Academics, who generally do not have abundant experience in the PPP industry, were not included in this survey because its aim was to deeply understand state-of-the-art perspectives on the evaluation of future PPPs in the industry and then to ensure the practicability of the research outputs. Furthermore, an econometric technique was justified, and adapted, to validate the macroeconomic factors related to infrastructure PPP projects.

Comprehensive analysis of the data obtained throughout the research led to the development and refinement of a life-cycle performance measurement model that is able to consider and capture the inherent complexities and uncertainties of PPPs over the life-cycles of the projects. This model was verified through a process of internal and external validation, which resulted in confirmation of the research findings and the reliability of the research. Thus, the proposed model in this research is practical and can be used by both public authorities and private-sector entities to effectively and efficiently evaluate the performance of their PPPs.

1.5 Thesis Structure

The thesis is structured by eight chapter topics: Introduction, Public-Private Partnerships and Performance Measurement, Research Methodology, Conceptual Framework, Case Studies, Core Indicators and Macroeconomic KPIs, A Life-Cycle Model of PPP Performance Measurement and Conclusions and Recommendations. Figure 1.1 indicates the organisation of this thesis, and a summary of each chapter (except Chapter 1) is presented subsequently.

Chapter 2 Public-Private Partnerships and Performance Measurement – An in-depth review of the normative literature, including the current scope of research on PPPs, is presented in this chapter, which is fundamentally divided into four sections: definition and types of PPPs; theories of performance measurement; performance measurement of PPPs and construction performance measurement. While previous PPP research has focused on six core areas, performance measurement, which is critical to any project's success, has received limited attention. To form a conceptual base, a review of developments in performance measurement theory and general construction project evaluation is also provided in this chapter. It indicates that KPIs and PMS are two prevalent approaches being widely applied within the construction industry. In summary, this chapter not only identifies a significant knowledge gap but also builds a theoretical foundation for this research on PPPs.

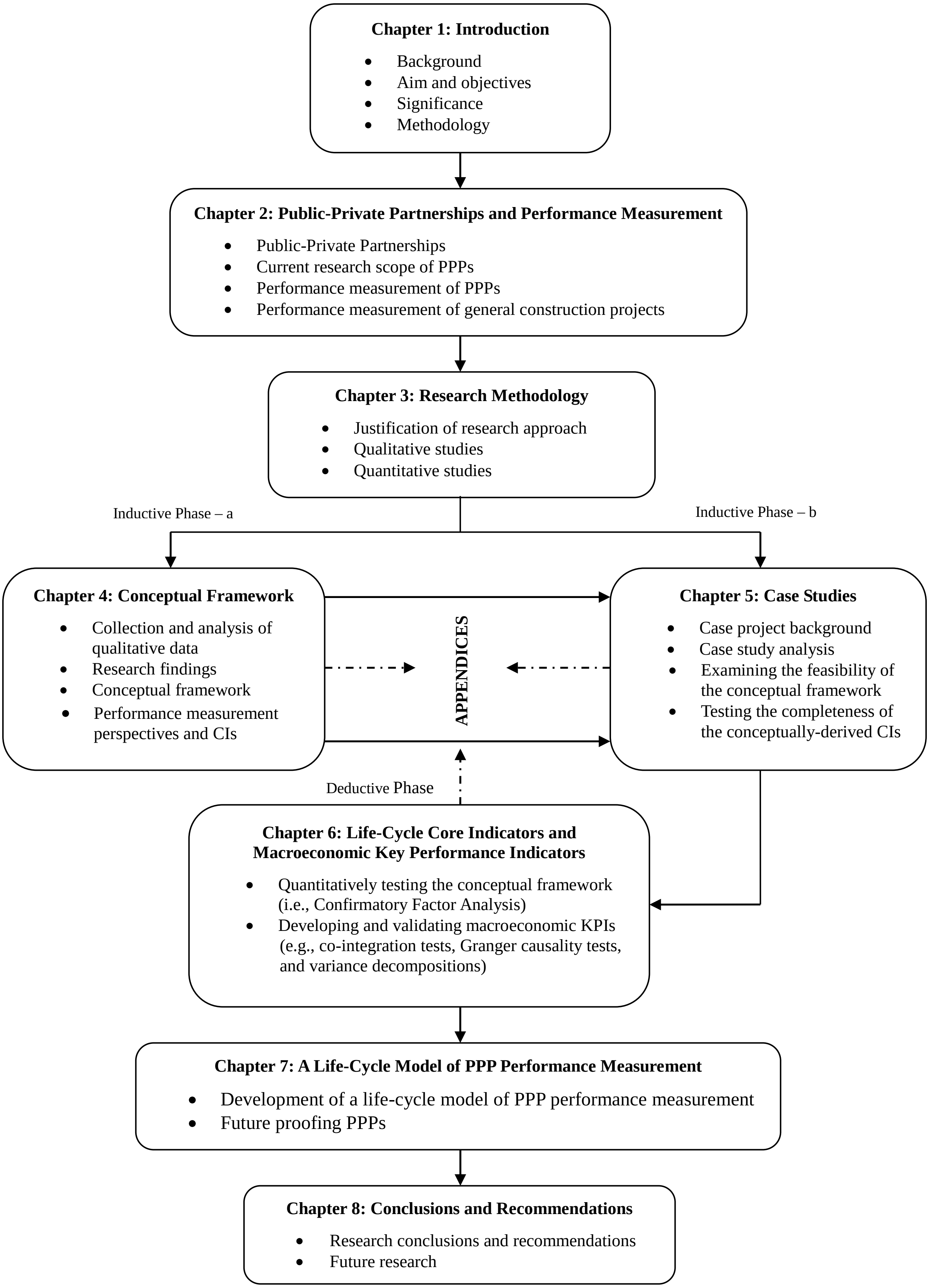


Figure 1.1 Organisation of the thesis

Chapter 3 Research Methodology – This chapter introduces the methodological strategy and the process of data collection required for this research. Based on the nature of PPP research, the 'Sequential Triangulation' that is defined as a balanced combination of inductive and deductive approaches (i.e., positivist and interpretivist) has been adopted as the main research strategy of this thesis. Therefore, the mixed research approach, which involves interviews, case studies, a questionnaire survey and econometric modelling, will be applied to achieve the identified research aim and objectives.

Chapter 4 Conceptual Framework – An exploratory study of PPP performance measurements is presented in this chapter. It aims to empirically interpret the PPP performance measurements being widely applied in the industry and to identify feasible ways to ameliorate them. This investigation depends on a series of key-informant interviews with experienced PPP professionals, especially the leading practitioners who are based in Australia, where the PPP market and industry have been acknowledged to be mature and sophisticated. The NVivo10 software was used to analyse the interview transcripts. A performance measurement framework was conceptualised within the context of social infrastructure PPPs as a result of the findings derived from the interviews. This then acts as a conceptual base for the further empirical studies that are presented in Chapters 5 and 6.

Chapter 5 Case Studies – The life-cycle PMS that was conceptually proposed from the exploratory study was empirically tested by two in-depth case studies of Australian social infrastructure PPPs to examine how well the PMS could be operationalised in the 'real-world' context. The case studies relied on semi-structured interviews with senior management personnel and reviews of documentary sources (e.g., project summaries and agreements) and identified that the life-cycle PMS is feasible and applicable for future PPP performance evaluation. The findings of this chapter were essential, as they formed a solid conceptual foundation for Confirmatory Factor Analysis (CFA), which is a theory-driven technique; therefore, a reliable theoretical base is required before performing CFA.

Chapter 6 Life-Cycle Core Indicators and Macroeconomic KPIs – The applicability and feasibility of the PPP life-cycle PMS are tested in this chapter. The main components of the PMS (e.g., five performance measurement perspectives and life-cycle core indicators) are validated quantitatively by CFA, relying on the survey data. A total of 135 completed responses, of the 368 distributed questionnaires, were used for analysis. CFA was conducted by using the AMOS version 21 of the ***S**tatistical **P**roduct and **S**ervice **S**olutions* (SPSS). Then, a vector error correction (VEC) model with a dummy variable was constructed to identify the causal relationships between the derived macroeconomic KPIs and PPP investments. The VEC model is carried out by using the EViews software package. This econometric study is useful for enhancing the practicability of the PPP life-cycle PMS.

Chapter 7 A Life-Cycle Model of PPP Performance Measurement – This chapter describes how the research findings contribute to the finalisation of a life-cycle model of PPP performance measurement and explains how the developed model will benefit the delivery of future PPPs. It can be noted that the life-cycle performance measurement model is practical because of the integration of Building Information Modelling (BIM) in supporting the process-based KPIs. BIM is a technology-focused methodology and, therefore, this chapter also demonstrates how BIM can ensure that the procured assets can be 'future-proofed' through the lens of life-cycle performance measurement. At the end, a 'user guideline' is developed in this chapter to assist the key stakeholders of PPPs to use the resultant life-cycle model.

Chapter 8 Conclusions and Recommendations – This is the final chapter of this thesis and the key research findings are summarised here. Additionally, practical and theoretical implications will be discussed and re-stated in this chapter, including the significance of the developed life-cycle model within the PPP industry and its theoretical contribution to the body of knowledge in association with project evaluation, performance measurement, infrastructure procurement and BIM. Also, recommendations for future research are outlined in this chapter.

1.6 Research Limitations

The research presented in this thesis is specific to social infrastructure PPPs and, therefore, it is not completely suitable for all economic infrastructure projects. Moreover, the abatement regime relating to the payment of concessionaires has not been detailed because it was considered to be beyond the scope of this research, which concentrates on how to comprehensively measure the performance of PPPs rather than to stimulate the private sectors' performance in the operational phase. Nevertheless, it is recommended in Chapter 8 that the abatement regime will be a promising topic for future research on PPP performance measurement.

For the case study section of this research, an interview with the financial manager of one selected project could not be secured, because of unavailability. Nonetheless, the project manager was familiar with every part of that project and provided the researcher with valuable and sufficient information about the project's financing. As a result, the negative impact of the lack of an interview with the financial manager was substantially minimised.

Confirmatory Factory Analysis, which is a widely-used statistical technique in social science research, was applied to analyse the significance level of the observed items. Normally, CFA is performed with a large sample size (i.e., $n \geq 200$); however, the sample size of the survey in this research was under this baseline (i.e., $n=135$). This is due to the low number of social infrastructure PPPs that had been, or were being undertaken, across Australia and the limitation of experienced practitioners who specialise in the life-cycle performance evaluation of social PPPs. Despite this limitation, the sample size of this research has been extensively demonstrated as being acceptable for social science studies (De Vaus, 2002), especially for PPP research that relies on CFA, by many researchers (e.g., Li *et al.*, 2005b; Jin, 2010; 2011; Yuan *et al.*, 2012).

1.7 Chapter Summary

PPPs have been widely used in the procurement and delivery of both economic and social infrastructure projects across the world because many governments have limited public budgets while still being expected to provide increased effectiveness and efficiency in public services. Despite the widespread application of PPPs, some of their failures have been reported in the normative literature. A variety of factors can determine the success of a PPP project, for which an effective and efficient performance measurement is pivotal.

Most procured PPPs in Australia and the UK, however, have not undergone a comprehensive performance measurement/evaluation. With the need to study the performance measurement of PPPs, the primary aim of this research with regard to the development of a life-cycle performance measurement model was determined and four relevant objectives were derived in this chapter. Then, the significance and methodology of this research were described and introduced, respectively.

This chapter also serves a role in providing an overview of this research. There are eight chapters embedded into this thesis, and the core contents of each chapter were summarised above. Fundamentally, the chapters to be presented as follows are comprised of qualitative and quantitative studies, including an exploratory study based on interviews, case studies, a questionnaire survey and econometric modelling. Finally, the research limitations were highlighted and these included the reason for non-inclusion of the problematic issues surrounding the abatement regime, difficulty in obtaining one interview for the case studies and the sample size of the survey.

CHAPTER 2 PUBLIC-PRIVATE PARTNERSHIPS AND PERFORMANCE MEASUREMENT

2.1 Chapter Introduction

A review of the literature surrounding Public-Private Partnerships (PPPs) is reported in this chapter, which is structured according to five themes: (1) public-private partnerships; (2) current scope of PPP research; (3) performance measurement; (4) performance measurements in PPP projects; and (5) performance measurements in construction. Additionally, the significant knowledge gaps in regard to PPPs are identified in this chapter.

Within this chapter, an introduction to PPPs is first provided. Then, an in-depth review of previous PPP research is undertaken, identifying that there are six key areas (i.e., critical success factors, roles and responsibilities of the public sector, concessionaire selection, risk management, project cost and time efficiency under different contracts, and project finance) within the available literature discussing PPPs. On the basis of this review outcome, a 'missing area' in the normative literature with regard to PPP performance measurement is outlined. To further examine the literature, the theories of performance measurement, past limited studies of PPP performance evaluation and prior research on construction performance measurement are reviewed.

This chapter provides vital background knowledge to the proposition of the conceptual framework that will be discussed in Chapter 4 and determines how this research can contribute to the body of knowledge. In summary, it serves as the theoretical base for the development of a life-cycle performance measurement/ evaluation model for PPPs.

2.2 Public-Private Partnerships

Public-Private Partnerships have been an important procurement strategy of many governments across the world. In order to significantly contribute to the literature of PPPs, it is necessary to understand both the general concept and relevant specific issues. Therefore, in this section, the definitions, benefits, types and structures of PPPs will be introduced, respectively.

2.2.1 Definitions of PPPs

An infrastructure project that is procured through the use of PPPs is undertaken by a private consortium, which is normally referred to as the *Special Purpose Vehicle* (SPV). Various definitions of PPPs can be found in the literature. For example, the European Investment Bank (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). The Public Private Infrastructure Advisory Facility (PPIAF) (2014) provides the following definition where a PPP "involves 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". To date, there is no universally accepted definition of PPPs and the meanings differ among countries.

The defining features of PPPs, compared with other forms of private participation in infrastructure, include risk transfer, long-term contract relationships and partnership agreements (Akintoye *et al.*, 2003; Zhang, 2004b). Kwak *et al.* (2009) state that "the complexity of contractual relationships between participants, and the long concession periods associated with PPPs, makes them distinct from traditional infrastructure development routes" (p.56). In other words, under PPP schemes, resources and risks associated with the procurement of an infrastructure asset are shared between the public sectors and private entities for the purpose of ameliorating the delivery of the project and ensuring the improvement in quality of the relevant public services (Norment, 2002). Specifically, governments embark on PPPs as they provide the following benefits (European Commission, 2003, p.15):

- accelerated infrastructure provision through allowing the public sector to translate capital expenditure into a flow of on-going service payments;
- timely project implementation through the allocation of design and construction responsibilities to the private sector;
- reduced whole life cost and improved performance motivated by the strong incentives of private-sector enterprises to minimise costs and improve

management over a project's life-cycle;

- reduction in risks for governments by transferring them to the private sector;
- improved service quality and innovation through the use of private-sector expertise and performance incentives; and,
- enhancement of prudent management of public expenditure and a reduction in corruption by the increase in accountability and transparency.

Owing to the benefits outlined above, a lot of governments in the world have expressed keen interest in the use of PPPs in infrastructure procurement. For example, in Australia, the states of New South Wales (NSW), Victoria and Queensland have been recognised as the 'Iron Triangle' of PPP implementation (Hodge and Duffield, 2010). These states, and other countries, have made significant contributions to the development of PPPs according to their actual situations; therefore, various types of procurement model have been developed over the past two decades, under the conceptual scheme of PPPs, and they are discussed below.

2.2.2 Types of PPP

The concept underlying PPPs has been developed substantially since the 1990s. As a result, there is great variety in the types of PPP that have been implemented to deliver infrastructure projects in order to meet various objectives and requirements. Notably, the typology of PPPs can be established on the basis of either the degree of private-sector involvement or the nature of the services and risk transfers written into the contracts (The World Bank, 2007; NSW Treasury, 2012).

According to the commitment level of the private-sector participants, several typical types of PPP can be found within the construction industry, cascading down from public procurement and design-build (DB) to build-own-operate (BOO) and purely private procurement. Table 2.1 summarises and describes the key issues of such typical types of PPP and Figure 2.1 further illustrates them, explicitly.

Table 2.1 Descriptions of typical types of PPPs

Types of PPP	**Characteristics**
Design-Build (DB)	• The private entities are responsible for the design and build of the projects.
Design-Build-Operate (DBO)	• The private entities are responsible for the design, construction and operation of the projects. • The private entities may also be responsible for the maintenance of the assets for an agreed period before the handover stage.
Design-Build-Finance--Maintain (DBFM)	• The private entities take on the responsibility of the designing, building and financing of the projects. • Under a DBFM contract, the public-sector participants retain full ownership of the procured assets.
Design-Build-Finance--Operate-Maintain (DBFOM)	• The private entities are responsible for the design, construction, financing, operation and maintenance of the projects. • Similar to DBFM, the public sector retains full ownership of the assets under DBFOM.
Build-Own-Operate--Transfer (BOOT)	• The private entities are responsible for the design, construction, operation and maintenance of the projects. • Ownership of the assets is transferred to the private entities for a concession period.
Build-Own-Operate (BOO)	• Similar to BOOT, the private entities are responsible for the design, construction, operation and maintenance of the projects; however, they retain ownership of the assets in perpetuity. • The public-sector participants may only agree to purchase the services associated with the assets for a fixed period.

Source: Kwak *et al.* (2009)

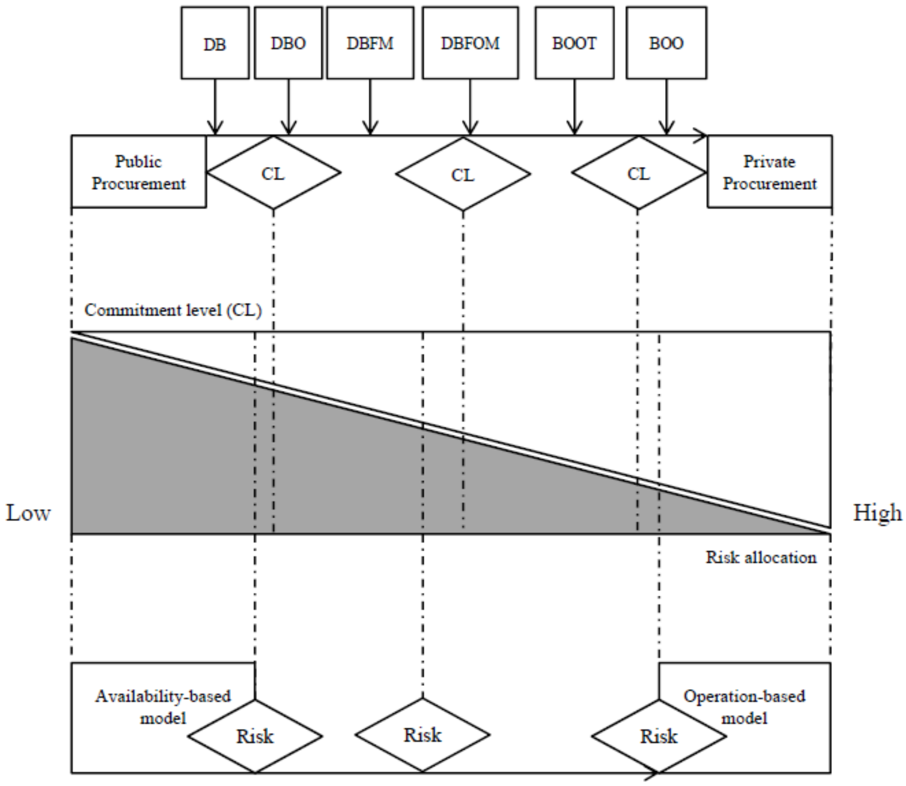


Figure 2.1 Types of PPPs

Additionally, the features of the aforementioned types of PPP have been reviewed, and a comparison of their advantages and disadvantages is presented in Table 2.2. It provides a critical insight into the benefits and suitability of each type of PPP. As indicated in Table 2.2, DBFM, DBOM and DBFOM are representative PPP models that have been widely used across Australia, the United Kingdom (UK) and the United States of America (USA) for the procurement of both social and economic infrastructure projects. Hence, the case studies presented in Chapter 6 of this research were based on these types of PPP.

Public-Private Partnerships also can be categorised in accordance with the level of risk allocation. Thus, there are two main types of PPP: the availability-based model and the demand-based model (Figure 2.1).

1. Availability-based PPPs: Availability-based PPPs are structured with the SPVs being responsible for privately financing the projects to design and construct the assets. After the completion of construction, the relevant public authority starts making monthly or quarterly payments to the private entity until the end of the operation. Abatements to such payments are triggered by unavailability of the asset or the SPV failing to meet the predetermined performance standards, which are stated in the contractual agreements between the involved parties. Under an availability-based PPP, "government retains demand risk and the main form of revenue for the SPV is therefore the service payment for making the asset available and providing the required services to the required performance standard" (NSW Treasury, 2015, p.2).

2. Demand-based PPPs: Demand-based PPPs, also known as operation-based or operational-model PPPs, are different from the availability-based PPPs. Under this model, demand risk is transferred to the concessionaire and, therefore, the private-sector participant has to actually operate it for the purpose of generating profits. In other words, the revenues of the assets are yielded by charging the third parties (i.e., end-users) rather than receiving service payments from the public-sector partners (NSW Treasury, 2015).

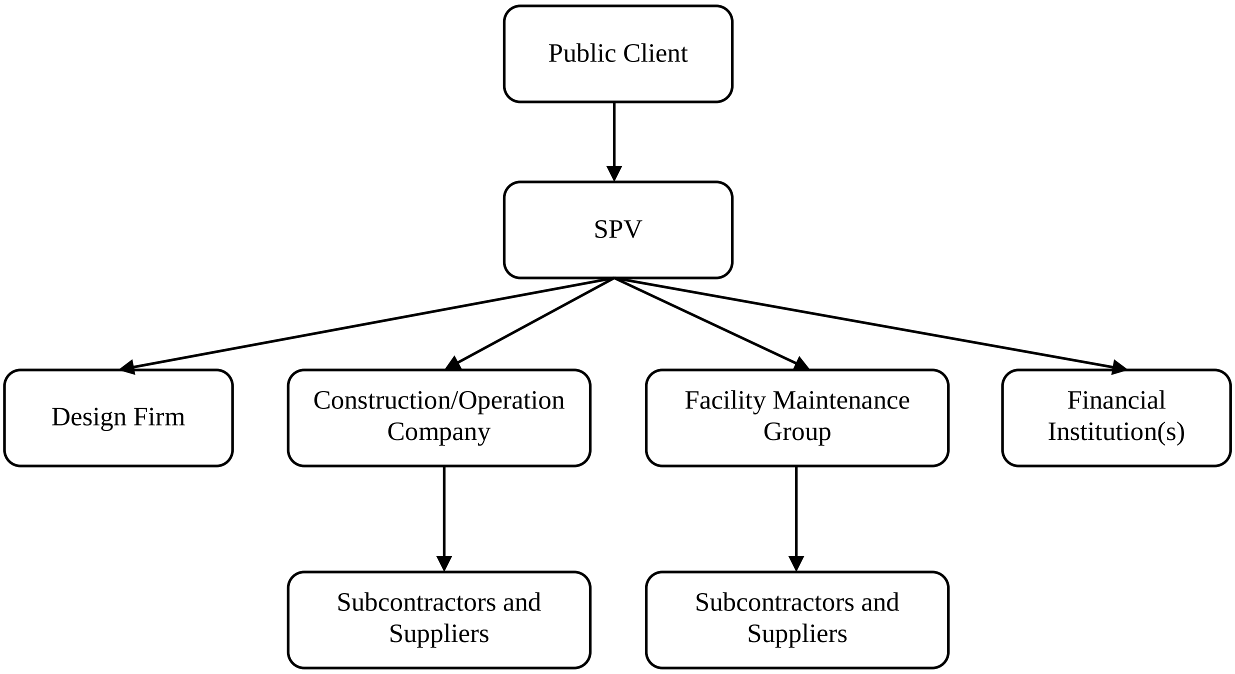
Table 2.2 Comparison of typical types of PPPs

Types of PPP	**Advantages**	**Disadvantages**	**Suitability**
DB/DBO	• Easy administration; and • Transparent and objective selection process (Pakkala, 2002).	• Lack of innovation and life-cycle cost control; • Tendency for ordinary project quality; and • Possibility of order changes and cost overruns (Anastasopoulos *et al.*, 2011).	These contracting approaches have been widely applied across the world and are suitable for social and economic infrastructure projects (Pakkala, 2002).
DBFM/DBOM/ DBFOM	• High quality; • Favourable for innovation; and • Low risk in project failure (Pakkala, 2002).	• Requirement for more resources and skilled workers (Pakkala, 2002).	DBFM, DBOM and DBFOM are widely used in Australia, the UK and the US. They are suitable for a variety of social and economic infrastructure projects (Kwak *et al.*, 2009).
BOOT/BOO	• Encouragement of private investment; • High knowledge and technology transfer; and • Enhanced cost and time efficiencies (Gatti, 2013).	• Additional costs incurred through payments to the service provider; and • Inflexibility (Delmon, 2005).	BOOT/BOO are suitable for the procurement of economic infrastructure projects, such as roads, railways and airports; however, BOO is appropriate for some social infrastructure, especially water treatment plants (The World Bank, 2015).

In summary, the types of PPP can be categorised by either the commitment level of the private-sector partners (e.g., DBFM, DBFOM and BOO) or the level of risk allocation (e.g., availability-based model and operation-based model). It has been mentioned above that one of the defining features of PPPs is the specific partnerships formed by various public and private entities (Akintoye *et al.*, 2003). To develop an evaluation model, with the aim of helping the key stakeholders to improve their projects' performances, an introduction to the typical structure of PPPs is required.

2.2.3 Structure of PPPs

The private-sector SPVs formed for the purpose of procuring infrastructure projects are normally represented by some organisations. For example, DBFM and DBFOM are popular and have been widely used globally, particularly within Australia and the UK. The SPVs under these two PPP models generally integrate with a design firm, a construction/operation company, a facility management group and a financial institution. Specialised organisations are substantially involved as critical members of SPVs in some special PPPs. For example, a waste management group would be an integral part of a project for a waste disposal service. Figure 2.2 depicts the structure of a PPP under the DBFOM model.



Source: Chinyio and Gameson (2009)

Figure 2.2 Structure of the DBFOM model under a PPP scheme

According to Carrillo *et al.* (2006), it is imperative to form a consortium for each PPP project as no one company is robust enough to completely and independently finance, design, construct, operate and/or maintain the asset. Essentially, SPVs can be viewed as independent entities, most of which possess their own business names. However, SPVs tend to develop a lean structure by outsourcing their contractual obligations and focussing on effective and efficient management at both project and organisational levels in order to satisfy the public clients' increasing demands for Value for Money (V*f*M), which can be defined as the optimum combination between whole-of-life costs and output qualities and benefits (Chinyio and Gameson, 2009).

2.2.4 Life-Cycle of PPPs

Life-cycle is an important concept in project management (Sidwell, 1990; Kerzner, 2013). According to the PMBOK® Guide published by the Project Management Institute (2013), the life-cycle of a project can be defined as the development process that integrates with a series of phases that are representative to the evolution of the project, from conceptualisation to closure, and it provides the project manager and or other key stakeholders with a more effective control and greater clarity regarding the scopes and deliverables of the project. With these benefits, the life-cycle concept has been widely used to manage different kinds of project, especially construction projects where a variety of complexities and uncertainties always surround the delivery of those projects (Bennett, 2003).

PPPs are recognised as being suitable for complicated and mega construction projects. However, the life-cycle of PPPs is loosely defined, and only a few studies have sought to determine the project phases of a PPP's life-cycle. For example, Chinyio and Gameson (2009, p.7) summarised a series of phases within a PPP life-cycle, such as a needs assessment, outlining of a business case, completion of a pre-qualification questionnaire, final invitation to negotiate, financial close, construction, operation and maintenance, and handover. Moreover, Yong (2010, p.4) determined six phases for a PPP project life-cycle, involving enabling environment, definition of the project, a project feasibility study, project structuring, transaction and post-implementation.

In addition, the European Investment Bank (2011) proposed a more practical life-cycle of PPPs, in its technical implementation guideline, whereby ten project phases can be noted, including: (1) project selection and definition; (2) option assessment of PPPs; (3) getting organised; (4) pre-tendering work; (5) tendering/bidding; (6) contract and financial close; (7) design and construction; (8) operation; (9) maintenance; and (10) handover (Figure 2.3).

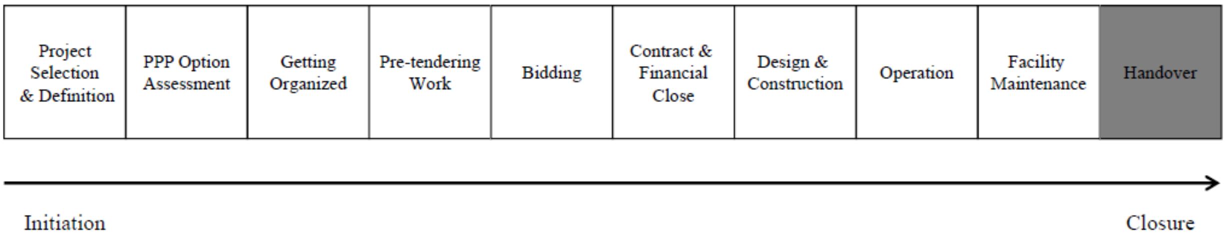


Figure 2.3 Project life-cycle of a PPP

Although the life-cycle perspective maintains a pivotal role, it is not substantially addressed in many areas of construction project management (i.e., performance measurement) (Haponava and Al-Jibouri, 2012), particularly in respect to PPPs (Zou *et al.*, 2008). This problematic issue will be logistically identified and discussed in the following sections of this chapter (particularly Sections 2.3 and 2.6.2).

2.3 Scope of PPP Research

Public-Private Partnerships, historically, have been perceived as the basis of a procurement approach that enables 'cost' and 'time' efficiencies owing to the conceptual rationale and the demonstrated positive impacts on a series of infrastructure projects. As a consequence, numerous studies have been undertaken by academic scholars and industrial practitioners to investigate PPPs. Kwak *et al.* (2009) identify that there are five key research areas within the normative literature on PPPs, including critical success factors, governments' roles and responsibilities, selection of concessionaire, risk allocation and project finance. Nevertheless, exploring the literature suggests that research on the risks of PPPs is not limited to risk allocation but also includes the frameworks and concepts proposed to effectively evaluate and manage the uncertainties that emerge during delivery of the projects. For examples, see Shen *et al.* (2006), Nisar (2007) and Zou *et al.* (2008). Further, as many PPPs have experienced budget and schedule overruns, intensive attention has been paid to understanding and/or modelling the cost and time efficiencies of PPPs under different types of project contract (e.g., Blanc-Brude *et al.*, 2006; Raisbeck *et al.*, 2010; Anastasopoulos *et al.*, 2013). Six core areas where research has been focused can be identified from the PPP normative literature, and they are:

1. *Critical success factors (CSFs)*: CSFs are defined as “those few key areas of activity in which favourable results are absolutely necessary for a particular manager to reach his or her goals” (Rockart, 1982, p.4). The identification of CSFs is considered to be the prerequisite in developing a PPP project protocol (Zhang, 2005b). Hence, many studies have attempted to list the CSFs of PPP projects within a qualitative context (e.g., Tiong, 1996; Qiao *et al.*, 2001; Jefferies *et al.*, 2002; Li *et al.*, 2005a; Zhang, 2005b; Jefferies, 2006; Chan *et al.*, 2010; Osei-Kyei and Chan, 2015).

2. *Roles and responsibilities of the public sector*: The public sector performs a vital role in facilitating PPP projects (Tam and Leung, 1997). One of the main contributing factors to the failure of PPP projects is a lack of support from the public sector. Essentially, a sequence of responsibilities and roles to be undertaken by the government partner is essential to ensure the successful outcome of a PPP, and they have been identified as including: (1) creating a positive investment environment; (2) establishing a sound regulatory framework and supportive authorities; (3) selecting an appropriate concessionaire; and (4) constant involvement throughout a project’s life-cycle (e.g., Kumaraswamy and Zhang, 2001; Pongsiri, 2002; Koch and Buser, 2006; Abdel Aziz, 2007; Warner and Hefetz, 2008; Calabrò, 2011; Soomro and Zhang, 2015; Rwelamila *et al.*, 2015).

3. *Selection of concessionaire*: “A concessionaire is a consortium formed particularly for a PPP project” (Kwak *et al.*, 2009, p.62). It is the principal participant, mainly responsible for most of the stages of a PPP project. Zhang (2004a) suggests that the selection of a suitable concessionaire can significantly influence the success of a PPP project. A number of studies have been undertaken in an attempt to explain how to select the most suitable concessionaire for a PPP infrastructure project (e.g., Treasury Taskforce, 1999;

Ahadzi and Bowles, 2001; Zhang and Kumaraswamy, 2001; Zhang *et al.*, 2002; Zhang, 2004a, b; Zhang, 2005a; Jang, 2011).

4. *Risk management*: Risk identification, evaluation and allocation are critical to the successful delivery of PPP projects, whereby the liability of the private investor in the design and construction stage is limited and the public sector primarily faces the financial and operational risks. A plethora of studies have examined PPP risks and provided valuable insights into PPP risk identification and allocation (e.g., Charoenpornpattana and Minato, 1999; Wang *et al.*, 2000a, b; Grimsey and Lewis, 2002; Thomas *et al.*, 2003; Li *et al.*, 2005c; Xenidis and Angelides, 2005a, b; Shen *et al.*, 2006; Nisar, 2007; Sachs *et al.*, 2007; Zou *et al.*, 2008; Jin, 2010, 2011; Xu *et al.*, 2010; Chan *et al.*, 2011; Li and Zou, 2011). Fundamentally, risks in PPPs can be classified as: (1) market risks, which arise due to uncertainties in the market demand for the infrastructure; (2) planning risks, which result from planning for private-sector participation; (3) project risks, which are associated with uncertainties in construction, completion, operation and financing; (4) political risks, which relate to wars, civil disturbances and breach of contract; (5) regulatory risks, which arise from a lack of suitably developed regulatory systems; and (6) systemic risks, which arise from fluctuations in exchange rates and interest rates.

5. *Project cost or time efficiencies under different PPP contracts*: It is common knowledge that cost and time savings are central to any PPP infrastructure projects. In the literature, the ‘cost’ and ‘time’ performances of PPPs are implicitly linked to the project CSFs (i.e., National Audit Office, 2003; Raisbeck *et al.*, 2010). Furthermore, the characteristics of PPP contracts are significantly relevant to the total cost and time of the projects. Considering this perspective, many researchers have explored PPP cost and time issues in association with the characteristics of specific contracting approaches (e.g., National Audit Office, 2000; Haskins *et al.*, 2002; Fitzgerald, 2004; Zietlow, 2005; Blanc-Brude *et al.*, 2006; Anastasopoulos *et al.*, 2009; Anastasopoulos *et al.*, 2010a, c; Raisbeck *et al.*, 2010; Anastasopoulos *et al.*, 2013).

6. *Project finance*: The success of an infrastructure PPP project depends largely

on well-planned financing. Nonetheless, financing a PPP is characterised as a difficult and complex task. This is because of the sheer number of internal and external factors that must be considered when initiating a PPP financial plan. A number of studies have attempted to explore the complexity of PPP finances in such areas as the financing strategy and financial engineering (e.g., Levy, 1996; Merna and Dubey, 1998; Ye and Tiong, 2000; Schaufelberger and Wipadapisutand, 2003; Zhang, 2005c; Devapriya, 2006; Daube *et al.*, 2008; Regan *et al.*, 2011a; Engel *et al.*, 2013; de Albornoz and Soliño, 2015).

While an array of studies have investigated the initiations and outcomes of PPPs over the past two decades, there have been few attempts to critically examine the projects from a process management perspective (Figure 2.4) (Yuan *et al.*, 2009). Process management is pivotal for business success, whether it is at the organisational or project level (Love and Holt, 2000; Kagioglou *et al.*, 2001). It is the application of knowledge, skills, techniques and/or systems to measure and improve the effectiveness and efficiency of the launched process, thus to ensure a higher organisational performance and ultimately satisfy key stakeholders' needs and requirements (Smith and Fingar, 2003). In essence, effective and competitive processes are one of the CSFs of PPP projects (Jefferies *et al.*, 2002; Koppenjan, 2005). Performance measurement forms the heart of process management (Lebas, 1995; Bititchi *et al.*, 1997; Kagioglou, 2001), but has surprisingly received very limited attention within the context of PPPs (Robinson and Scott, 2009; Yuan *et al.*, 2009). Based on this finding, this current research will attempt to fill this significant knowledge gap by developing a performance measurement model for PPPs.

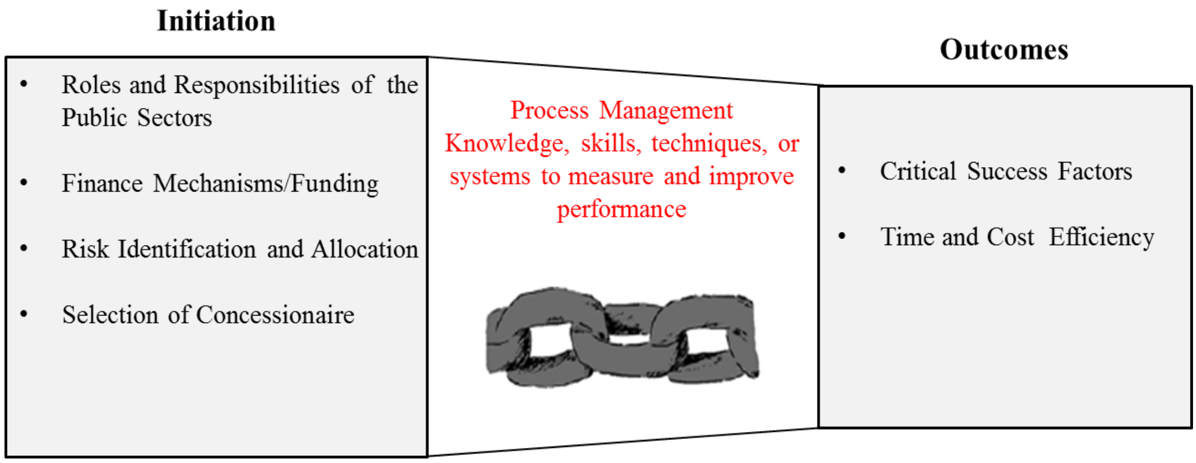


Figure 2.4 Current PPP research scope: Process management – the 'missing link'

It can be identified that extensive research has been undertaken to investigate PPPs, yet the studies conducted for measuring the performance of PPPs are limited. This provides this research with an opportunity to contribute to the PPP normative literature by developing a performance measurement system. To achieve this aim, it is necessary to review the theoretical system of performance measurement and to discuss why it is critical to PPP projects (Latiffi *et al.*, 2009).

2.4 Performance Measurement

Performance measurement is defined as "the process of quantifying the efficiency and effectiveness of action" (Neely *et al.*, 2005, p.1229). Kaplan (1990) argues that performance measurement is the prerequisite of performance improvement. With this objective, over the two last decades, a large number of studies have been initiated to contribute to the theoretical development of performance measurement (Gunasekaran and Kobu, 2007). The theoretical development of performance measurement and research concerning performance measurement design are reviewed in this section.

2.4.1 Development of Performance Measurement

Performance measurement is practical and can be applied to "assess the success of organisations" (Kennerley and Neely, 2003, p.214). Historically, the concept underlying performance measurement can be traced back to the Medieval Period, when an assessment of 'time' performance had been predominantly used within the early-modern accounting framework and the double-entry accounting system used by organisations (Johnson, 1983; Bruns, 1998). Since the 1900s, owing to organisations' development with regard to the separation of ownership and management, the dominant position of 'time measurement' has been gradually replaced by financial measures, specified investment returns, cash flow and profit margin (Kennerley and Neely, 2003).

By the 1980s, there was a growing perception that financial measures alone were no longer sufficient or powerful enough to measure organisational performance in the modern corporate environment, and this emerged from both academia and industry (Kaplan and Norton, 1996a). Due to the increasingly competitive markets, organisations in various economic sectors have had to respond more to external activities and develop long-term success strategies in order to satisfy customers' increasing demands and to maintain their market shares (Parker, 2000). However, conventional financial measures are lagging indicators (Dixon *et al.*, 1990), which lead to short-termism rather than long-term success and provide no insight into how an organisation's performance is achieved or how that performance can be improved (Hayes and Abernathy, 1980; Kaplan, 1986). More importantly, financial measures fail to indicate a set of intangible critical factors, such as customer satisfaction and strategy (Skinner, 1974; Kaplan and Norton, 1992; Neely *et al.*, 1995; Parker, 2000).

Such aforementioned deficiencies of traditional financial measures weaken an organisation's competitiveness and have forced researchers and industrial practitioners to pursue a more balanced performance measurement framework (PMF) that is capable of effectively and efficiently measuring organisational performance, even beyond today's intensively changing environment (Parker, 2000). The subsequent revolution is that a plethora of general performance measurement systems (PMSs) have been devised over the past 20 years, such as the Performance Measurement Matrix, Performance Causality Model, SMART Pyramid (i.e., Strategic Measurement and Reporting Technique) and Macro Process Model (Keegan *et al.*, 1989; Fitzgerald *et al.*, 1991; Lynch and Cross, 1991; Brown, 1996). A PMS can be defined as "a structure in which strategic, tactical and operational actions are linked to process to provide the information required to improve the program or service on a systematic basis" (del-Rey-Chamorro *et al.*, 2003, p.47).

Among the developed general PMSs, the *Balanced Scorecard* (BSC) is the most popular system. Kaplan and Norton (1992; 1996) first introduced the BSC in their seminar paper in the year of 1992, in which they outlined four performance measurement perspectives: financial; customer; internal business process; and learning and growth. Since its proposition, the BSC has been widely implemented across different industries and has been described as a soundly performing strategic control tool (Mooraj *et al.*, 1999; Kennerley and Neely, 2003). Another well-known PMS is the *Performance Prism* developed by Neely *et al.* (2001). It contains five interrelated facets: (1) stakeholder satisfaction; (2) strategies; (3) processes; (4) capabilities; and (5) stakeholder contribution (Neely *et al.*, 2002). The Performance Prism has been demonstrated as a system that is robust in measuring the organisational performance within a multiple-stakeholder environment (Neely *et al.*, 2001). Gradually, since their emergence, PMSs have overwhelmed sole financial measures because of their provision of information that is useful for the organisation's decision-making and actions to advance the achievement of both short- and long-term strategies (Gunasekaran and Kobu, 2007).

With the contributions of these many noted researchers, 'performance measurement' has now evolved into a theoretical system that has the aim of assisting organisations to: (1) identify success, satisfaction level of customer needs, where problems exist, and where improvements are essential; (2) understand their processes and what they both know and do not know; (3) ensure the appropriateness of every decision; and (4) indicate whether the expected and planned outcomes have been met (Parker, 2000; Gunasekaran and Kobu, 2007). In the scheme of management research (e.g., process management), performance measurement is a key area because it is a critical process that has substantial impact on the success of an organisation (Kagioglou *et al.*, 2001; Bourne *et al.*, 2003; Neely, 2004; Neely *et al.*, 2005).

2.4.2 Importance of Performance Measurement in Construction

The importance of performance measurement for organisational success has been acknowledged by researchers. Essentially, performance measurement is a useful and essential tool for key stakeholders to manage the resources of their organisations and to evaluate whether the business outputs are in alignment with the corporate strategies (Baldwin *et al.*, 2001; Kulatunga *et al.*, 2007; Yu *et al.*, 2007). Tapanya

(2004) also argues that performance measurement is critical because it is a management mechanism designed and implemented specifically to ensure that organisations can operate and move towards their goals and objectives. In practice, the operation of an organisation needs to be supported by an effective and efficient performance measurement system, due to its substantial contribution to the improvement of business output quality, which then leads to increases in customer satisfaction, market share and organisational profits, all within an intensively changing corporate environment (Theeranuphattana and Tang, 2007).

Performance measurement, as identified from the researchers' perspectives above, is able to benefit organisations by realising their success, in a complex and long-term context, through the provision of assistance for business performance improvement. There is widespread consensus that construction projects are extremely complex and dynamic systems (Lyneis and Ford, 2007). Accordingly, it has been acknowledged by academia that performance measurement is a critical topic for construction research (Love and Holt, 2000; Bassioni *et al.*, 2004; Nudurupati *et al.*, 2007; Yu *et al.*, 2007; Yang *et al.*, 2010). Furthermore, a qualitative study conducted by Latiffi *et al.* (2009) indicates that practitioners recognise the importance and significance of performance measurement in achieving success at both project and corporate levels within the construction industry, especially "as a mechanism to identifying potential areas for improvement and to support the process of developing the organisation's strategy" (p.410).

As noted above, performance measurement is important, particularly for construction projects. Latiffi *et al.* (2009) stated that performance measurement plays a decisive role in developing strategies at various levels within construction (i.e., project, corporate and industry). With this perspective in mind, the following sections form an analysis of the literature in regard to the design of a performance measurement system, performance measurement of PPPs and general construction project performance measurement.

2.4.3 Design of Performance Measurement

The design and implementation of performance measurement within an organisation is a systematic and sophisticated process (Neely *et al.*, 2000; Lohman *et al.*, 2004). In that regard, a series of studies have been undertaken to identify what matters should be addressed and followed when designing a performance measurement system (Bourne *et al.*, 2000).

A review of the literature suggests that "a wide range of performance measurement design processes is provided, and they have been proposed "jointly and severally, from theory and practice, by both academics and practitioners" (Bourne *et al.*, 2003, p.5). For example, Neely *et al.* (1995) identify that the design of a PMS/PMF should logically address the issues of: (1) what performance measures are to be used; (2) what purposes will be served; and (3) what benefits will be provided. In addition, Bourne *et al.* (2000) support this proposition and proffer a procedure to design and implement PMSs that covers: "(1) the design of the performance measures; (2) the implementation of the performance measures; and (3) the use of the performance measures" (p.757).

Since the 1990s, there have been attempts to systematically develop processes for the design of performance measurement. According to Bourne *et al.* (2003), categorising the performance measurement design processes provided by the literature is not easy and there are two sources of categorisation that can be found: the procedure-based process and the approach-based process. In the first category, three types of procedure for performance measurement design can be summarised as:

- The 'needs-led' procedure: This is a "top down procedure for developing performance measures, where the customer, business and stakeholder needs are severally or jointly identified and used as a basis for the development of performance measures" (Bourne *et al.*, 2003, p.6). Under this framework, the measures are primarily designed with an aim of controlling the progress of the businesses towards fulfilment of these needs. Representative research studies that support this procedure include Kaplan (1994), Kaplan and Norton (1993; 1996b), and Neely *et al.* (1996; 2000).

- The 'audit-led' procedure: In contrast to the 'needs-led' procedure, the 'audit-led' procedure can be considered to be a bottom up approach, whereby the design of a PMS is initiated with an audit of the measures being used to evaluate the organisation's performance. "The information collected is then used to challenge the status quo and as a basis for amending the existing performance measures" (Bourne *et al.*, 2003, p.6). An example of this approach is the work completed by Dixon *et al.* (1990).

- The 'model-led' procedure: This is based on a "prescribed theoretical model of the organisation as a rationale for designing the performance measures that should be deployed" (Bourne *et al.*, 2003, p.6). An example of this kind of approach is the propositions proposed by Krause and Mertins (1999).

However, as demonstrated by Platts (1990; 1994), 'procedure' should not be the only criterion that academics and practitioners can follow during the design of their PMSs. According to the perspective of change management, process consultation, facilitation and the structure of the debate are all necessary components of performance measurement design (Schein, 1969; Duck, 1993; Martin, 1993; Hunter *et al.,* 1995) but they have been considered to be the 'soft' issues critical to the successful implementation of any PMS (Bourne *et al.*, 2003). Given this point of view, Bourne (1999) claims that the development of a new performance measurement is a "learning process" and the study of participation and engagement is important for the outcome of a performance measurement design (Neely *et al.*, 2000). In order to address the 'soft' issues, the 'approach-based' process of performance measurement design was raised and this second category incorporates:

- The 'consultant-led' approach: The 'consultant led' approach is "where the majority of work is undertaken by an individual (or group of individuals, usually consultants – hence the term used here) almost in isolation from the rest of the management team" (Bourne *et al.*, 2003, p.7). This approach is underpinned by reviews of the works being conducted by the consultants. Information and data are normally gained and collected through interviews of managers and key stakeholders (e.g., management advisors). An example of a study that was undertaken in accordance with this approach is the research by Kaplan and Norton (1993).

- The 'facilitator-led' approach: Unlike the 'consultant-led' approach, the 'facilitator-led' approach is a configuration in which "the majority of the work is undertaken by the management team together in facilitated workshops" (Bourne *et al.*, 2003, p.7). In the workshops, the members of the management team are encouraged to criticise the measurement work done by others. In essence, the 'facilitator-led' approach currently is not limited to the management team, but has been extended to elicit information from the assembled group. Examples of this approach are the later research conducted by Kaplan and Norton (1996a) and Norton (1997), for the amelioration of the BSC, and the study conducted by Neely *et al.* (1996).

As noted above, while the 'procedure-focused' methods are concerned with the 'hard' factors (performance measures) in the design of a PMS, the 'approach-based' processes focus on the 'soft' issues (opinions of management personnel). Bourne *et al.* (2003) claimed that it is difficult to determine which process can overwhelm the other one. In essence, numerous studies of the development of PMSs or PMFs have been conducted by using multiple processes, for example, Kaplan and Norton (1993) and Neely *et al.* (1996), whereby the 'needs-led', 'consultant-led' and 'facilitator-led' processes were applied simultaneously. Bourne *et al.* (2000) and Neely *et al.* (2005) are the advocates of this method and suggest that the design of a PMS can start with an understanding of managers' and/or key stakeholders' viewpoints about the current practices in performance measurement and then performance measures can develop according to the needs and/or actual situations of the organisation. Nevertheless, deriving the performance measurement perspectives, which are known as the indicative aspects or the categories of homogenous KPIs, cannot be ignored during the process of identification of performance measures, because they are used to determine what performance indicators should be involved (Niven, 2006). Accordingly, this current research relied on the design strategy proposed by Bourne *et al.* (2000) and Neely *et al.* (2005) with a consideration of Niven's (2006) points of view; therefore, an interpretation of current practices in the performance measurement of PPPs was undertaken, then the performance measurement perspectives and their relevant KPIs were identified and derived in a step-by–step fashion (Figure 2.5).

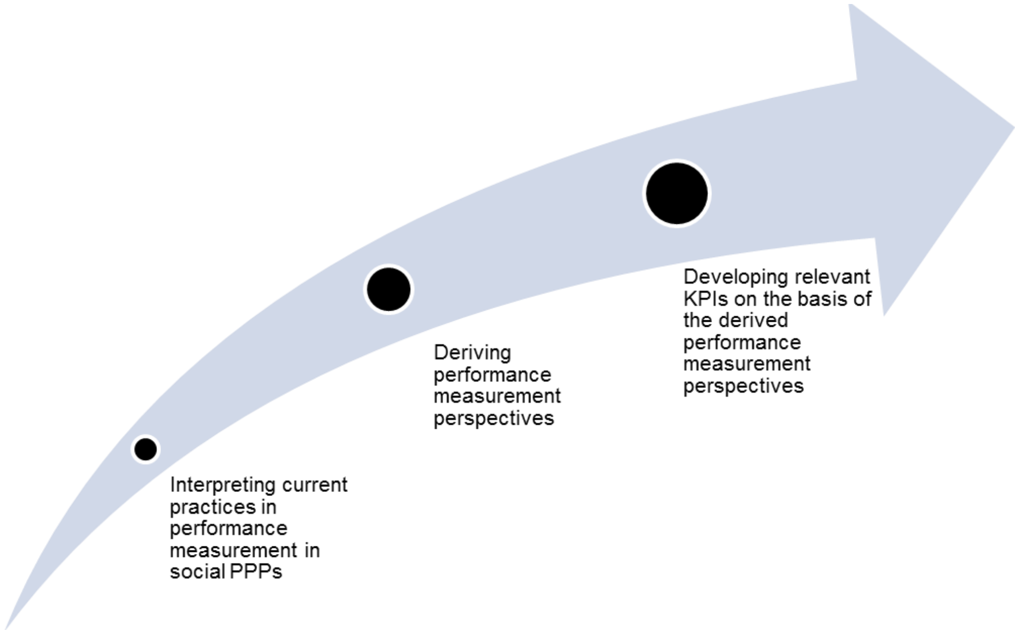


Figure 2.5 Design process of performance measurement system

2.5 Performance Measurements of PPPs

The performance measurement of PPPs, as demonstrated above, has not been identified as a main research area and, subsequently, has received limited attention in the normative literature, even though it is extremely important for a project's success (Yuan *et al.*, 2009). However, several empirical studies examining PPP performance measurements have been conducted over the past five years, for example, Garvin *et al.* (2011); Yuan *et al.* (2012); Mladenovic *et al.* (2013) (Table 2.3).

Table 2.3 Research related to PPP performance measurement

Authors	**Categories of KPIs**	**Project Types**
Garvin *et al.* (2011)	Organisational structures, remedies and dispute resolution, and hand-back requirements.	Economic
Yuan *et al.* (2012)	Physical characteristics, finance and marketing, innovation and learning, stakeholders and process.	Not specified
Mladenovic *et al.* (2013)	Economic, technical, and operation and maintenance.	Economic

Table 2.3 indicates that the majority of the research undertaken to investigate how to measure the performance of PPPs has tended to concentrate solely on KPIs within

the context of economic infrastructure projects. Theoretically, "KPIs are measures that are indicative of (the) performance of (an) associated process" (Beatham *et al.*, 2004, p.106), and they can also be deemed as the metrics "used to quantify the efficiency and/or effectiveness of an action" (Neely *et al.*, 2005, p.1229). However, the use of KPIs has received a great deal of criticism. For instance, KPIs are limited for any decision-making process because they are lagging indicators and, therefore, not powerful enough to improve performance (Bassioni *et al.*, 2004), which is particularly crucial to the success of PPPs (Yong, 2010). Further, KPIs are concerned with a particular project rather than company performance, and thus long-term corporate-related issues (i.e., strategy) cannot be addressed properly within a purely KPI framework (Kagioglou *et al.*, 2001).

An important principle of performance measurement is that performance measures must reflect the context in which they are applied (Neely, 1999). It has been previously discussed that PPP projects are undertaken by SPVs. An SPV is an independent and legal entity with a formal organisational structure and is responsible for the public asset's design, construction, operation and maintenance over a long concessional period (Figure 2.2). Therefore, the SPVs exhibit a dual character, implying that they are operating within a context where goals at company and project levels must be met (Zheng *et al.*, 2008; Chinyio and Gameson, 2009). In other words, performance measurements of PPPs should concentrate on the outputs, at both corporate and project levels, in a long-term context. Hence, a sole KPI is not robust in capturing the attributes of PPPs and a more complex performance measurement/ evaluation approach is urgently required (Yuan *et al.*, 2009). However, as identified by Toor and Ogunlana (2010), no widely and commonly accepted performance measurement framework is currently available for infrastructure projects, including PPPs. Thus, this research will fulfil the demand for a sophisticated approach to be devised for evaluating PPP performance.

2.6 General Construction Performance Measurement

To contribute to the performance measurement/evaluation of PPPs, there is a need to review performance measurements in construction, which include the approaches developed to measure general construction projects and construction companies. This is because PPPs are in the nature of construction projects, and each SPV formed to procure a project is a legal entity with a formal and sophisticated organisational structure. An interpretation and understanding of construction performance measurements at both project and company levels is vital for determining how to substantially ameliorate the performance measurement of PPPs, whereby both project and corporate goals must be achieved (Chinyio and Gameson, 2009; Yong, 2010).

2.6.1 KPIs and PMSs in Construction

Designing an effective and efficient system to measure business performance at either project or corporate level is a complicated and challenging process (Kagioglou *et al.,* 2001; Bourne *et al.,* 2000). The concept of performance measurement has received a great amount of attention because it is an essential activity that organisations must perform in order to achieve their strategies (Neely *et al.*, 2005), especially for those operating within the construction industry where both organisational and project goals need to be met (Love and Holt, 2000; Bassioni *et al.*, 2004). Fundamentally, performance measurement in construction has been focused mainly on three levels: (1) industry; (2) corporate; and (3) project (Elyamany *et al.*, 2007), with an emphasis being placed on KPIs and PMSs (Bassioni *et al.*, 2004; Haponava and Al-Jibouri, 2012).

The use of KPIs has become the most popular performance measurement approach for the construction sector (Bassioni *et al.*, 2004; Beatham *et al.*, 2004; Chan and Chan, 2004; Haponava and Al-Jibouri, 2010; Lai and Lam, 2010). Table 2.4 identifies the KPIs that have been derived for construction projects by prior research. Basically, most construction organisations measure their performances on the basis of traditional quantitative methods, such as financial reports, and at the project level using time, cost, quality and safety. It was discussed above that KPIs have been criticised owing to their deficiencies that are normally referred to as lagging and project-focused indicators, even though they are being widely applied within the construction industry.

Table 2.4 KPIs at the construction project level

Authors	**Aspects for Measurement**	**Measurement Levels**
Kumaraswamy and Thorpe (1996)	Cost/financial, project duration, quality, health and safety, quality of workmanship, functionality/utility	Project
Songer and Molenaar (1997)	Cost/financial, project duration, quality, client and project manager satisfaction, user expectation and satisfaction, quality of workmanship, meeting specification, dispute minimisation	Project
Lim and Mohamed (1999)	Cost/financial, project duration, quality, client and project manager satisfaction, user expectation and satisfaction, quality of workmanship, health and safety, functionality/utility	Project
Love and Holt (2000)	Product, service performance, corporate ability, individual ability, productivity, quality, environment, financial aspects	Company
Cox *et al.* (2003)	Time, cost, quality, safety, productivity	Company and project
Chan and Chan (2004)	Cost/financial, project duration, quality, speed of construction, transfer of technology, quality of workmanship, health and safety	Project
Sohail and Baldwin (2004)	Time, cost, quality, stakeholders' roles and responsibilities, partnership, social-economic factors	Project
Luu *et al.* (2008b)	Time, cost/financial, quality, safety, customer satisfaction, project team performance, change and material management	Project
Haponava and Al-Jibouri (2010)	Time, cost/financial, quality, safety, value and objectives, stakeholders' requirements, communication	Project
Hwang *et al.* (2010)	Schedule (time), cost/financial, dimension (space)	Project
Lai and Lam (2010)	Time, profit, environment, quality, safety, effectiveness of process, level of dispute, staff satisfaction, innovation	Project
Idrus *et al.* (2011)	Quality of finished project, construction cost, construction time, occupational health and safety, labour dependency, contractor's project management, quality of coordination by the construction team, contractor's manpower capacity, construction flexibility, environment friendliness, level of technology	Project

Molenaar and Navarro (2011)	Cost, schedule, quality, safety, public information management, environmental stewardship, traffic reliability during construction	Project (i.e., highway projects)
Almahmoud *et al.* (2012)	Cost, time, scope, quality, safety, satisfaction	Project

Apart from KPIs, PMSs also have been substantially considered in relation to construction (e.g., Kagioglou *et al.*, 2001; Bassioni *et al.*, 2005; Luu *et al.*, 2008a; Chan, 2009), and Table 2.5 reports the key studies of PMSs relating to construction. Despite their widespread applications, PMSs are normally used at the industry and corporate levels, while only a limited number of studies have developed them at the project level (Bassioni *et al.*, 2005; Luu *et al.*, 2008a; Chan, 2009). In fact, PMSs are suitable for measuring not only industry or corporate performance, but also project outputs and/or outcomes. Considering this perspective, Alarcon and Ashley (1996) developed a general performance model (GPM), and Kagioglou *et al.* (2001) proposed a BSC that encompasses the 'project perspective' with the purpose of systematically measuring construction projects.

Table 2.5 Key studies of PMSs in construction

Authors	**PMSs and Measurement Perspectives**	**Measurement Levels**
Alarcon and Ashley (1996)	GPM: Cost, schedule, value, effectiveness	Project
Kagioglou *et al.* (2001)	BSC: Customer, internal business process, learning and growth, financial	Project
Bassioni *et al.* (2005)	Framework based on BSC and Business Excellence Model: Leadership, stakeholder focus, strategic planning, deployment	Company
Luu *et al.* (2008a)	BSC-oriented SWOT Matrix: customer, process, learning and growth, financial	Company
Chan (2009)	BSC: Customer, internal business process, learning and growth, financial	Industry

2.6.2 KPIs, PMSs and PPPs

Performance measurement systems are viewed as total systems integrated with a set of measures (i.e., KPIs) (Neely *et al.*, 2005). They overwhelm sole KPI framework because of their emphasis on, and indications of, particular issues that are essential for achieving short- to long-term goals at multiple levels (e.g., industry, corporate and project) (Kagioglou *et al.*, 2001). The management of PPPs emphasises meeting both short-term objectives and long-term strategic goals at both project and corporate levels (Grimsey and Lewis, 2005; Yong, 2010). Similar to traditional lump sum projects, PPPs possess a short-term objective regarding the successful delivery of projects. However, the long-term strategic goals of PPPs make them distinct from other conventional projects (Kwak *et al.*, 2009). Fundamentally, PPP projects share a common strategic goal: the achievement of best value, which emphasises efficiency, V*f*M and performance standards (Akintoye *et al.*, 2003; Zhang, 2006b). This strategy covers issues in relation to the "public client's overall strategic plan and mission objectives, (the) private sector's long-term development and payoff strategy, (and) the general public's requirements of quality public facilities and services" (Yuan *et al.*, 2009, p.257). Although V*f*M is a key component of best value, it has been viewed as the principal benchmark of the strategic objectives of PPPs in the majority of the countries across the world (Grimsey and Lewis, 2005; Henjewele et al. 2011). The Treasury Taskforce (1997) of the UK states that PPPs should not be used if they cannot provide taxpayers with better V*f*M than traditional procurement.

Mindful of this critical issue, PMSs are more suitable for PPPs than sole KPIs when evaluating projects' performances because they express a stronger ability to make balanced measurements that involve measures specifically devised to reflect and improve the effectiveness and efficiency of the actions taken to achieve strategic goals and tactical objectives at different levels (Neely *et al.*, 2005). Table 2.6 shows a comparison between PMSs and the sole KPIs framework, and indicates that PMSs possess a higher suitability for PPP performance measurement.

Table 2.6 Comparison between PMSs and sole KPIs framework in a PPP context

Approaches	**Inherent Critical Issues in PPP Performance Measurement/Evaluation**	
	Project-level Objectives	**Corporate-level Goal**
PMSs	√	√
Sole KPIs framework	√	×

In spite of the widespread benefits attributable to the use of PMSs, performance measurements of construction projects have been categorised as being product-oriented evaluations, whereby the performance of the projects are normally measured after the completion of construction (Haponava and Al-Jibouri, 2012). Therefore, as criticised by Haponava (2009) and Haponava and Al-Jibouri (2010), the product-oriented evaluation is only a simple review of construction inputs and outputs and is not useful for improving the projects' performances during the development process To put it simply, the project life-cycle/process perspective has not been substantially addressed in the practice of performance measurement within construction, including PPP projects. Notably, endogenous and exogenous factors that can substantially affect project success may change significantly throughout the life-cycles of the projects (Sidwell, 1990, Guo *et al.*, 2010; Singh *et al.*, 2011). With this in mind, to obtain performance measurements in construction projects without considering a life-cycle perspective juxtaposed with dynamic measures can lead to ineffective and inefficient decision-making during the delivery of the projects. Yet, despite the importance of life-cycle performance measurements, this remains an area that has received limited attention at the project decision-making level within construction.

2.7 Chapter Summary

PPPs have attracted lots of attention from academia, as well as industry; therefore, a plethora of studies have been undertaken to investigate this prevalent procurement situation. An in-depth, comprehensive and critical review of the normative literature of PPPs has been conducted in this chapter. The review provides this research with a solid contextual and theoretical foundation to contribute to the body of knowledge of PPPs.

A number of concepts that are necessary for this research were introduced and classified, including their definitions, typical types and structures, and the project life-cycles of PPPs were discussed. In addition, an exploration of the normative literature suggests that past research on PPPs primarily concentrated on six key areas (i.e., CSFs, the roles and responsibilities of governments, concessionaire selection, risk management, cost and time efficiencies, and project financing), but was mostly limited to performance measurement, which has been acknowledged as one of the

CSFs for the delivery of any PPP project.

To determine how to design performance measurements for PPPs, a review of the development and importance of performance measurement was also initiated and it suggests that performance measurement is vital for organisational long-term success. Following this, the studies regarding the design processes of performance measurement systems also were analysed with the aim of introducing and describing how to develop a PMS. This will act as a basic route for designing a PMS in this research. Finally, a review of the literature of performance measurements in relation to general construction projects was presented in this chapter, in order to conceptually identify a promising way to develop a new performance measurement approach for PPPs. It was deduced that KPIs and PMSs are two measurement mechanisms that dominate within construction, and PMSs are more appropriate for PPPs because they tend to marry with the nature and inherent features of PPP projects, whereby short- to long-term objectives and goals at both project and corporate levels must be achieved. However, in previous research relating to construction management, there is a lack of project performance evaluation methods that consider the life-cycle perspective in their practices (including PPPs), even though it is an extremely critical issue.

In summary, according to the reviews presented in this chapter, this research will make an essential contribution to the normative literature through the development of a life-cycle PMS for PPPs, in order to bridge the significant knowledge gap regarding PPPs in terms of a ‘process perspective’. This PMS will be specifically demonstrated, tested, examined and enriched, in the following chapters, through the use of a mixed methods research approach, which involves interviews, case studies, a questionnaire survey and econometric modelling. This sophisticated research methodology will be presented in the next chapter.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Chapter Introduction

This research seeks to significantly contribute to the body of knowledge of Public-Private Partnerships (PPPs) through the development of a life-cycle performance measurement system (PMS) for PPPs. To achieve this aim, the research strategy, philosophy and approaches adopted for the investigation are described in this chapter.

This chapter identifies and justifies the strategy and philosophy of this research. Then, upon this basis, the exploratory study, the case studies and quantitative modelling are outlined. Also introduced and discussed, sequentially, in this chapter are other important issues, regarding the data collection, research instruments and techniques (e.g., interview, questionnaire survey, Confirmatory Factor Analysis and vector error correction model).

3.2 Research Strategy

Based on the primary research aim determined in Chapter 1, the most important issue that had to be considered during the initial stages of the research was how to evaluate PPP projects effectively and comprehensively and what performance measures (i.e., key performance indicators – KPIs) needed to be used (Yuan *et al.*, 2009). The previous PPP research that has been critically reviewed in Chapter 2 indicated an important hint with regard to the approaches that would be suitable for this research. For instance, the studies conducted by Yuan *et al.* (2012) and Mladenovic *et al.* (2013) focused on developing KPI frameworks for PPPs through the use of questionnaire surveys. In essence, the questionnaire survey has been the most prevalent approach for testing the derived KPIs of construction projects (e.g., Cox *et al.*, 2003; Chan and Chan, 2004; Luu *et al.*, 2008b; Molenaar and Navarro, 2011; Almahmoud *et al.*, 2012).

Alternatively, Haponava and Al-Jibouri (2010; 2012) applied a mixed-methods approach to develop a performance measurement framework for construction projects. Specifically, in their two studies, exploratory interviews were first undertaken to obtain the information required to identify which issues needed to be covered in evaluating the performance of a construction project. After that, they validated the KPIs that were derived from the literature by using a quantitative approach (i.e., content validity ratio), and then undertook a case study to test the applicability of the proposed framework. Notably, such ‘triangulation’ has been recognised as an effective method by construction management researchers when investigating the important managerial issues (e.g., input, output and process) of projects being studied (Love *et al.*, 2002). Therefore, it is worthy of consideration for research on PPPs, which are most commonly formed for construction projects.

The concept of triangulation is based on the assumption that the inherent bias that originates in a study, from its data sources, researcher and method, can be neutralised by introducing other data and methods, as well as the views of a different investigator (Jick, 1974). According to Black (1993), the design methodology should be based on the data that needs to be collected to achieve the identified research objectives. Thus, the methodological design of this research is similar to Haponava and Al-Jibouri (2010; 2012), and was developed by carefully considering the data required to support the realisation of the objectives identified in Chapter 1.

Research design is defined as a logical sequence that connects the findings derived from empirical studies to the initial question(s) and ultimate conclusion(s) of the research (Creswell, 2014). In this thesis, the research design was based on ‘sequential triangulation’, whereby qualitative and quantitative methods are used for studying the topic simultaneously (e.g., interviews, case studies, questionnaire survey and econometric modelling) (Figure 3.1). It is notable that the triangulation approach has been advocated by researchers and widely applied in a variety of studies for both social and natural sciences (e.g., Jick, 1979; Todd, 1979; Morse, 1991; Colgate, 1998; Oppermann, 2000; Love *et al.*, 2002; Leidy and Wyrwich, 2005; Plowright *et al.*, 2008; Bjurulf *et al.*, 2012). Figure 3.1 illustrates that this research was conducted following the procedures below:

1. Undertaking an exploratory study to propose a conceptual model;
2. Conducting case studies to empirically test the feasibility of the conceptual

model and to refine the hypotheses determined for quantitative studies;

3. Testing the derived hypotheses by using quantitative modelling.

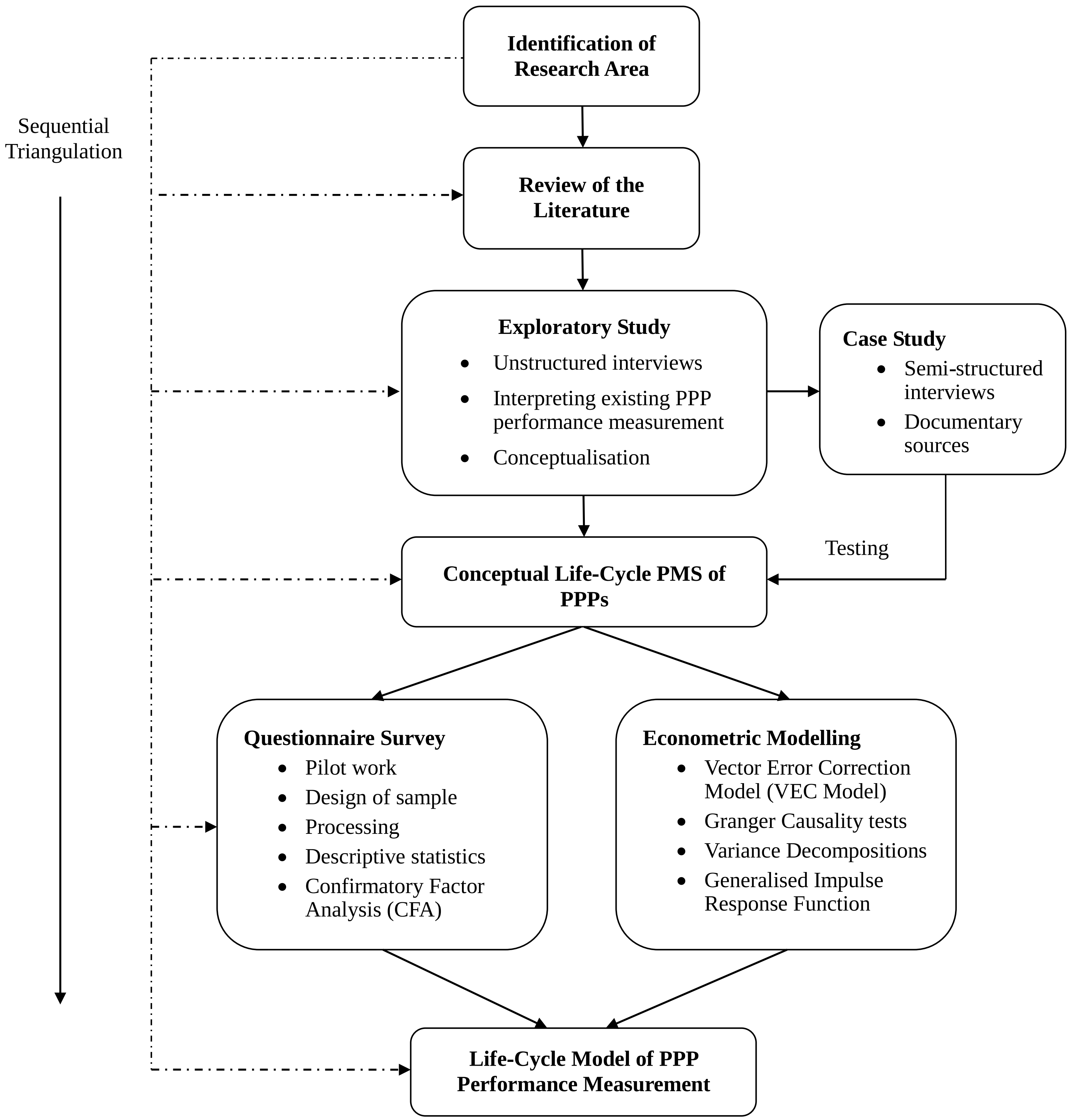


Figure 3.1 Research design and strategy

As indicated by Figure 3.1, both the knowledge derived from the literature and the data gained from the interviews were used to conceptualise a life-cycle PMS that could be applied to PPPs. Then, this conceptual model was empirically tested by the case studies and further validated and refined through the use of quantitative statistical and econometric techniques. Notably, the role of the case studies was critical in this research because they not only empirically examined the feasibility of the whole conceptual framework but also explicitly highlighted and refined the hypotheses that needed to be tested by the quantitative studies. This provided a solid theoretical base for CFA, which has been acknowledged as a theory-driven technique and therefore requires a clear and reliable conceptually hypothesized model (Schreiber *et al.*, 2006). According to Flyvbjerg (2006), the case study is valuable for all stages of a research project and, therefore, it is the prerequisite of a comprehensive quantitative analysis. In addition, econometric techniques are robust in identifying the statistical relationships between the observed variables, while the questionnaire survey is capable of verifying the appropriateness of the variables (Jick, 1979). Mindful of this, it is noted that the conceptual model proposed in this research would undergo a rigorous quantitative examination.

The process of building and testing theory should be an integral part of the research process (De Vaus, 1991). Walker (1994) argues that the focus of testing a theory must be moved from the general area to a particular issue in order to evaluate the variance between the expected and observed responses, and researchers should attempt to explain why there may be a significant variance. De Vaus (1991) claims that the "key to empirical testing of theory is to look for evidence that disproves the theory, as supporting examples can usually be found but are (a) weak form of evidence" (p.21). Fundamentally, empirical research can offer strong evidence to explain phenomena, while interpretive methods yield supporting evidence only and they lack the ability to validate (Popper, 1959; Marczyk *et al.*, 2005).

According to Schultz (1962), "the most serious question, which the methodology of the social science has, is: How is it possible to form objective concepts and objective verifiable theory of subjective meaning structures?" (p.34). In addressing this issue, key-informant interviews and case studies were conducted in the preliminary stage of this research to interpret and identify 'how' the performance of PPP projects is being evaluated within the industry and 'what' actions should be taken to improve the existing evaluation approach. In essence, a performance measurement can be improved only after its problems have been identified. Neely *et al.* (2005) support this point of view and argue that an in-depth interpretation of current performance measurement/evaluation is critical to the successful development and implementation of a new measurement approach within an organisation. As suggested by Haponava and Al-Jibouri (2010; 2012), key-informant interviews and case studies are the prevalent methods being used in the exploratory works that aim to identify the deficiencies of the approaches applied to measure construction project performance.

3.3 Justification of Research Approach

PPPs are special and complex construction projects because of their integration of public and private sectors (Kwak *et al.*, 2009; Yong, 2010). "Research in construction management can be categorised as being at the intersection of natural science and social science (Love *et al.*, 2002, p.294)". While natural science investigates events that are comprised of a variety of facts independent from people's thinking, social science concentrates on studying participants (i.e., key stakeholders in projects). Accordingly, two methodologies have tended to dominate in the empirical research of construction management; the positivist and interpretivist approaches. However, this is in spite of Love *et al*. (2002) and Sage *et al*. (2014) suggesting the need for methodological pluralism to advance the "scope of theory" in construction and engineering management.

Empiricism is referred to as a set of philosophical beliefs that have developed upon the idea that experience, rather than reason, is the main source of the knowledge of the world (Morick, 1972). Therefore, empirical research is a practical way of investigating the nature of the world or society by using the methods that focus on actual experiences rather than theories or assumed principles. In other words, "empiricism dictates that one can settle questions about the nature of human thought and action by accepting only assertions and claims that can be probed by direct observation" (Love, 2001, p.64). Important ideas and concepts can be derived and raised through discussion, argument and the opinions of various authorities.

3.3.1 Interpretivist and Positivist Approaches

The interpretivist approach focuses on selecting what data should attend to imply ‘theory’. The belief of interpretivism relating to ontology and epistemology is that realities are multiple and relative (Hudson and Ozanne, 1988). These realities are underpinned by other systems for their meanings, leading to the fact that they are difficult to interpret in terms of fixed realities (Lincoln and Guba, 1986; Neuman, 2006). The interpretivist approach avoids using structural frameworks and adopts more flexible structures, which are receptive to deriving the meanings of human interactions and capturing what is perceived as reality (Carson *et al.*, 2001; Black, 2006). For that matter, interpretivist researchers are open to new knowledge, building that knowledge with the help of informants as they investigate topics of interest on the basis of prior insight into the research context. This insight is assumed to be insufficient for developing a fixed research design, owing to the multiple, complex and unpredictable nature of what is perceived as reality (Hudson and Ozanne, 1988). Thus, inductive inference is dominant within the interpretivist approach, whereby reasoning proceeds from specific data to general law. The data suggest generalisations, which can lead to the discovery of a lawful relationship through repeated testing and confirmation (Babbie, 2007).

The positivist approach emphasises understanding the world within the context of the natural sciences. It places emphasis on facts, as distinct from values or meanings, and the use of the scientific method by which theory is deduced as a result of generating and testing hypotheses (Hughes, 1980). The ontology of positivism is based on a belief that the world is external and a single objective reality exists for any research phenomenon (Carson *et al.*, 1988; Hudson and Ozanne, 1988). Hence, positivist researchers primarily adopt a structured and controlled approach, with a clearly identified topic and constructed hypotheses, when undertaking their research (Churchill, 1996). Positivist researchers are isolated from the participants of the research, creating a distance and making an explicit distinction between science and personal experience (Carson *et al.*, 2001). Essentially, a positivist can identify causes and effects through ‘the constant conjunction’ of events, resulting in what has been called the ‘covering law’ orthodoxy (Popper, 1959). This orthodoxy can be essentially devoted to the pursuit of explanations, which take the form of general laws. In contrast with interpretivism, deductive reasoning that emphasises ‘top-down’ logic plays a major role in positivism. In empirical research, “both induction and deduction are essential to the process of the hypothetico-deductive scientific method” (Babbie, 2007, p.45).

As mentioned above, the generalisations derived from the data can result in general law by repeatedly testing and confirming them. According to Popper (1959), theories cannot be conclusively proven from repeated observations that confirm them; however, they are able to be disconfirmed or falsified by just one instance where their predictions are not confirmed. Fundamentally, the epistemological position of an interpretive perspective rejects the natural sciences as an appropriate base for social science inquiry (Hudson and Ozanne, 1988). The anti-naturalist school of thought believes that there is a significant difference between the subject matter of the social sciences and that of the natural sciences and, therefore, an entirely different approach to empirical research is required (Love, 2001).

3.3.2 Approach for the Research on PPP Performance Measurement

A barrier to the use of a purely positivist approach for this research originates from the nature of the principal participants involved in PPP projects. If a positivist ontology was solely assumed, the project participants being studied would be considered to be uniform and passive agents who do nothing more than observe and record the conjunction of events. Under this view, “the social system that exists in a project would be taken to be no more than the sum of the individuals” (Love *et al.* 2002, p.296). Nevertheless, human beings are capable of learning and changing, both consciously and unconsciously, not only their own behaviours but also the form and structure of any system to which they belong. Such ontological claims do challenge the wisdom of attempting to apply a purely positivist methodology to the social system of construction projects, especially PPPs.

Public-Private Partnerships, as mentioned above, are sophisticated construction projects with complicated stakeholder networks and delivery processes (Kwak *et al.*, 2009; European Invest Bank, 2011a). “Construction projects are extremely dynamic and complex and invariably consist of multiple interdependent components” (Love *et al.*, 2002, p.296), which contain multiple interacting feedback processes and non-linear relationships. Moreover, construction projects are essentially human enterprises and, therefore, cannot be solely understood in terms of technical relations among their components or by purely using a scientific approach. Hence, a major problem associated with the management of such projects is in regard to the explanation and predication of human behaviour; however, the scientific approach assumes that human behaviour can be based on the premise that regularity does exist (Chau *et al.*, 1998). Further, Neely *et al.* (2005) argues that human issues maintain a decisive role in performance measurement and, therefore, interpreting the practice in performance measurement and practitioners' perspectives is extremely critical to the success of a PMS. However, if the positivist approach is solely applied for designing and implementing a new PMS, many critical and in-depth viewpoints of the key stakeholders/practitioners will be largely ignored (Bourne *et al.,* 2000).

The scientific method has no place in social research if human behaviour is completely random and unpredictable (Chau *et al.*, 1998). Nevertheless, a large amount of data that are necessary for identifying the factors to be involved in measuring the performance of a PPP are concerned with the managerial issues of the project, which are normally referred to as 'intangible' or 'soft' variables (Yuan *et al.*, 2009). This implies that the interpretivism should not be discarded in the research on PPP performance measurement/evaluation. Nonetheless, as claimed by Chau *et al.* (1998), the functions of a positivist approach and the interpretivist method are applied differently in their pursuit of knowledge due to the attributes of the research problem to be addressed. This determines that careful consideration must be given to the problematic issue of how to frame the research problem (Black, 1993). Fellows and Liu (1996) elaborate that the design of methodology must be set against: (1) the objectives of the research; (2) the needs of each particular stage that is reached; and (3) the type of knowledge to be explored.

A comprehensive performance measurement/evaluation of PPPs is a sophisticated system that should be suitable for the nature of PPPs and able to capture the 'intangible' and 'tangible' deliverables or 'hard' and 'soft' issues of the projects (e.g., stakeholder satisfaction and expectations, strategic goals, engineering and technology) (Yuan *et al.*, 2009; Zhou *et al.*, 2013). Over the last decade, there has been limited attention paid to the investigation of how to comprehensively evaluate the performance of PPPs (Hodge, 2004; Yuan *et al.*, 2012). With this in mind, this research was conducted with the aim of obtaining a balance between inductive and deductive reasoning and, therefore, it was designed as a study that synthesises both qualitative and quantitative research techniques (Love *et al.*, 2002). This integrative research approach provides benefits because it is able to (Greene *et al.*, 1989):

- enable triangulation and thus discover the convergences of results;
- be complementary, because overlapping and different facets of phenomena may emerge;
- be developmental, whereby findings from qualitative research is used sequentially to help inform quantitative research; and
- add scope to the research.

Robson (1993) states that "we can never obtain results for which some method has not been used to collect them, (so) the only feasible strategy is to use a variety of methods" (p.290). This implies that some unknown and inexplicit issues in regard to the obtained results will be triggered if the research solely relies on a singular methodological approach. Therefore, to gain a better understanding of the performance measurement/evaluation of PPPs, a triangulation approach, which refers to a combination of different methods, was applied in this research. In essence, "triangulation is not an end in-itself but an imaginative way of maximising the amount of data collection" (Love, 2001, p.67).

Although a plethora of studies have been undertaken that advocate the application of 'triangulation', some opposite perspectives have been raised from several schools of thought (e.g., purists and situationalists). For instance, Blaikie (1992) argues that the qualitative and quantitative approaches should not be used simultaneously in a research study. Nevertheless, pragmatists claim that there is a false dichotomy existing between qualitative and quantitative approaches, and researchers need to effectively and efficiently adopt both paradigms in an understanding of social phenomena (Easterby-Smith *et al.*, 1994; Creswell, 2014). As stated by Robson (1993), "by using a logic equivalent to that of the classical test theory, the error due to methods is regarded as averaging out when a triangulated approach is used as a research methodology" (p.290).

3.4 Exploratory Study

A balanced combination of both the inductive and deductive methods, as introduced above, is the basic research strategy of this thesis (Figure 3.1). Therefore, a qualitative exploratory study and case studies were undertaken for conceptualisation and model validation, respectively. Essentially, the use of an exploratory study is prevalent within research that is based on induction and can be applied to derive hypotheses, while the case study is a powerful tool for model validation, in addition to hypothesis generation.

The exploratory study has been widely used and is normally conducted when the problems are in a preliminary stage. Theoretically, exploratory research can not only assist in determining research design and data collection, but also can be used to draw definitive conclusions and provide insights into the given situation (Babbie, 2007). According to Nunes *et al.* (2010), the application of an exploratory study in a research helps to frame and refine the research topic and questions, gain background information, develop the research method and propose its conceptualisation. Kotler and Armstrong (2006) elaborate that the aim of an exploratory study is to understand and interpret preliminary information and/or build up the conceptual framework.

According to De Vaus (1991), exploratory studies are critical and should be initiated before the main research. They are "an invaluable source of contextual data, which have the ability of moving the researcher into the phenomenon's ecology and into the core of respondents' accounts, thus partitioning the broad emergent theory into workable, theoretically-relevant conceptual units" (Nunes *et al.*, 2010, p.75). Samson (2004) argues that the research gaps often emerge after evaluating the data collected from exploratory studies. In social science, exploratory research is popular and it can be used to address all kinds of questions (i.e., 'what', 'how', and 'why') and then generate valuable conceptual issues from the data itself (Babbie, 2007).

Exploratory study, notably, relies on literature review and/or qualitative approaches, in which in-depth interviews play a dominant role (Nunes *et al.*, 2010). A study can commence with exploratory research that is underpinned by qualitative data collection, and the researcher(s) can use the results of the analysis of the collected data to design the subsequent study (Tashakkori and Teddlie, 1998). Van Teijlingen *et al.* (2001) further specify that the first stage of a research project may encompass the use of a series of in-depth interviews, so as to address the issues to be investigated and pilot the questionnaire to be used in the future survey.

An exploratory study can be used to create analytical generalisations rather than a statistical summary; thus, it can capture the complexity and dynamism of the organisational settings of projects (Loosemore, 1994; Blackwood *et al.*, 1997). In this instance, the 'theory' to be generated in this research can be defined as a set of concepts relating to 'life-cycle performance measurement', which can effectively and efficiently reflect the entire performance of PPPs. A theory can provide for a critical insight into an interpretation, which leads to an in-depth understanding of the phenomenon that is being studied (Agar, 1986).

Inductive inference, as implied above, is vital for exploratory study. Nevertheless, existing theories will be largely neglected if a purely inductive approach is applied to the research problem (Love, 2001). Essentially, the inevitable result of a purely inductivist statement will be 'theory-laden' (Chalmers, 1976). While "it is difficult to ignore previous theory accrued in one's mind before commencing the research process" (Glasser and Strass, 1987, p.253), a creative and useful theory, presumably, would not be generated from any research that solely relies on deduction (Love, 2001). This argument can be supported by Parke (1993), who states that "both extremes are untenable and unnecessary and the process of on-going theory advancement requires 'continuous interplay' between the two so as to lessen the gap between know and knowable" (p.256). In fact, "induction and deduction are dialectical and not mutually exclusive research approaches" (Miles and Huberman, 1984, p.134), and prior identified theory provides assistance in both guiding the data collection process and interpreting research findings (Love, 2001).

Exploratory study plays an important role in a plethora of studies in the normative literature of construction project management and PPPs (e.g., Gyi *et al.*,1999; Low and Shi, 2002; Love and Irani, 2004; Thevendran and Mawdesley, 2004; Tranfield *et* *al.*, 2005; Dewlaney and Hallowell, 2012; Jugdev *et al.*, 2013; Pinder *et al.*, 2013; Liu *et al.*, 2015b). Turner (2005) argues that an exploratory study is critical to project management research because it is useful for deeply understanding the risks and uncertainties of the projects' processes and its technical and commercial issues. PPPs, as addressed above, contain more dynamic and complex processes and technical business issues than are present for general construction projects. For that matter, it is rational and necessary to conduct an exploratory study for this research.

3.5 Case Study

3.5.1 Role of Case Study in Research

A case study is an in-depth examination of the contextual information of a single example. According to the traditional wisdom, a case study "cannot provide reliable information about the broader class, but may be useful in the preliminary stages of an investigation since it provides hypotheses, which may be tested systematically with a large number of cases" (Abercrombie *et al.*, 1984, p.34). With this view, a case study is normally used to generate hypotheses. Dogan and Pelassy (1990) state that "one can validly explain a particular case only on the basis of general hypotheses" (p.121).

Case study possesses the nature of an exploration and it is suitable for research that attempts to uncover a new topic from an original perspective (Hakim, 1987). In social science, it is widely used in a wide range of topics for the purpose of exploring different issues. For instance, as advised by Miles and Huberman (1984), qualitative data gained from case studies can be used to "preserve the chronological flow, assess causality and derive fruitful explanation" (p.15).

Based on the conventional perspective, a case study is: (1) most useful for generating hypotheses; that is, in the first stage of a total research process (while other methods are more suitable for hypothesis testing and theory building); and (2) biased towards verification, that is, it has a tendency to confirm the researcher's preconceived notions (Flyvbjerg, 2006, p.221). To put it simply, it is traditionally considered to be a pilot method that is only suitable for the preparation of the systematic hypothesis testing of a 'real' study. As argued by many researchers, there is no value in a case if it is not linked to hypotheses.

Case study, essentially, is "useful for both generating and testing of hypotheses but is not limited to these alone" (Flyvbjerg, 2006, p.229). In fact, this point of view can be dated back to the 1970s, during which Eckstein (1975) asserted that "case studies are valuable for all stages of the theory-building process" (p.80). During the theory building process, a case study is also appropriate for testing or verifying propositions (Flyvbeerg, 2006), though some scholars criticise that there is a subjective bias in the use of a case study because it is not underpinned by 'scientific methods' and allows too much room for the researcher's arbitrary justifications; therefore, they are less rigorous than quantitative methods and their outputs related to proposition testing are unreliable (Diamond, 1996). However, such aforementioned critique is criticised by Campbell (1975) as making fallacious points, and he believes that the case study is as rigorous as quantitative methods because it "can 'close-in' on real-life situations and test views directly in relation to phenomena as they can unfold in practice" (Flyvbjerg, 2006, p.235). In construction management research, case studies have been acknowledged as an effective way to test the feasibility and applicability of the performance measurement approaches of construction projects (e.g., Chan and Chan, 2004; Bassioni *et al.*, 2005; Haponava and Al-Jibouri, 2012). This is because theorising and testing related to construction management should run alongside practical situations; otherwise, the dangers of armchair theorising or validation would emerge (Seymour and Rooke, 1995).

Bonoma (1985) argues that the case study is a methodology that largely relies on interviews, verbal reports and/or unobtrusive observation as its primary data sources. Yin (1984) suggests that the case study is primarily adopted to investigate technical issues of a contemporary phenomenon within the 'real-world' context and, thus, it needs to be used when multiple sources of evidence are applied and/or when it is difficult to ascertain the boundaries between the observed phenomenon and its context. Testing the PMS of a PPP needs to be based on various evidences to ensure validity because PPPs are complex projects with the participation of both public and private sectors. In addressing this issue, a multiple case design with multiple methods was used to enable comparisons and contrasts to be drawn from the case projects, because replication forms a foundation in dealing with the problematic issue regarding validity (Yin, 1984).

3.5.2 Unit of Analysis

Unit of analysis is the main entity being analysed in a study and it can be expressed in a variety of forms via individuals, groups, activity processes and/or the dimensions of organisational behaviour (McClintock *et al.*, 1979). According to Yin (1984), a case study offers the framework within which the unit of analysis fits. Essentially, the units of analysis vary according to the dimensions of the scope of activities and they are bound together by the fact that they are embedded in the same case, incorporating identifiable boundaries, and a sequence of common questions is applied to them (McClintock *et al.*, 1979).

Units of analysis, in research, are related to the 'what' and 'who' that will be, or are being, investigated and analysed. Under the exploratory stage of this research, the units of analysis were the social infrastructure of PPP projects. The selection of projects to be studied forms a corollary that is critical to decisions about the units of analysis (Love, 2001), in this case because the complexities originating from different contract types of PPPs determine the areas of focus for a projects' performance measurements (Yuan *et al.*, 2009). In this research, the participating organisation was used as a contextual backdrop to circumstances for each project rather than the object under investigation, even though its features and characteristics were important in the analysis of cases.

The boundaries of the social infrastructure of PPPs, on the other hand, have been taken into account, and they are defined as enabling the evaluation of the projects' performance over their life-cycles in the research. Thus, those individuals (i.e., senior project management personnel), who were essentially involved with the PPPs, acted as key informants for interpreting and identifying the core measures and perspectives that could be adopted to comprehensively and effectively measure the projects. Throughout the case studies, an experienced communications manager and a project director, both of whom were familiar with the developmental situations of the PPPs that were under study, served as coordinators to arrange interviews with the members of the project teams.

3.5.3 Case Study Selection

There are a variety of types of contract existing within the scheme of PPPs, such as DB, DBO, DBOM, DBFM and so on. As presented above, DBOM and DBFM are the two most widely-used PPP contracts in Australia, especially in the state of Western Australia, where this research was primarily conducted (WA Department of Treasury, 2015). For the purpose of effectively testing the developed PMS, the social infrastructure PPP projects that operated under contracts embracing almost all crucial steps (e.g., design, construction, finance, operation and maintenance) were most ideal for this research. Therefore, two concessionaires, which possessed extensive experience in the procurement of privately financed public assets and, at the time, were undertaking social infrastructure PPP projects that were procured using DBOM or DBFM in Australia, were approached and established as the reference points for this research.

In the early stages of the case studies, initial meetings were conducted with the management staff to explain the nature of this study and its major research aim and objectives. All partner organisations of the SPVs expressed their keen interest in participating in the research, since a comprehensive performance evaluation would ultimately benefit their future PPP projects by enhancing key stakeholder satisfaction and realising V*f*M.

The main contractor of each SPV identified one potential social infrastructure PPP project for the researcher, and further meetings were held to discuss the research nature with the senior management personnel of the projects, involving project managers and or project directors. The PMS to be developed would be a life-cycle model; thus, the PPP practitioners within the relevant public authorities who were responsible for the key works at the inception stages of the projects were met as well. The focal areas of these meetings were about the aim and objectives of this research and what kind of information the researcher would require.

Confidentiality was the utmost concern throughout the data collection period and analysis. To protect the identities of the participating consortia, serial codes were allocated to the projects that were involved in the research, which will be referred to as Project-A and Project-B. Generic descriptions of the projects used for study can be found in Chapter 5. Notably, the two case studies were undertaken in parallel, though there was a time differential of two months between the starts of the projects. This enabled the investigator to become familiar with existing performance measurement systems of social infrastructure PPPs.

3.5.4 Reliability of Case Study

Reliability refers to consistency and is viewed as a precondition for validity. The definitions of reliability are varied, and Stern (1979) identifies it as "consistence" and explains that "for observations to have scientific value, there must be assurance that different observers of the same people or events would use abstractions in the same way" (p.12). For research within the framework of social science, such as case studies, reliability is normally referred to as an issue "where the assessment of research subjects is carried out with a certain degree of subjectivity by the researcher(s) themselves" (Love, 2001, p.82). Kirk and Miller (1986) emphasise this issue by claiming that "reliability depends essentially on explicitly described observational procedures" (p.41).

An integral part of this research was collecting the performance measurement data of the PPPs by reviewing the projects' documentation and conducting unstructured interviews. The procedures established for deriving information in the case studies are similar due to the similarities of the selected PPPs in their contract types and development processes. Specifically, interviews were used to interpret what problems dominated in the approaches applied for measuring the projects and identifying how to ameliorate the projects' performance measurements. Notably, it is impossible to determine the reliability of the data derived from the interviews because they were undertaken on a one-to-one basis (Love, 2001). Nonetheless, the findings identified from the interviews were consistent in terms of development of a comprehensive PMS for PPPs.

3.5.5 Validity of Case Study

The use of multiple sources of data in developing a PMS for PPPs with case studies addresses two facets of validity – external and internal. Essentially, validity refers to the 'truthfulness' of the issues identified from studying the cases. Validity is of concern in research that relies on interviews and documentary sources. As indicated in Chapter 2, past research has demonstrated and proved the reliability of introducing triangulated sources to develop PMSs for construction projects (Haponava and Al-Jibouri, 2010; 2012). Interviews were applied to understand the practices in performance measurements of the PPPs and to identify what actions should be taken to improve them. To ensure the accuracy, notes were given to each respondent after every interview to resolve any discrepancies and eliminate interviewer bias.

The external validity, which is normally referred to as generalisation, is difficult to address owing to the small sample. Nevertheless, generalisations still can be drawn when a common framework is adopted to collect data in a consistent manner, as it was in both cases, and the use of multi-case studies is an effective way to allow for generalisations of propositions or hypotheses, which can then later be tested to a given population sample (Yin, 1984). Fundamentally, the role of researchers in case studies is not to enumerate statistical theories, but to provide description, undertake testing and/or generate theory (Eisenhardt, 1989).

3.6 Data Collection of Qualitative Research

3.6.1 Data Collection Strategy

There are two types of triangulation approach that can be identified in the literature: between (or across) approach and within-method (Denzin, 1988). While the ‘within methods’ triangulation focuses on cross-checking for internal consistency or reliability, the ‘between methods’ approach is concerned with testing the degree of external validity (Love, 2001). In this research, the ‘between methods’ approach was applied; thus, multiple methods were adopted to collect data from the exploratory study and case studies (Table 3.1).

Table 3.1 Key issues of the data-collection methods in qualitative studies

Methods	**Advantages**	**Disadvantages**
Interviews (i.e., open-ended questions)	Wider coverage of topics and features of procurement process; usefulness in conveying empathy; building of trust; and in-depth understanding of respondents' points of view and interpretations.	Sampling problems; bias of respondents; and difficulty in analysing and interpreting responses to open-ended questions.
Documentary sources (i.e., documents, files and reports)	Non-reactive and quantifiable; analysed data provided by management personnel; independent sources; and lower cost.	Problems resulting from time requirements in accessing and retrieving data; validity and reliability of sources; and data limitations.

Sources: Adapted from Sutherland (1978) and Bowditch and Bruno (1989)

Table 3.1 indicates that both interviews and documentary reviews are pivotal for the exploratory stage and case studies of this research. The documentations selected for the studies included the project summaries, master plans and agreements, all of which indicate the deliverables and scopes of the PPPs and provide for implications regarding the focuses of the performance evaluations of the projects. Moreover, interviews were conducted with the senior management personnel responsible for each critical phase of the selected PPPs (e.g., initiation, planning, design, construction, operations and maintenance) in their offices or meeting/conference rooms at their company buildings. Such interviews emphasised the importance of obtaining useful and explicit information about the approaches used to measure the project performances of the selected PPPs.

3.6.2 Interview Techniques

Interviews were used as both primary and secondary sources of data. As a primary source, they were conducted for the purpose of determining how to measure the performance of PPPs comprehensively. As a secondary source, they were used to confirm the information gathered from documentary sources. Taylor and Bogdan (1984) believe that respondents seldom express their true ideas and views within structured interviews because the interviewers perform as if they are disinterested in the topic of discussion, while the unstructured interviews are more interactive and 'in-depth' because they are based on open-ended questions and the interviewers act as the research tool themselves rather than using an interview schedule or protocol. Unstructured interviews are useful in identifying and learning about the problematic issues that may not be observed directly. No other method, essentially, "can provide the detailed understanding that comes from directly observing people and listening to what they have to say at the scene" (Taylor and Bogdan, 1984, p.79). Therefore, the unstructured interview technique was applied throughout the exploratory stage and case studies of the research. However, the aim and objectives of the research would be explained to respondents before conducting an initial interview. Furthermore, the following definition of life-cycle performance measurement of PPPs also was presented in order to allow all respondents to fully understand the intention of the interviews and to ensure consistency.

> "A life-cycle performance measurement of a PPP is an evaluation that focuses on measuring the performances of all critical phases of the project, including initiation, planning, procurement, design, construction, operation, facility maintenance and asset handover".

According to Oppenheim (1992), the tendency of interview questions is to move from general areas to specific aspects of the projects, which previously had been identified by reviewing the normative literature and examining the documentary sources available. The protocols designed for the interviews of the exploratory phase and case studies are available in Appendices A and B, and the lengths of the interviews ranged from 60 to 90 minutes, with some participants being interviewed more than one time. The interviews were conducted on a one-to-one basis and were open-ended, to stimulate conversation. Each respondent was allowed to talk freely, without any interruption or intervention, in order for the interviewer to explicitly understand their ideas and draw a clear picture of their perspectives on the topic of the study.

As the literature review previously identified, the defining feature of PPPs is an inclusion of private-sector entities in the provision of essential public services. Hence, in the case study stage of this research, the main concessionaires of the selected PPPs acted as the links between the investigator and other participants involved in the projects. This enabled better understanding of the deliverables of each phase of the projects' life-cycles (e.g., design, construction, operation, maintenance and handover), which are associated with the entire performances of the projects. Throughout the research, interviews were conducted in the respondents' offices and, on some occasions, were at the head offices of the concessionaires and subcontractors. However, not all management professionals involved in both projects agreed to participate in the research and, therefore, they were not interviewed.

The interview strategies of the exploratory phase and case studies were similar. During the stage of exploratory investigations, unstructured interviews were conducted to understand what approaches were being used to evaluate the performances of PPPs in the industry and to identify how to ameliorate such approaches in the future. In the case studies, initial interviews with the project managers were conducted to gather and understand general information relating to the projects (e.g., types of contract, responsibilities of all involved private organisations and their values), during which sessions the deliverables over the projects' life-cycles were noted. Thereafter, interviews with the management personnel or senior advisors responsible for each of the projects' phases (e.g., design managers, financial managers, construction managers, operation managers and facility/asset managers) were conducted, relying on the questions about the approaches that were applied to measure the outputs of their activities. The information derived from this stage was then used to identify the problematic issues that the respondents raised within the context of PPP performance measurement. Finally, specific questions were used in the final interview stage to identify how to ameliorate the performance measurement of PPPs and to derive what measures should be involved in evaluating PPPs. All of the derived measures acted as the generated hypotheses to be quantitatively tested in the questionnaire survey. Further, for a deeper interpretation of PPP performance measurement, interviews with the directors and contract advisors of the public authorities involved with the selected projects also were undertaken.

Interviews with PPP professionals only occurred when they were available to be interviewed. All PPP practitioners who participated in the research had been previously involved with several PPPs in Australia, the UK and the USA and, thus, such participants are acknowledged as experienced practitioners in the PPP industry. During the case studies, interviews with all project advisors were arranged through the main contractor in order to gain a degree of trust and to break down any barriers or misconceptions that participants may have had about the objectives of the research. In fact, it was difficult to determine in advance when the project managers and/or advisors could be interviewed, so they were conducted on an *ad hoc* basis.

While the initial interviews during the case-study process were designed to focus on gaining an understanding of the respondents' backgrounds, the subsequent interviews were specific to their particular roles in the projects (i.e., initiation, planning, procurement, design, construction, operation or maintenance), all of which are the key areas for the performance measurement of PPPs. Additionally, an important aspect that was taken into account when interviewing all respondents was the notion of a 'hidden agenda', so the interviewer's specific areas of interest were not allowed to be explicitly displayed to respondents in order to avoid bias. The answers to the questions of the interviews would be biased if the respondents were questioned directly about the proposition of introducing the process-based (i.e., life-cycle) perspective to measure PPPs, so there was an assumption, inherent in the research, that all respondents possessed an in-depth understanding of the research problem.

Oppenheim (1992) argues that "the hidden agenda is only hidden in the sense it should not be too obvious to the respondent" (p.70). Nevertheless, data collated from interviews can be subject to bias because of the interviewer's misinterpretation or manipulation. To avoid bias, researchers should attempt to "act as a neutral medium through which questions and answers (are) transmitted" (Love, 2001, p.75). In fact, the aim of the interviews in the qualitative phase of the research was to collect objective data by maintaining the fiction of an interesting conversation, which has been identified as an effective way of avoiding unbalanced questions and obtaining bias-free data (Briggs, 1986).

To clarify the respondent's answers, the researcher attempted to avoid introducing any ideas that could form part of the respondents' subsequent answers. In addition, the researcher was careful and mindful of the feedback given via respondents' verbal and non-verbal responses. Bearing this perspective in mind, the researcher avoided providing obvious signals, such as approvingly smiling and nodding when a respondent failed to answer a question. The notes of the interviews were provided to the respondents for review so as to ensure the accuracy of the recording of their expressed views and ideas.

Another issue that was addressed when interviewing was concerned with the need for digital recordings of the interviews. Recording interviews enables the study to: (1) encourage fluency; (2) allow the interviewer to pay close attention to what is being said; (3) retain direct quotations for reporting; and (4) preserve the flavour of tone. As contended by Oppenheim (1992), the interview can still proceed with note-taking if the respondent refuses to consent to recordings. Accordingly, note-taking was also used as a medium to record the interviews.

During the qualitative studies, all interviews had been digitally recorded, with respondents' permission, and then transcribed and checked for accuracy. It was mentioned above that the interviews necessary for the research were conducted in the respondents' offices or meeting and conference rooms within their companies and, thus, it was very easy to decipher the respondents' views and comments because of the quiet environment. In fact, all respondents were comfortable about having their ideas and comments recorded and they understood that digital recordings of the interviews would be useful for further interpretation, ensuring higher quality of the research output.

3.6.3 Documentary Sources

Documentary sources are normally referred to as unobtrusive measures (Robson, 1993). Review of documentation is considered to be a method that is complementary to the application of other approaches in research conceptualisation. As the SPVs of the PPPs selected for the case studies of this research had agreed to fully support the research, the researcher was given full access to the documentations of the projects Notably, the primary aim of this research was to develop a life-cycle PMS for PPPs; thus, the most suitable documentations for the case studies would be those that could completely reflect the entire delivery process of the projects and the approaches agreed to by the involved parties to evaluate the projects' performances. Therefore, the 'Project Summary' and 'Project Service Agreement' of the selected PPPs were the ideal documents.

The analysis of documentary sources is commonly known as content analysis, which is non-reactive in nature (Holsti, 1969). According to Krippendorf (1980), content analysis is "a research technique for making replicable and valid inferences from data to their context" (p.21). To put it simply, content analysis is the extraction and categorisation of the information obtained from documents. Inferences from the extracted data can only be drawn if the relationships with the meanings of the data can be maintained among their institutional, societal and cultural contexts (Krippendorf, 1980). In this research, content analysis was used as a supplementary approach that accompanied the interviews so as to understand the focuses of the approaches being applied for measuring the projects' performances. In the case studies, data was elicited by the researcher from various documentary sources, which have been mentioned above, in order to better understand the delivery processes of the case projects and to identify how the developed PMS could be put into use by them to solve their existing problems. The information available in the project documentation was in a permanent form and, thus, could be re-analysed throughout the period of the data collection. This enabled "reliability checks to be undertaken through corroboration of the findings" with the management personnel of the selected case projects (Love, 2001, p.77).

An important point that must be addressed in the review of documentary sources is to objectively understand what performance measures or indicators have already been used to evaluate the performances of the selected case projects over their life-cycles. To fulfil this purpose, it is generally necessary to design and implement a coding system, specific to the aim of the case studies of the research, to classify objective issues that can be identified from those documentary sources and to supplement the subjective data derived from interviews and/or observation (Love, 2001). In this research, the case studies were applied for model testing rather than hypothesis generalisation. Accordingly, the coding system was designed to satisfy the major aim of the case studies. With this perspective, a particular coding system was devised, as shown in Figure 3.2, and it was useful in determining what performance measures had been used in each case project throughout its life-cycle. This provided supplementary assistance in interpreting the limitations of the case projects' performance measurements derived from the interviews and helped to identify how the developed model could contribute to these 'real-world' projects in ensuring V*f*M and achieving long-term project success.

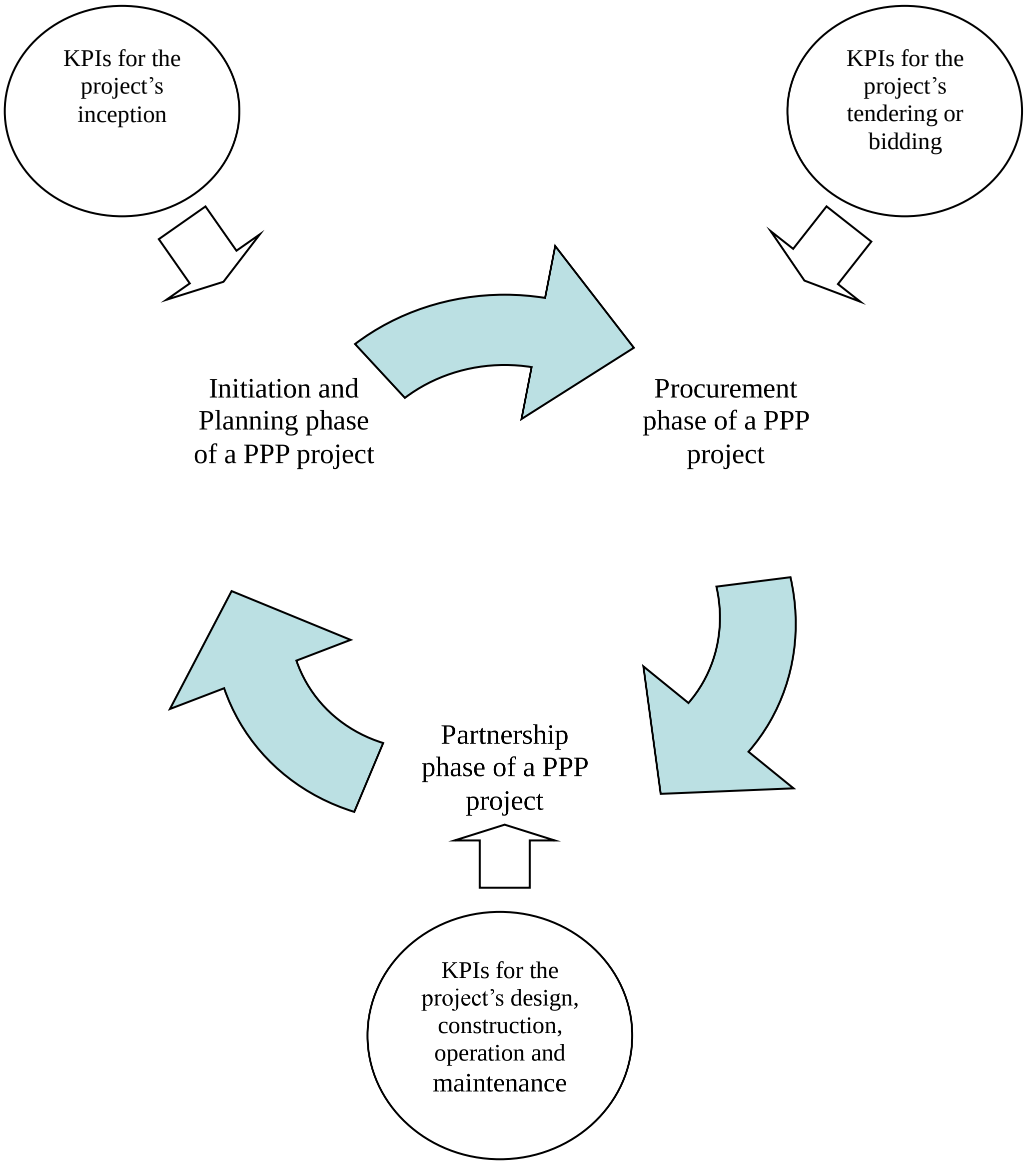


Figure 3.2 Coding system for the identified performance measures/indicators

3.7 Research Hypotheses

In light of the research objectives and the findings elicited from the exploratory study described above, two research hypotheses relating to the identified performance measurement perspectives of the PMS and their relevant performance indicators (i.e., measures) were generalised as follows:

1. Five Performance measurement perspectives
$F^1 - H_0$: The five measurement perspectives are not significant for measuring PPPs.
$F^1 - H_1$: The five measurement perspectives are significant for measuring PPPs.

2. Relevant core performance indicators
$F^2 - H_0$: The conceptually derived indicators are not significant for measuring PPPs.
$F^2 - H_1$: The majority of the derived indicators are significant for measuring PPPs.

The performance perspectives, as defined in Section 2.4.2, are the indicative measurement aspects synthesised by a series of measures/key performance indicators (KPIs) (Kaplan and Norton, 1996a). Hence, the sequential quantitative studies (i.e., questionnaire survey and econometric modelling), which will be described below, aimed to quantitatively test the derived "perspectives" (i.e., hypotheses generated above) as well as their integrated performance indicators.

3.8 Quantitative Research

Quantitative research was conducted to empirically test the hypotheses generalised from the qualitative study, and it was divided into two parts: questionnaire survey and econometric modelling. These quantitative studies attempted to test the derived measurement perspectives and their relevant KPIs.

3.8.1 Questionnaire Survey

The questionnaire was formulated on the basis of the aim and objectives of this thesis, as well as the hypotheses generated above. As a result, the questions are based on the findings identified from the preliminary qualitative studies. Mindful of this, the purpose of the survey was deep verification of the applicability of the identified 'perspectives and measures', rather than to understand the respondents' general ideas about performance measurement of PPPs. Therefore, the respondents were asked to select a recently completed or on-going PPP project with which they were most familiar and then to answer the questions accordingly. This enabled each selected project to be viewed as a separate case, leading to increased reliability of the findings (Love, 2001).

Questionnaire Development

The questionnaire, where both closed- and open-ended questions were used (Appendix J), was developed with an emphasis on extracting information about the performance measurement perspectives and relevant KPIs of the PPPs with which the respondents had been recently involved. With the exception of nominal and ratio data, a Likert Scale categorised from '1' to '5' was adopted to determine the extent of implementation, agreement and/or effectiveness for different questions that were posed to respondents. The developed questionnaire contains the following six sections, which were devised according to the hypotheses generated from the literature review, exploratory study and case studies.

1. Background information;
2. Performance measurement perspectives for social infrastructure PPPs;
3. Performance indicators of the Initiation and Planning Phase of PPPs;
4. Performance indicators of the Procurement Phase of PPPs;
5. Performance indicators of the Partnership Phase of PPPs; and
6. General comments.

The first section of the questionnaire aims to understand the general background information of the respondents. Hence, the questions used in this section relate to the respondents' locations, their experience in the PPP industry and procurement of social infrastructure, their main roles in those PPP projects and the characteristics of their involvement (e.g., project values and concessionaire periods). This section is useful and valuable for indicating the reliability and representativeness of the information to be provided in the remaining sections of the questionnaire.

The purpose of the second section of the questionnaire, *Performance Measurement Perspectives for Social Infrastructure PPPs*, is for gaining information about the importance of the derived performance perspectives in the PPPs with which the respondents had been involved. As defined above, performance perspectives serve as the basis of a PMS and they are used for selecting relevant performance indicators or measures, which are the central part of a PMS. Thus, the closed-ended questions of this section were designed to understand the importance of such perspectives.

Sections 3 to 5 of the questionnaire were devised to select the KPIs that were derived according to the identified measurement perspectives. In addition, the derived KPIs were based on the nature of the life-cycle of PPPs, which is divided into three main phases (e.g., initiation and planning, procurement and partnership) by the European Investment Bank (2011a). In other words, the KPIs presented in these three sections were proposed in accordance with not only the developed measurement perspectives but also the characteristics of PPP projects' life-cycles; therefore, they are considered to be the life-cycle KPIs of PPPs. Hence, the closed-ended questions are specific to an identification of the relationship between the derived life-cycle KPIs and the measurement perspectives.

The last section of the questionnaire (i.e., Section 6) is dominated by open-ended questions. It provides the respondents with an opportunity to express their comments on the survey and/or raise the important issues that may have been ignored by the questionnaire. For instance, it gives the respondents the chance to address some critical indicators that should be involved but had been neglected throughout the survey. In summary, the comments provided in this section were used to support the statistical analysis that was undertaken.

Sample Design and Population

The process of sampling is conceptually viewed as a procedure regarding the use of a small number of items or parts of the whole population to generalise conclusions that are particularly relevant to the entire population (Zikmund, 1988; Biemer and Lyberg, 2003). Notably, it is well known that the sample needs to be representative of the population in order to produce a theoretical and practical value, so that the results obtained from the sample approximate to those which would be obtained if it was possible to survey the entire population. The aim of this research is to develop a life-cycle PMS for social infrastructure PPP projects. Thus, it was necessary for the respondents who participated in the research to be experts who were familiar with the whole development processes of social PPPs. To fulfil this requirement, purposive sampling, rather than random sampling, was applied in this research.

Purposive sampling, which is also known as judgemental/selective sampling, is one of the non-probability sampling techniques. Unlike probability sampling, non-probability sampling emphasises the concept that the units that are investigated are based on the judgement of the researcher. In other words, the goal of purposive sampling is not to randomly select from the population in order to create a sample with the intention of yielding generalisations. Rather, it aims to assemble a sample by concentrating on particular characteristics of the population that are of interest. Essentially, purposive sampling is useful when the researchers require the expertise of individuals who are specialised in particular fields in order to deal with a topic that integrates with a high level of uncertain issues (Foreman, 1991). PPPs are extremely complex construction projects (Chinyio and Gameson, 2009; Yong, 2010); therefore, a PMS of a PPP is undoubtedly associated with various uncertainties raised over the project's life-cycle (Yuan *et al.*, 2009; 2012). Thus, the respondents who participated in this research on life-cycle performance measurements of PPPs needed to be knowledgeable about all critical parts of their projects, including initiation, planning, procurement, design, construction, operation and facility maintenance. Mindful of this, purposive sampling was considered to be the most suitable technique within the context of this research. The studies undertaken by Jin (2010a, b) support this justification, in which purposive sampling was applied for a survey regarding risk allocation of PPP projects.

To satisfy the nature of purposive sampling and the research aim, the target population of this survey was the senior management personnel who had been involved in the procurements of several social infrastructure PPP projects. They include the PPP professionals and project decision-makers from both public and private sectors. As suggested by Tan (2004), the sample should be drawn through a judgemental selection procedure when using a purposive sampling technique. The purposive sample selection of this research relied on the procedure proposed by Jin (2010a), which involves three steps, adapted as follows: (1) identify social infrastructure PPP projects in Australia; (2) classify major partners of the identified projects; and (3) identify professionals and decision-makers in the projects' major partner organisations from the public domain.

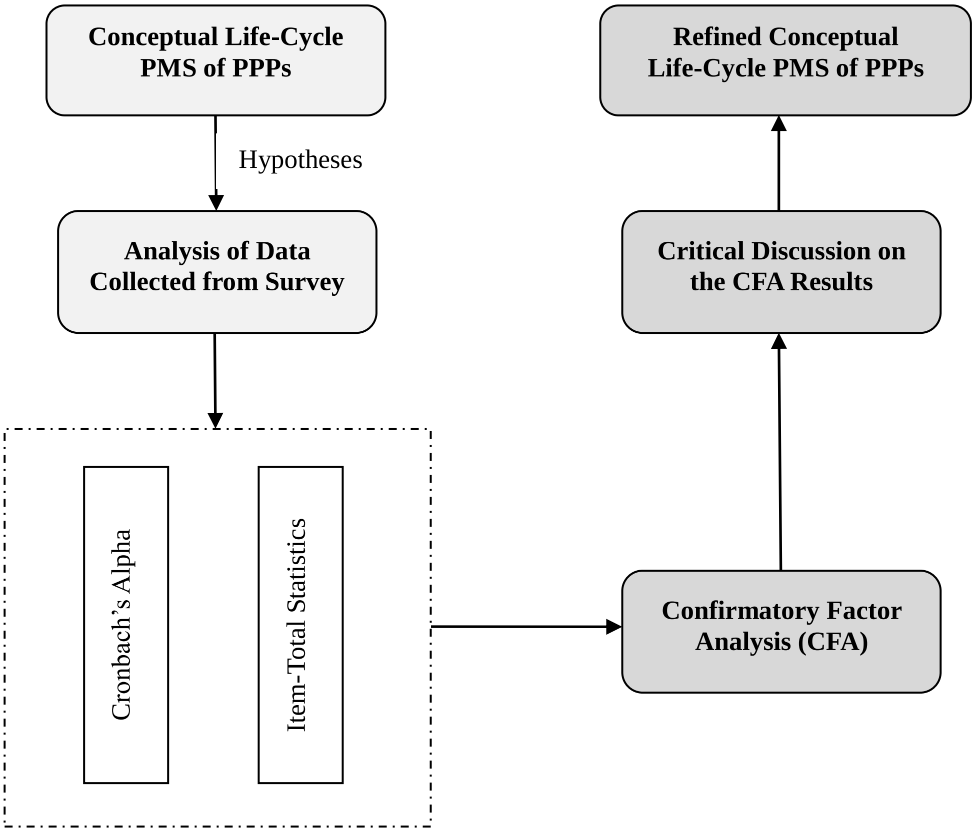
Before determining the sample size of the main survey, a pilot survey was conducted with the 25 respondents who had participated in the exploratory study of this research. Those respondents were all experienced PPP practitioners such as project managers, procurement and financial advisors, architects, operation managers, and facility and asset managers. The aim of this pilot work was to test the potential response rate, suitability and comprehensibility of the questionnaire. The devised questionnaire was inputted to SurveyMonkey and then sent to the respondents via emails. All respondents were asked to critically review the design and structure of the survey, and the majority of the comments that were received were positive. As a result, only some minor changes had to be made to the questionnaire.

According to Leedy (1988), the sample size of a survey depends on the degree to which the sample population approximates the qualities and characteristics of the general population. In the main survey of this research, a total of 368 questionnaires were distributed and 135 completed questionnaires were returned. The response rate of this survey is 36.68%, which is considered to be acceptable in comparison with past studies of PPPs, for example, 12% in Li *et al.* (2005), 9.4% in Salman *et al.* (2007), 11.4% in Jin (2010) and 13.02% in Yuan *et al.* (2012). In essence, the response rate of this survey is not very high; however, it is acceptable for social science research purposes (De Vaus, 2001). Throughout the survey, all respondents were given two weeks to complete the questionnaire; however, emails were sent after two weeks to kindly remind the respondents who had not yet provided responses.

Methods of Data Analysis

Selection of the method adopted for analysis of any survey data depends upon the complexity of the research and the hypotheses to be tested (Taris, 2000). Data obtained from the questionnaire in this research underwent statistical analysis by using the AMOS software package of Statistical Product and Service Solutions (SPSS), which was formerly known as the Statistical Package for the Social Sciences. After creating the dataset, which will be discussed in Chapter 5, the collected data were analysed under multiple statistical techniques.

The analysis of the collected data in this research adapted a logical analysis process proposed by Yuan *et al.* (2012). As indicated by Figure 3.3, descriptive statistics were first used to understand the features and reliability of the collected data. The reliability of the survey data was examined by using Cronbach’s alpha and item-total statistics, which are the indices of reliability and internal consistency relating to the variation accounted for by the true score of the ‘underlying construct’ (Hatcher, 1994).



Source: Adapted from Yuan *et al.* (2012)

Figure 3.3 Process of the analysis for the questionnaire survey data

The descriptive analysis provided a frame of reference for the inferential statistics. After testing the reliability of the research instrument and survey data, Confirmatory Factor Analysis (CFA) was adopted to inferentially analyse the survey data. Statistically, CFA is a multivariate procedure established to test how well the variables being measured represent the number of constructs. Essentially, it is also a technique that largely relies on pre-constructed theory and is primarily conducted to quantitatively confirm the theoretical relationships, rather than to explore the linkages between the items (Schreiber *et al.*, 2006). Accordingly, CFA is ideal for this research because the items to be observed and the relevant data collection were completely based on the conceptual model proposed from the qualitative exploratory study that relied on key-informant interviews. The factor analysis model expresses the variation and covariation in a set of observed continuous variables y (j = 1 to p)

as a function of factors η (k = 1 to m) and residuals ε (j = 1 to p). Thus, it can be mathematically written as:

$$y_{i1} = v_1 + \lambda_{11}\eta_{i1} + \lambda_{11}\eta_{i2} + \ldots + \lambda_{1k}\eta_{ik} + \ldots + \lambda_{1m}\eta_{im} + \varepsilon_{i1}$$

$$\vdots$$

$$y_{ij} = v_j + \lambda_{j1}\eta_{i1} + \lambda_{j2}\eta_{i2} + \ldots + \lambda_{jk}\eta_{ik} + \ldots + \lambda_{jm}\eta_{im} + \varepsilon_{ij}$$

$$\vdots$$

$$y_{ip} = v_p + \lambda_{p1}\eta_{i1} + \lambda_{p2}\eta_{i2} + \ldots + \lambda_{pk}\eta_{ik} + \ldots + \lambda_{pm}\eta_{im} + \varepsilon_{ip} \qquad \text{(Eq. 3.1)}$$

where v_j are intercepts; λ_{jk} denote factor loadings; η_{ik} stand for factor values; and ε_{ij} are residuals with zero means and correlations of zero with the factors. According to Equation 3.1, the factor analysis model is able to be represented in matrix form and shown as Equation 3.2:

$$y_i = v + \Lambda\eta_i + \varepsilon_i \qquad \text{(Eq. 3.2)}$$

Here, v is the vector of intercepts; Λ is the matrix of factor loadings; and ε_i is the vector of residuals. Over the past several decades, CFA has been widely used in social science research and acknowledged as a robust tool for the hypothesis testing undertaken for factor analytical problems (Gorsuch, 2013). As suggested by Suhr (2006, p.1), CFA should progress with the following procedure:

1. Review the theory and research literature to support model specification;
2. Specify a model;
3. Determine model identification;
4. Collect data;
5. Conduct preliminary descriptive statistical analysis;
6. Estimate parameters in the model;

7. Assess model fit; and,
8. Present and interpret the results.

Based on the aforementioned concept, in this research, CFA is therefore applied to quantitatively examine whether the measures of a construct comply with the researcher's initial understanding of the features and natures of the KPIs of the social infrastructure PPP projects. After running CFA, insignificant KPIs were eliminated and an "optimal" life-cycle PMS was developed for PPPs.

3.8.2 Econometric Modelling

The life-cycle of a PPP project is constituted of a series of phases, in which an assessment of the macroeconomic environment maintains a decisive role in the project's *ex-ante* evaluation that is a vital part of the Initiation and Planning phase of PPPs (European Commission, 2001; European Investment Bank, 2011a). In Section 3.6.2, it was explained that the concept of life-cycle performance measurement to be addressed throughout this research is a comprehensive evaluation that is capable of dynamically capturing all critical phases of PPPs. Thus, macroeconomic issues need to be incorporated into the PMS to be developed in this thesis. Yuan *et al.* (2009) support this justification and argue that the PMS of a PPP project should encompass the measures specifically devised for assessing the macroeconomic environment within which the project operates, as they can provide the public-sector participants with significant assistance in decision-making about infrastructure procurement. Considering these viewpoints, an econometric technique was applied in this research to determine the macroeconomic KPIs suitable for PPPs.

Econometric techniques are robust in specifying statistical relationships between the observed variables at the macroeconomic level. They can be developed either on the basis of rigorous economic theory or without considering any established economic model (Sims, 1980). Performance measures (i.e., KPIs) are the indicative issues causally associated with the organisation's entire performance (Neely *et al.*, 2005). Therefore, the macroeconomic KPIs conceptually derived in this research were subjected to the Granger causality test, variance decomposition (VDC) and generalised impulse response function (GIRF) in order to empirically test them.

The Granger causality test, on the one hand, is a statistical concept originally proposed by Granger (1969) and it completely relates the predictability of an independent variable (*X*) to the relevant dependent variable (*Y*). The concept of Granger causality is underpinned by a simple assumption using three variables X_t, Y_t and W_t (where W_t is a vector of a possible explanatory variable). Then, a forecasting of Y_t can be conducted using the lagged terms Y_{t-1} and W_{t-1}. After obtaining the estimates, the forecasting of Y_t can be undertaken again by taking advantage of Y_{t-1}, X_{t-1} and W_{t-1}. If the second forecasting (that involves an additional lagged value X_{t-1}) expresses a better predictable performance than the preliminary forecasting that incorporated Y_{t-1} and W_{t-1} only, it can be identified that X_{t-1} contains valuable information that is not included in Y_{t-1} and W_{t-1} but is essentially helpful to forecast Y_t. Under this circumstance, a conclusion was drawn by Granger (1969) that X_{t-1} Granger causes Y_t.

VDC, on the other hand, is a technique used to interpret the amount of information that relates to how each endogenous variable contributes to the forecasting of other variables in auto-regression. According to Sims (1980), the VDC is based on a major concept that the forecast error variance is split into a series of components that are capable of measuring the contribution of each variable observed within a future period of time. It can provide assistance for understanding how much of the forecast error variance of each variable can be explained by the exogenous shocks to other variables. If the shock of an independent variable is able to significantly explain the forecast error variance of a dependent variable, it is concluded that the dependent variable is endogenous, and vice versa. Mindful of this, the VDC is a technique that can provide insight into the relationship between the variables, in terms of their contribution level, which is referred to as the *Relative Variance Contribution* (RVC). The RVC can be written as follows:

$$RVC_{j \to i}(s) = \frac{\sum_{q=1}^{s} c_{ij}^{(q)} e_{jt}^{2}}{e_{it}^{2}} \qquad \text{(Eq. 3.3)}$$

where s represents the number of future observed periods; and e_{it}^{2} and e_{jt}^{w} are the variances of the observed variables in the vector auto-regression (VAR) and vector error correction (VEC) models (i.e., y_{it} and y_{jt}). The RVC forecasts the contribution of the variable *j* to the variance of the variable *i* in upcoming periods.

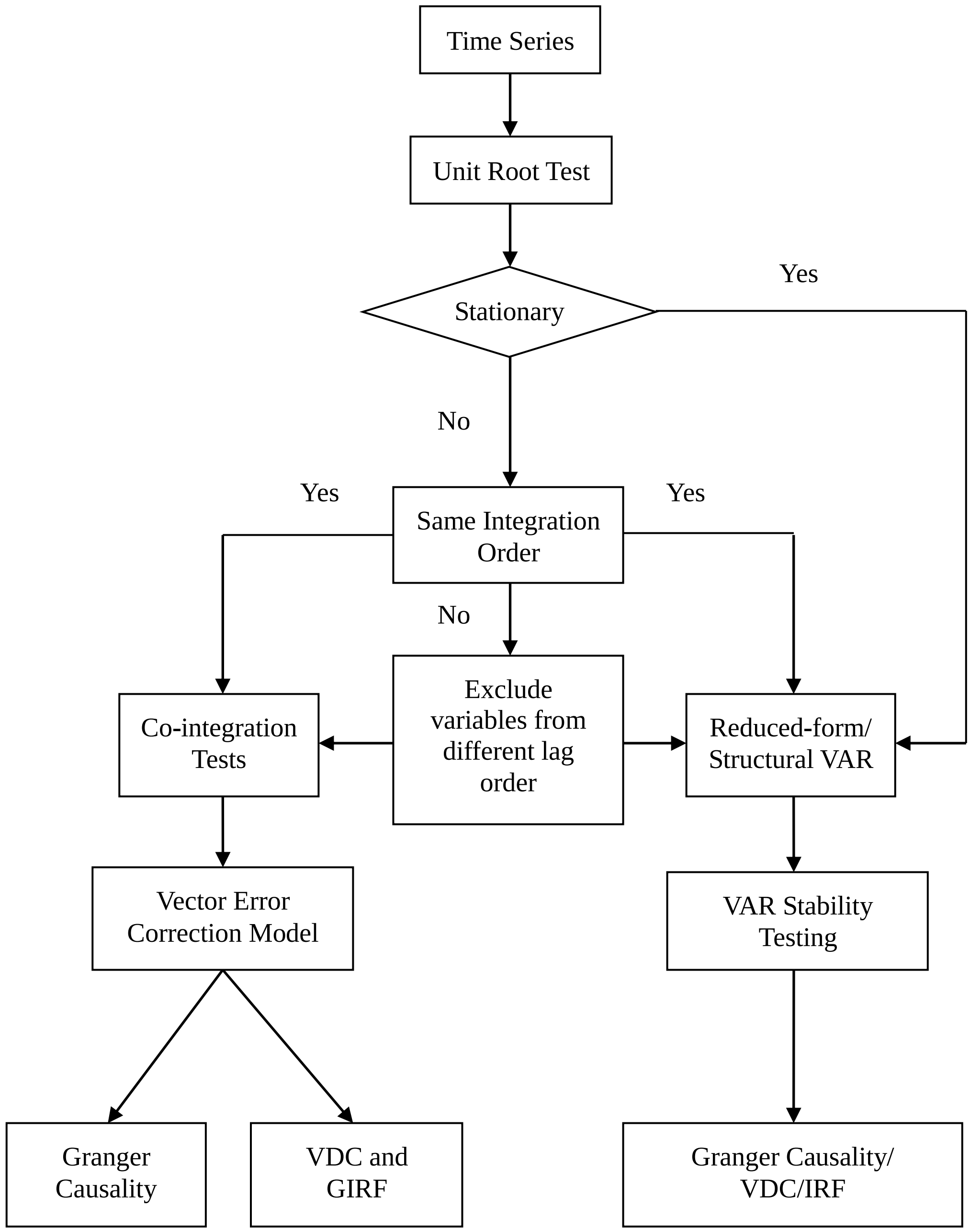
In addition to the Granger causality test and the VDC, the GIRF has been applied for estimating the dynamic interactions between the endogenous variables. Koop *et al.* (1996) defines the GIRF as the following equation:

$$GI_x\left(h,\delta,\prod_{t-1}\right)=C_h\delta \qquad \text{(Eq. 3.4)}$$

where C_h and $\prod_{t-1}$ are the matrices, while δ represents some known vector. The GIRF has been widely used in econometric analysis as it is powerful in describing the dynamics between the endogenous variables of a time-series model. Notably, the GIRF statistically explains the effects of one standard deviation shock of an endogenous variable on other variables, rather than reflecting the responsive values resulting from the each variable's structural shocks.

The Granger causality test, VDC and GIRF are normally conducted under the vector auto-regressive models (e.g., reduced-form VAR, structural VAR – SVAR, and VEC model) with time-series or panel data. A flowchart has been developed (Figure 3.4) to explicitly indicate the procedure of the VAR econometric modelling to be presented in Chapter 5. According to this diagram, prior to formulating VARs, unit root tests must be undertaken to examine whether the time-series data inputted are stationary. If the data are stationary, the reduced-form VAR or SVAR can be directly constructed to run the Granger causality tests, VDC and IRF; otherwise, the VEC model should be formulated for further tests after testing integration order and co-integrations between the observed variables.

PPPs are projects with long-term contractual arrangements (Kwat *et al.*, 2009). With this in mind, the long-term relationships between variables must be considered when conducting any econometric modelling for PPPs. Amongst the VAR models, only the VEC model takes into account the co-integrations, which are defined as long-term convergences between the observed variables (Johansen and Juselius, 1990). Hence, VEC is considered to be the most suitable model for validating the derived macroeconomic KPIs. The strong ability of the VEC model in construction investment estimation has been acknowledged by researchers, and it is robust in estimating both the demand and supply sides of the construction sector (Jiang and Liu, 2011; Liu and London, 2013).



Source: Liu (2011)

Figure 3.4 Flowchart of VEC/VAR modelling

The VEC model was first proposed by Engle and Granger (1987). It integrates auto-regressive and error correction representations into the co-integrated system, so it is a VAR with a co-integrated restriction and error correction term. According to Engle and Yoo (1987), embedding co-integration into the VAR can help to improve the performance of the model and avoid misspecification of the results. The form of the VEC model is represented by Equation 3.5:

$$\Delta Y_t = \alpha ecm_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad \text{(Eq. 3.5)}$$

where ΔY_t represents the vector in difference; α is the adjustment coefficient; ecm_{t-1} is the error correction term; Γ_i is the coefficient matrices; and ε_t is the vector of error term.

In this research, a dummy variable was imposed as an exogenous variable to the VCM model (Eq. 3.5) to quantify the effect of an exogenous variable. Statistically, a dummy variable is a variable that takes the value *1* or *0* to indicate the occurrence of special events, such as disasters, global crises, wars and so on. If a special event occurs in the *i*-th period, the values of this period will be represented as *1* and, otherwise, *0*. After imposing an exogenous dummy variable, a VEC-D model (i.e., a VEC model with a dummy variable) can be represented as Equation 3.6:

$$\Delta Y_t = \alpha ecm_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \delta D_t + \varepsilon_t \quad \text{(Eq. 3.6)}$$

where D_t is a dummy variable and δ is the coefficient of the dummy variable. The VEC-D model has been adapted in past studies to identify how the endogenous and/or exogenous variables causally affect the construction sector/projects (e.g., Jiang and Liu, 2011; Liu and London, 2013); thus, it is an acceptable econometric technique for construction management research.

3.9 Chapter Summary

The research design and methodology have been described and justified in this chapter. Based on the aim and objectives of this research, the triangulation research strategy, which is comprised of both qualitative studies (e.g., exploratory study and case studies) and quantitative studies (e.g., questionnaire survey and econometric modelling), was presented and discussed. To address the rationale of the implemented research strategy, this chapter also provided a justification for the philosophical basis of the research approach.

The exploratory study and case studies were discussed respectively and the process designed for data collection was explained. Also, the reliability and validity of the case studies was discussed in order to provide a detailed insight into the qualitative studies. Additionally, this chapter explained the quantitative methods that have been used for this research, including the questionnaire and its relevant analytical methods (e.g., Cronbach's alpha, item-total statistics and CFA) as well as the vector error correction model and its associated econometric techniques (e.g., Granger causality test and variance decomposition).

The methodological approaches applied in this thesis were justified as being useful and powerful in achieving the aim and objectives of the research and the hypotheses that were identified. A detailed description of the interpretation of the findings derived from the exploratory interviews can be found in Chapter 4. After that, two detailed case studies are presented in Chapter 5 to test the feasibility and applicability of the conceptual framework proposed in Chapter 4. Finally, the results provided from CFA and econometric techniques are analysed in Chapter 6 to quantitatively examine the main components of the developed life-cycle PMS.

CHAPTER 4 CONCEPTUAL FRAMEWORK

4.1 Chapter Introduction

An exploratory study, for the purpose of understanding the performance measurement (PM) of PPPs, was undertaken and is presented in this chapter. An interpretivist approach that is based on non-structured interviews was used to empirically interpret the prevailing practices in project performance measurement/ evaluation within the context of social infrastructure PPPs. All interviews were conducted with senior practitioners who had been substantially involved with the procurement and/or delivery of social infrastructure PPP projects across states of Australia that included New South Wales, Victoria, Queensland and Western Australia. The focuses and shortcomings of the existing PM of social infrastructure PPPs were identified during the interviews. In addressing these problematic issues, a feasible future direction with recommendations for improving the performance measurement of PPPs was proposed and will be discussed in this chapter. Then, a performance measurement framework (PMF) will be conceptualised according to such findings and identifications.

The rest of this chapter comprises six sections: (1) data collection of the exploratory study; (2) research findings; (3) life-cycle PMF of PPPs; (4) performance measurement perspectives of the proposed conceptual framework; (5) identification of core performance indicators; and (6) chapter summary. This chapter relates the exploratory stage for further comprehensive research of the performance measurement of PPPs, providing a conceptual foundation for developing a performance measurement system of PPP projects, which can ensure that assets are ‘future-proofed’ over their life-cycles.

4.2 Exploratory Study for PPPs – Interviews

The exploratory study undertaken to understand the practices in performance measurement of PPPs is built on a justified research approach – an interpretivist approach relying on interviews. It has been demonstrated in Chapter 3 that research on PM has tended to marry with the ontology and epistemology of interpretivism because reality and multiple perspectives are sought to gain an understanding of its use in practice (Neely *et al.*, 2000; Neely *et al.*, 2005). For that matter, a qualitative study with the aim of interpreting current practice in PM in PPPs is necessary for a comprehensive research regarding the development of a life-cycle performance measurement system for PPP projects. This section generally describes the data collection and analysis of the exploratory study of this research.

4.2.1 Data Collection of Exploratory Study

Research relying on interpretivism is primarily non-quantitative. Thus, the interviews with key stakeholders who had experience with PPPs were undertaken to solicit their views and opinions about the issue of PM. According to Kuma (1989), to meet this objective requires the purposive selection of a sample size of 10 to 35 participants who have specialised knowledge of the topic. Accordingly, a total of 25 in-depth interviews with key stakeholders who had participated in the procurements and/or delivery of infrastructure PPP projects were conducted over a period of eight months (Table 4.1). Each interview ranged from 60 to 90 minutes, with permission to digitally record them. Of note, the research was undertaken in Western Australia where, to date, there have been no economic PPPs constructed. Thus, the research was limited to PM for social infrastructure, such as hospitals, prisons, schools and public housing projects.

Table 4.1 Sample information of the exploratory study (interviews)

Respondents	**Number**	**Serial Codes**
Public clients	3	PC-01 to PC-03
Project managers	3	PM-01 to PM-03
Architects/design managers	4	A/DM-01 to A/DM-04
Financial advisors	4	FA-01 to FA-04
Contract advisor	1	CA-01
Legal advisors	3	LA-01 to LA-03
Procurement advisors	3	PA-01 to PA-03
Operations managers	2	OM-01 to OM-02
Asset managers	2	AM-01 to AM-02

The key-informant interviews conducted for this exploratory study were organised as conversations and are suitable for all stages of the research within the framework of social science, especially for the following situations: (1) understanding the points of view of specific groups/individuals; (2) identifying directions for programmes' or projects' future developments; and (3) gathering essential information for the design of a further comprehensive study (Kuma, 1989). The respondents (i.e., interviewees) who participated in the research had between 8 and 20 years of experience with social infrastructure PPP projects. All interviews were non-structured, but the following indicative questions provided the stimulus for dialogue:

- How are/were the performances of the PPPs that you are/were involved with evaluated?
- What do you consider to be the limitations/gaps associated with PM of PPPs?
- What do you consider to be areas where PM of PPPs can be improved?
- What do you consider to be the difficulties in implementing a new PM?

The interviews focused on the: (1) current PM approaches and their shortcomings; (2) direction for ameliorating PM; and (3) potential difficulties in implementing a new PM approach. At the beginning of each interview, the respondent was asked to select a completed or on-going social infrastructure PPP project with which he/she had been or was currently involved.

4.2.2 Data Analysis

The textual narratives compiled were analysed using the software NVivo 10, which combines the efficient management of non-numerical, unstructured data with powerful processes of indexing and theorising. NVivo 10 enabled additional data sources and journal notes to be incorporated into the analysis as well as the identification of emergent new themes. The development and re-assessment of themes, as the analysis progressed, accords with calls to avoid confining data to pre-determined sets of categories (Silverman, 2001). Kvale (1996) suggests that 'ad hoc' methods for generating meaning enable the researcher 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). The data that were collected from the 25 interviews were coded and can be seen in Appendix C.

4.3 Research Findings

The findings of this exploratory study will be logically presented in this section, including the existing PM of social PPPs, and the directions and difficulties involved to improve them. Critical issues that will be analysed and discussed in this section form a foundation to propose a conceptual framework.

4.3.1 Practice in Performance Measurement in PPPs

Understanding the existing approaches used to measure performance in PPPs is pivotal to developing a new and effective system for performance evaluation. In addressing this issue, a project manager (PM-01) stated:

> "The performance evaluation of our social infrastructure PPP projects before the assets' operations is similar to that of the projects procured by using traditional methods. This kind of evaluation aims to measure whether the project was delivered on time and on budget and also evaluate whether the procured asset can meet the predefined quality specification."

All interviews indicated that the PM of PPPs is comprised of two parts: (1) the evaluation for design and construction; and (2) the measurement during operation. It was also made explicit by those respondents that the design and construction of PPPs were evaluated against time, cost and quality (TCQ) while the measurements for the assets' operational performance relied on a series of key performance indicators (KPIs). This was emphasised by a public-sector advisor (PA-02) who made the following comment:

> "The performance evaluation conducted for social PPPs was divided into two parts. First, the measurements for design and construction are pretty straightforward focusing on time, cost and quality. Second, many social infrastructure PPPs are behind the availability-based or operational model, and there are KPIs associated with the assets' operations, covering a series of issues. Take a water treatment plant, for example. The KPIs will be around issues like the quality of the water in terms of whether it is

> bacteriological qualities, heavy metals, and the colour and smell of it. And, there are KPIs of quantity. The contract has specified the plant would have needed to be able treat so much water in a certain period of time. In summary, the KPIs are based around those two types of output parameters. If the private sector cannot meet those, they will get abated potentially."

The key emergent themes and issues arising from the interviews in regard to how existing PM was being undertaken are presented in Figure 4.1. While TCQ factors typically have been used to evaluate conventional procurement arrangements (e.g., traditional design and build forms), PPPs are more complicated due to the financial commitments of the private and public sectors, stakeholder interests and their long-term impact on taxpayers. Shaoul (2009) argues that TCQ measures are ineffective for PPPs because "understanding the reality that underpins the rhetoric of 'on time and to budget' is not straightforward" (p.36). Hence, a robust evaluation/ measurement mechanism is required, which can accommodate an array of multiple views throughout the asset's life-cycle (Zhou *et al.*, 2013). Bearing this perspective in mind, it is necessary to identify whether or not existing PM approaches (i.e., TCQ and operational KPIs) are robust and suitable for capturing the holistic performance of PPPs.

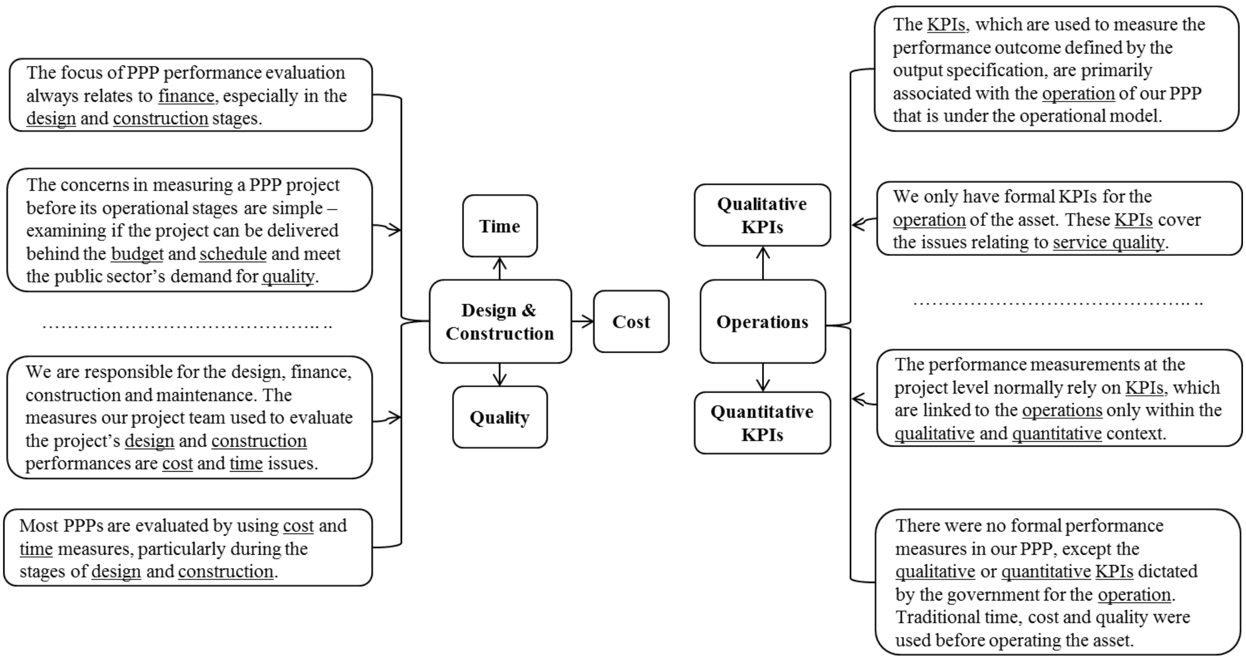


Figure 4.1 Existing performance measurement of PPPs

4.3.2 Shortcomings of Existing Performance Measurement in PPPs

It was widely agreed that the existing PM approaches being utilised within social infrastructure PPPs were myopic and that there was a lack of systematic measures designed to evaluate some critical issues of the projects' design and construction stages, such as innovation, asset sustainability and stakeholder satisfaction. In particular, a project manager who had been involved with delivering three social infrastructure PPPs (PM-02) stated:

> "The conventional method for evaluating PPP design and construction is not sufficient … there is the lack of formal and systematic measures to evaluate if the outputs are innovative or sustainable for a long-term period, or what the key stakeholders' satisfaction levels are …"

The public sector not only relies on private entities to financially invest in infrastructure, but also draws on their expertise to engender innovation and to develop an asset that is sustainable and able to meet stakeholders' needs. By focusing on TCQ, there is a proclivity for the 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 (A/DM-01) 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 sectors should bring to a public project; however, the approach we are using cannot reflect that."

Reflecting on the use of TCQ as measures, a senior financial advisor (FA-03) proposed that the value for money (V*f*M) analysis that is considered by the *Public Sector Comparator* (PSC) offers a mechanism for *ex-ante* evaluation, which intends to provide a business case for PPPs and then enable potential non-financial benefits to be considered; however, it was made explicit that there was no mechanism in place to measure whether both value and non-financial benefits were being attained. In essence, the PSC has been criticised as an incomplete evaluation, which simply and solely emphasises life-cycle costs and largely neglects the qualitative life-cycle issues critical to decision-making (Grimsey and Lewis, 2005). Furthermore, the PSC normally lends itself to political bias; for example, in assessment of retained risks that push up the PSC's NPV (Net Present Value), and in anecdotal use of differential discount rates. This prevailing 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 holistic performance (European Investment Bank, 2011a; Haponava and Al-Jibouri, 2012). According to one financial advisor (FA-03), the lack of performance measures of non-financial benefits in *ex-ante* evaluation adversely impacts critical decision-making and hinders the realisation of V*f*M.

At this juncture, attention is drawn to Grimsey and Lewis's (2004) definition of V*f*M, which focuses on "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 also on ensuring minimal maintenance issues and sustainability during operations. According to Grimsey and Lewis (2005) and Takim *et al.* (2009), 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, like social benefits to the community (European Investment Bank, 2011b).

An effective and efficient PMS can provide a PPP with the drive and direction toward the achievement of its strategic goals and forms the basis for decision-making. Within a PPP, key areas of focus (i.e., CSFs) are invariably defined and used to identify the needs of the SPVs and stakeholders; KPIs provide the measure of achievement. The respondents (n=23) stated that KPIs are only specific to the operational phase of PPPs, though it was acknowledged that they should be distributed to other key areas such as initiation, design, construction and maintenance. The KPIs used within the operations process of a PPP were deemed to be 'static' and unable to respond to the asset as it was subjected to changing conditions. This point was raised by a senior procurement advisor (PA-01) who suggested that:

> "Operational KPIs may be suitable for the period when the construction is completed but might not be appropriate for the next 20 years. A mechanism is needed for adjusting some of them as time changes, but limited work has

> been done."

Within the state of WA, a significant number of the PPPs that have been constructed are now in operation. The KPIs that had been developed were designed prior to the partnership phase of the PPP and, thus, the sustainability of such operational KPIs was deemed questionable by the respondents. The respondents defined the sustainability of KPIs in PPPs as their ability to be of relevance and to accommodate the changes to the asset over its life. An effective and efficient PM must reflect the context in which it is operating, yet it would appear that this issue has not been adequately considered. In addressing this issue, a procurement advisor (PA-02) suggested that a mechanism is required to constantly refine KPIs because assets, macro conditions and technology are subjected to changing conditions. In validating this suggestion, a procurement advisor (PA-03) for the Australian state government made the following comment:

> "PPPs are quite challenging because of the length of the contract. How do you deal with the factors raised by change of time? Some of our private prisons built in the 1990s have been modified in terms of their capacity, and we are in quite a different environment from when they were built. So, what are we evaluating against, the original business case or the actual outcomes? So I don't think the KPIs are always working. A more dynamic and smart concept should be adopted when designing the KPIs or a formal mechanism should be introduced to review the KPIs. However, the governments fail in doing so."

A number of issues other than the sustainability of the operational KPIs emerged during the interviews with the two procurement advisors. Firstly, limited attention was being given by the public sector to measure a project's performances during its early stages (e.g., conceptualisation - business study, initiation, planning, and procurement). Secondly, the process of evaluating the asset's contribution to the public (i.e., local communities) had not been considered and, most likely, would not be, since this would require a modification to the contractual conditions that were in place. Finally, the scopes of the operational KPIs were limited as they were deemed to be myopic for the long-term nature of PPPs. In recognising these limitations, an operations manager (OM-1) suggested that:

> "The KPIs implemented for the operations of PPPs are too narrow and the indicators about the long-term impacts of the procured infrastructure assets on the public (i.e., local communities/regions) are not involved. But they are very important and the governments should carefully consider how to design them. This is an issue being overlooked."

The views regarding the shortcomings of the PM of PPPs that were derived from the interviews and have been presented above can be summarised as follows: (1) traditional TCQ is too simple to capture CSFs and uncertainties that exist in PPPs; (2) the financial-based assessment of V*f*M cannot reflect the potential non-financial benefits provided by PPPs; (3) operational KPIs are not applicable for a long-term period; (4) no formal PM mechanism is available for refining the launched KPIs; (5) there are gaps in systematically measuring the preliminary outputs of PPP projects; and (6) the social impacts of the assets are largely ignored.

4.3.3 Recommendations for Improving the PM of PPPs

Identification of the problem was a relatively straightforward process and enabled the respondents to 'take stock' of the current issues surrounding PM. After this step, respondents were asked to propose ways to improve PM within social PPPs. While acknowledging PM was imperative and there was a need for change, respondents 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. While there was pessimism about the likelihood of any change process happening in the near future, respondents expressed their desire for a PM to be launched, particularly considering changes in WA's economic environment as a result of the falling price of iron ore and oil and a reduction in the Goods and Services Tax (GST) contribution from the federal government. A fall in revenue for WA's budget has resulted in a reduction of infrastructure spending. Thus, PPPs have now become a valuable proposition for new infrastructure investment. With this in mind, a public client (PC-03) suggested "now it's possibly the right time to address performance measurement in PPPs so we can look at future proofing our assets using tools such as Building Information Modelling

(BIM)”. BIM has been used widely in design and construction. However, it is also appropriate for the operation and maintenance of complex projects. An asset manager (AM-02) made the following statement:

> “BIM enables effective operation and maintenance. For example, facility maintenance in one of our PPP projects over the past decade is actually quite poor. Effective facility maintenance is not replacing products when they are broken, but it is replacing them before they are outdated so that the service quality would not be affected. BIM can help us manage that and the facility managers become more proactive in their works after using it. Since the use of BIM, they have been being clear where the money is spent to maintain the facility, what products should be replaced, and when they would be replaced. This is all what BIM can tell us, and it is very easy for the FM manager to handle everything and maintain the facility properly.”

Life-Cycle/Process-based Performance Measurement

Many of the interviews (n=17) suggested that the PM adopted for PPPs should be robust and take into account a project’s life-cycle so as to accommodate uncertainties and complexities (e.g., those relating to documentation, financing, taxation and technical details) that so often materialise from the *Initiation and Planning* and *Procurement* phases of a project. Contrastingly, however, the Director of a public authority (PC-01) and a leading financial advisor for PPPs (FA-01) suggested that a life-cycle approach to PM was cumbersome to implement due to the complexity associated with the stakeholder network and a project’s longevity. Despite these difficulties, several innovative ideas to overcome such hurdles were promulgated. For example, a procurement advisor (PA-01) suggested a process-based evaluation would be a promising way to address a life-cycle perspective for PM. A process approach is akin to the use of ‘stage gates’ and focuses on evaluating the deliverables (i.e., tangible and intangible outputs) of each project phase using a series of performance measures. This approach also was reiterated by an architect (A/DM-02) who stated that a “PPP should be evaluated against the development process of the project rather than the finally-procured asset” and a senior legal advisor (LA-02) who stated:

> "A performance evaluation conducted to measure the deliverables of each project phase by using relevant phase-based performance measures will be a feasible approach to replace 'traditional' *ex-post* evaluation in PPPs."

Respondents who advocated a life-cycle PM proposed that a realistic assessment of V*f*M was required to underpin this approach through an inclusion of tangible and intangible measures. For example, a senior financial advisor (FA-03) of PPPs made the following comment:

> "A life-cycle performance measurement must be accompanied by a real life-cycle V*f*M assessment; otherwise, it will fail in meeting your expectation. The governments always stated the tool they used to determine V*f*M is 'life-cycle'; but this is not true, because that method, such as the PSC, is only financially-based or an assessment for project life-cycle cost. V*f*M must be strategically addressed throughout the project life-cycle and so its evaluation should include the qualitatively and quantitatively objective performances of the assets (e.g., broader community outcomes). All of these cannot be reflected by the project's proposed cost benefits."

The placement of a strategic emphasis needs to be launched on the creation and assessment of V*f*M with its evaluation requiring the determination of quantitative and qualitative outputs. Thus, a consideration of the contribution of a PPP to a local community will be required. For example, in the case of a school, its ability to enhance educational quality should be contemplated and, for a hospital, the consideration may be to improve patient satisfaction.

Stakeholder-Oriented Performance Measures

"A life-cycle/process-based PM approach needs to reflect the deliverables that are produced from each phase of a project" (LA-02). With this in mind: "What kind of performance measures will be involved in a life-cycle PM?" A defining feature of a PPP is its stakeholder network. Therefore many of the respondents (n=19) indicated that a stakeholder-orientation was an appropriate stance to take for designing performance measures. Such measures are concerned with not only examining stakeholder satisfaction but also their expectations. The public, which are customarily end-users, form a critical component of the stakeholder network and, thus, performance measures must be married to their needs. In recognising this need, a design manager (A/DM-01) made the following comment:

> "Stakeholder issues, particularly the end-users of the assets, should be added to the performance measurement of the operation of a PPP, especially that of hospitals and stadiums. But this is relevant to not only end-users' satisfactions but also their willingness to use the public assets for a long period of time."

In addition to the public's need, a contract advisor also reinforced the requirements to ensure employee satisfaction during the operation of a facility, particularly in regard to the impact that changing technology and functional use can have on morale and productivity. In the case of a hospital, the contract advisor (CA-01) provided the following example:

> "To measure the holistic performance of a PPP, such as a hospital, the measurement approach must be against the current functionality as well as the maintenance and the delivery of future changes, such as changes in technologies and functional use. In fact, they are very important for the government as the asset will be handed back after the concession period … we also have to be concerned with not only patients' satisfaction, but also professional employees' performances and satisfaction such as doctors, nurses, midwives and even porters, because all of them can determine the service quality of the hospital."

Implicitly in this case the need for 'future proofing' an asset is again highlighted, with emphasis being placed on flexibility and adaptability to change. A lack of a formal mechanism to ensure the future proofing of an asset was also identified by a number of respondents (n=12).

Difficulties of Implementing a Life-Cycle PM

The introduction of a new PMS will be an arduous task for organisations and their PPP projects. Such difficulties must be identified prior to the implementation of any

PMS; if not, the probability of failure will be high (Neely *et al.*, 2005). It was widely acknowledged among the respondents (n=20) that this was a problematic issue, but it was suggested that access to data and the subsequent analysis of KPIs would determine the effectiveness and efficiency of a new PMS. It was also identified that obtaining the necessary data posed the main hurdle, though it was suggested that if BIM was used in conjunction with Construction-Operations Building Information Exchange (COBie) the ability to implement an effective and efficient PMS would be significantly improved. According to Love *et al.* (2013), a PMS juxtaposed with BIM can enable assets to be 'future-proofed' by providing key decision-makers with the ability to make informed decisions across a project's life-cycle.

Apart from the issues pertaining to the acquirement and management of data, a public sector director (PC-01) and a project manager (PM-01) suggested that a way to effectively absorb the 'lessons' learnt from an analysis of the KPIs is important and difficult in PPPs because this relates to a realisation of the projects' performance improvements. However, the information obtained from the evaluation process is complex because it results from an integration of multiple stakeholders. These two respondents considered that a robust system designed for learning the lessons derived from evaluations will be necessary for supporting the PPP life-cycle performance measurement. Essentially, as addressed in the literature review (Chapter 2), the concept of life-cycle performance measurement in this research is specifically dependent upon the implementation of business process management, whereby continuous improvement throughout the project life-cycle forms an integral part of its delivery strategy (Pedler *et al.*, 1991). 'Organisational learning' has been identified as a 'vehicle' for delivering consecutive organisational improvement and incremental innovation in business processes (Buckler, 1996; Scarbrough *et al.*, 1998). According to Kululanga *et al.* (2002), to facilitate a learning organisation, particularly for construction firms, the mechanisms that stimulate 'learning and innovation' culture must be embraced. However, few construction organisations have systems or mechanisms to capture and absorb their lessons learned or express their interest in doing so (Love *et al.*, 2003). To shed light on this field, the learning mechanisms need to be embedded within the PPP life-cycle performance measurement. These mechanisms act as stimulators that can assist the organisations to systematically acquire this important feedback (Love *et al.*, 2004). Such lessons may contribute to a significant development of the organisation's 'learning capability', which is a key enabler for business growth and success (Buckler, 1996; Wang and Ahmed, 2003).

Additionally, the abatement regime also was identified as a problematic issue by a project director (PC-03) and a procurement advisor (PA-03), both of whom were involved with procurements of PPPs as senior management personnel within state governments of Australia. The abatement regime of a PPP is a mechanism implemented to provide financial incentive to the service provider (i.e., the private entity participating in the asset's operation). It is directly linked to payments to the private sector and can be used to monitor whether the organisation responsible for providing the public service can meet the predefined and agreed service requirements. As claimed by PC-03 and PA-03, a wider abatement regime, which is able to cover tangible and intangible issues rather than the output quality and quantity of the PPP operations, should be designed within the life-cycle PM. They also proffered that such a new abatement regime must be a 'balanced' mechanism without substantially increasing the life-cycle costs of a project; otherwise, the potential profitability will be reduced.

4.4 Life-Cycle PMF of PPPs

A conceptual model is proposed in Figure 4.2, as a consequence of the findings and discussions that were derived and presented in the foregoing sections of this chapter. This model is a life-cycle PM integrated with a set of measurement components and techniques that embrace tangible and non-tangible outputs that accommodate a stakeholder orientation and, thus, it is able to benefit practitioners by resolving the existing limitations of PM of PPPs that were identified above.

As illustrated by Figure 4.2, the life-cycle PM with a wider V*f*M assessment is capable of completely examining both financial and non-financial benefits to be provided by PPPs and effectively reflecting the deliverables of each critical phase of the projects. Thereby, it can deal with the problematic issues of existing performance measurements of PPPs, in regard to the narrow scope of the V*f*M assessment that primarily concentrates on cost benefits (i.e., PSC) and the lack of systematic PM mechanisms relevant to the outputs of a project's inception stage. Additionally, the development of a life-cycle PM for PPPs is under the strategy of stakeholder orientation, leading to a position where the stakeholder-oriented performance measures, with an emphasis on stakeholder satisfaction and expectation (e.g., innovation, sustainability of the asset and impacts on the public), dominate within the proposed model. Thus, this model can marry with the inherent complexities and uncertainties of a PPP stakeholder network, particularly when it is a social infrastructure PPP project, which incorporates various key stakeholders, such as public clients, creditors, shareholders, concessionaire, sub-contractors, end-users and professional staff who are associated with the provision of the service. In essence, the usefulness and applicability of the stakeholder-oriented model to organisational performance measurement has been acknowledged by both academia and industry; for example, the *Performance Prism* and the *Balanced Scorecard*.

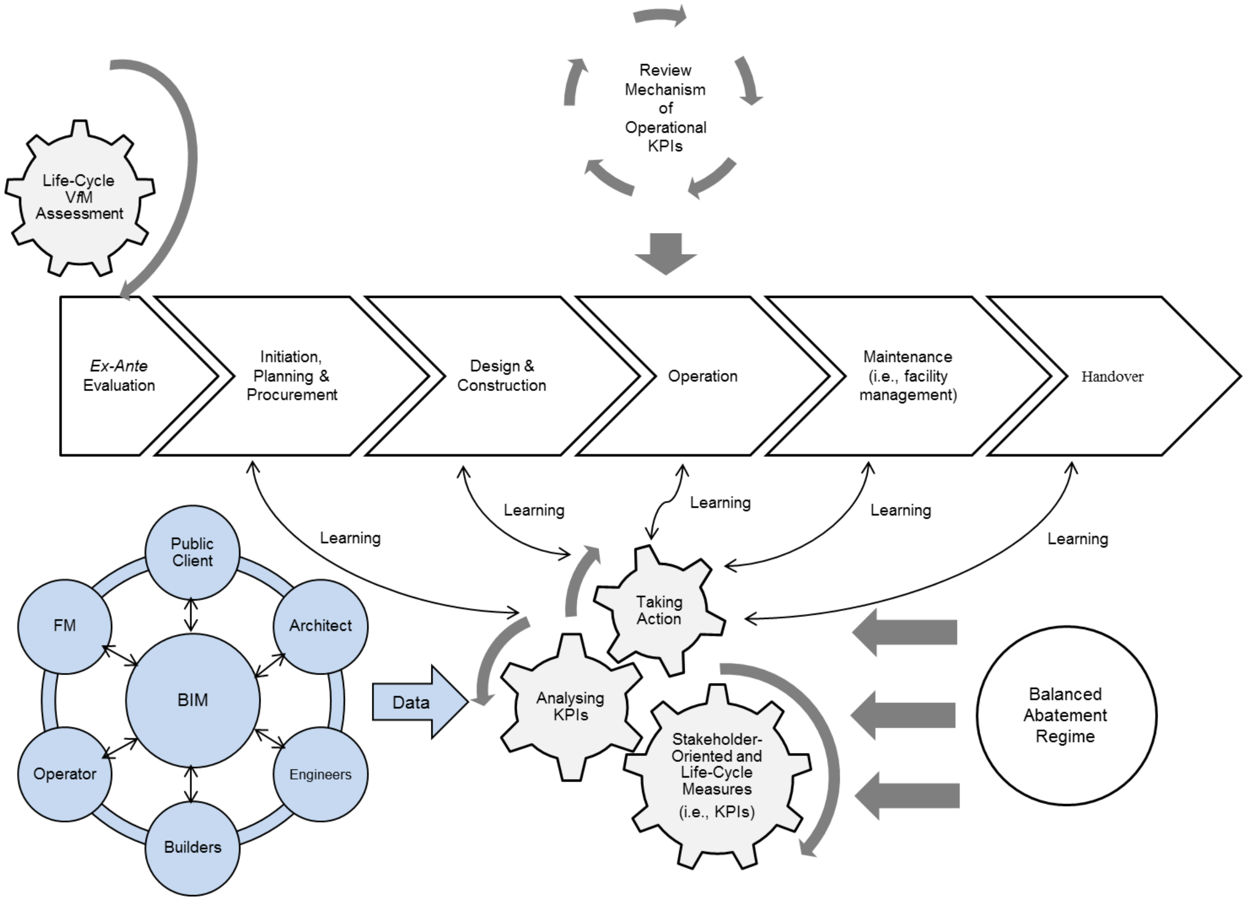


Figure 4.2 Life-cycle/process-based PM of social infrastructure PPPs

The proposed life-cycle PM is unique and practical, owing to its embedded review mechanism that relates to the operational KPIs. This innovative mechanism provides assistance in ameliorating the ability of the operational KPIs in accommodating the project's changing business environment. Moreover, the 'learning mechanisms' were installed into the proposed model, and this can help the management teams of PPPs to absorb the measurement lessons throughout the projects' life-cycles and to enable effective performance improvements. Moreover, the need for a balanced abatement regime was addressed, which therefore, can encourage the involved private consortia to adopt this new PM approach to ensure a better performance without substantially increasing the project's life-cycle costs. However, as highlighted in Chapter 1, the aim of this research is to investigate how to comprehensively and effectively measure the performance of social infrastructure PPPs, rather than to develop a new regime for the public sector to stimulate and govern the private sector's performance in an asset's operations. Thus, the issues concerning a balanced abatement regime have not been explored and will not be detailed in the following chapters of this thesis, but it would be a valuable topic for future research on PPPs.

In addition, the life-cycle model is underpinned by the introduction of BIM. It was indicated above that data efficiency, which emphasises the effective and efficient accessing and managing of necessary data, might be a hurdle that will be harmful to the practicability of the new PM approach. Conceptually and practically, BIM is a technology-focused methodology that is robust in its justification and evaluation through effectively and efficiently engendering useful information on design, construction, operation and facility management in construction projects, particularly mega infrastructure projects (Love *et al.*, 2013).

According to the European Investment Bank (2011a), the development process of PPPs contains eight stages (i.e., *ex-ante* evaluation, selection and definition, PPP option assessment, getting organised, pre-tendering work, the bidding process, contract and financial close, and contract management and *ex-post* evaluation), which can be categorised into three main interrelated phases (Figure 4.3): (1) Initiation and Planning; (2) Procurement; and (3) Partnership (e.g., design, construction, and operation, maintenance and handover). Based on this definition and the concept underlying the conceptual model (Figure 4.2), a life-cycle performance measurement framework (PMF) was developed, as depicted in Figure 4.3, and it is a process-based life-cycle evaluation framework. It has been identified above that there are two kinds of formal evaluation in social infrastructure PPP projects: one is an *ex-ante* evaluation used to offer assistance in investment decision-making by assessing feasibility and costs, and the other is an *ex-post* evaluation that examines whether the project's actual construction and operational outputs and outcomes can meet the predetermined standards. Thus, two 'evaluation nodes' can be normally noted in the performance evaluation system of a PPP, either at the initiation stage or at the end of the construction of the project. Nonetheless, in the developed PMF (Figure 4.3), two additional 'evaluation nodes' are placed into the development process of PPPs (i.e., Evaluations 2 and 3), and the 'whole-of-life measurement', which is able to capture the performances of initiation and planning, procurement, design and construction, operation and maintenance, was launched to replace the conventional evaluation approach.

The developed life-cycle PMF is an effective and efficient tool that can add value to the decision-making process of PPP projects. Notably, it is suitable for both public authorities and private entities that are involved with the delivery of social PPPs. For instance, in the inception phase (i.e., Initiation and Planning), the project director of a PPP within a public authority can have a clearer understanding of the potential feasibility and/or the appropriateness of the conceptualisation and definition of the project by undertaking a broader V*f*M assessment and reviewing the relevant KPIs of each stage. This will result in more rational and reliable decision-making because the developed framework is powerful in capturing the issues that would be changed dynamically over the project's life-cycle. Similarly, the private consortia of PPPs can benefit from the provision of a life-cycle insight into the deliverables of the design, construction, operations and management of projects. In summary, under this framework, the project director and manager of a social infrastructure PPP, in either the public or private sector, can grasp useful information on the project's performance by evaluating relevant stakeholder-oriented KPIs at each 'evaluation node', and can identify the potential areas for future improvements and changes. Then, effective and efficient responsive actions can be taken to maintain satisfactory performance at each stage of the project in order to eventually achieve V*f*M.

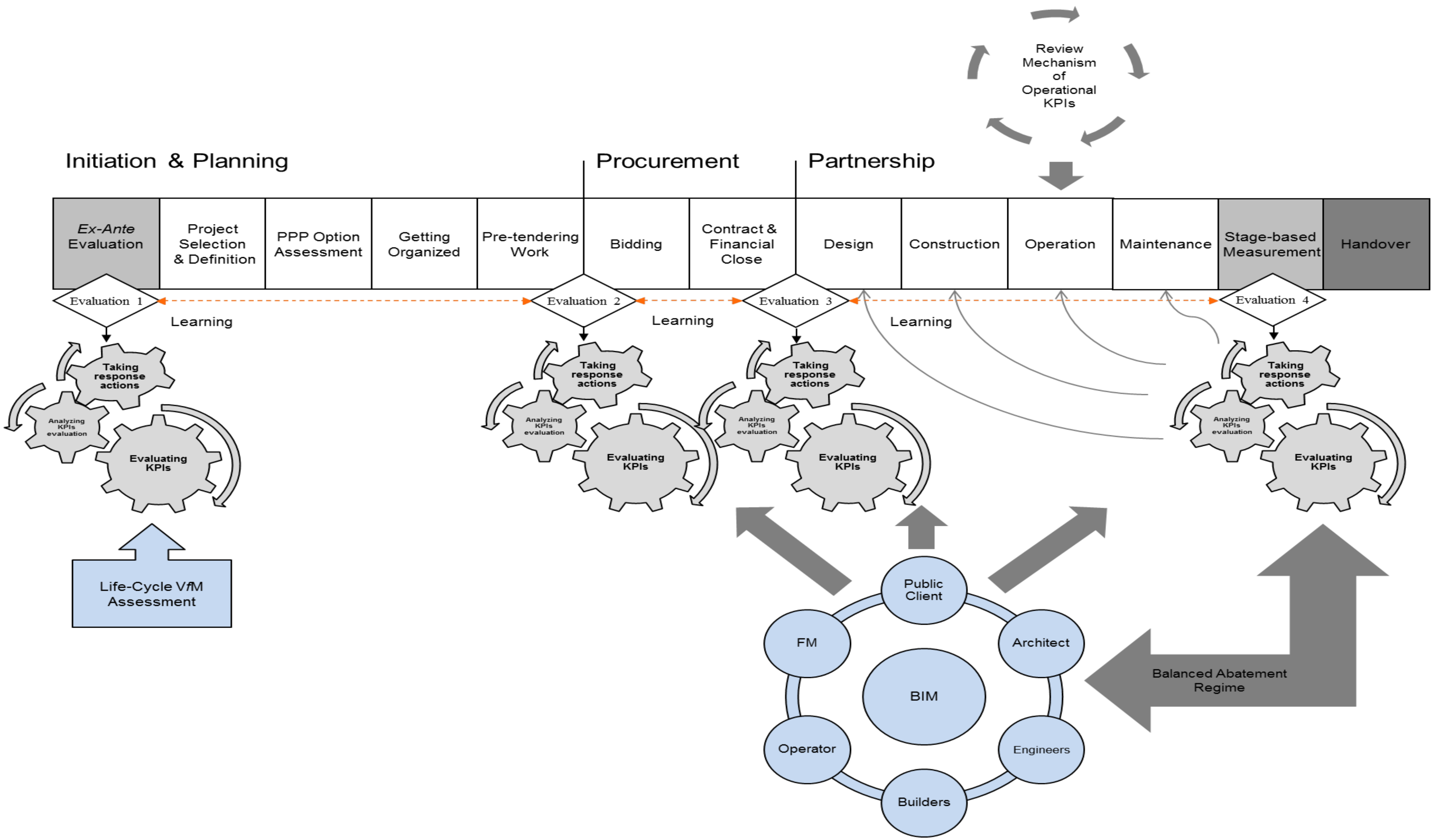


Figure 4.3 Conceptual PMF of social infrastructure PPPs

4.5 Measurement Perspectives of the Conceptual PMF

A conceptual PMF was proposed as a result of the findings from the interpretations of current practices in PMs of PPPs. According to the procedure of the design of the performance measurement system (PMS) (Figure 2.5), PM perspectives that serve as the basis for identification of performance measures (i.e., KPIs) need to be derived after interpreting the current PM approaches. On the basis of Figures 4.2 and 4.3, it is noted that the proposed PMF is a process-based framework with an emphasis on stakeholder-oriented KPIs supported by BIM and a long-term strategic goal (i.e., V*f*M). These features completely comply with well-known stakeholder-oriented PMFs, such as the Balanced Scorecard (BSC) and the Performance Prism, which are useful in helping an organisation's key stakeholders to determine the performance measurement perspectives in light of their strategies (Neely *et al.*, 2002). Therefore, a critical discussion on the suitability of the BSC and Performance Prism is presented and it provides assistance in deriving the measurement perspectives for the proposed conceptual PMF.

4.5.1 Balanced Scorecard and PPPs

Over the last two decades, the BSC is undeniably one of the most reputable stakeholder-oriented PMFs used in construction (Robinson *et al.*, 2005), and it has been used at various levels (e.g., industry, corporate and project) (Kagioglou *et al.*, 2001; Bassioni *et al.*, 2008; Chan, 2009). Additionally, the KPIs derived by Yuan *et al.* (2009; 2012) for PPPs originated from the BSC.

Many criticisms of this framework, however, have been raised by researchers and practitioners. Neely *et al.* (2001) regarded some measures of the BSC as being too narrow to capture the factors that are critical to business success. For example, in the BSC approach, the view of what constitutes a stakeholder is not broad enough and covers only customers and shareholders, largely neglecting such key stakeholders as suppliers, alliance partners, employees, regulators, local community and/or pressure groups, all of which are essential for the performance and success of an organisation or project. Furthermore, the BSC fails in highlighting "the relationship between the measures proposed for certain goals" (Kagioglou *et al.*, 2001, p.87). Also, no mention is made of the contribution of stakeholders to an organisation (Neely *et al.*, 2001). In summary, the components of the BSC cannot keep pace with today's increasingly changing environment of businesses, especially under the conditions of multiple-stakeholder complexities and integration (Neely *et al.*, 2001).

Importantly, the SPVs encompass a set of parties, such as the client, concessionaire, private sub-subcontractors and constituent members (Yong, 2010). Thus, an effective integration of various stakeholders is imperative for the successful delivery of PPPs (Kwak *et al.*, 2009). Nonetheless, the BSC has inherent deficiencies in measuring organisational performance effectively and efficiently against a multiple-stakeholder environment. Mindful of this, it is not capable of effectively and substantially capturing and reflecting the nature and context in which PPP projects operate and this framework, on its own, might not be a suitable choice for the theoretical support of the development of a PMS for PPPs.

4.5.2 Performance Prism and PPPs

Based on the characteristics of PPPs, a PMF that is capable of simultaneously measuring outputs at project and corporate levels to achieve long-term success and to deal with the complexities raised by multiple stakeholders is an ideal management tool to underpin the performance measurement of PPP projects. Accordingly, the Performance Prism proposed and developed by Neely *et al.* (2001) is deemed to be a feasible framework. This is because the Performance Prism is a holistic framework structured to shed light on the complexity of multiple stakeholder integration and to provide assistance in directing and guiding the design of performance measurement for long-term success within a particular business environment (Neely *et al.*, 2002). Its robust ability in measuring organisational performance, particularly within a multiple-stakeholder environment, has been tested by Neely *et al.* (2001) in a case study for the logistics industry. The Performance Prism contains five interrelated facets designed for measurement (Neely *et al.*, 2001, p.6-7) (Figure 4.4):

1. *Stakeholder Satisfaction*: who are our stakeholders and what do they want and need?
2. *Strategies*: what strategies do we need to satisfy these sets of wants and

needs?

3. *Processes*: what processes do we need to allow our strategies to be delivered?
4. *Capabilities*: what capabilities (people, technology and infrastructure) do we need to put in place to allow us to operate our processes?
5. *Stakeholder Contribution*: what do we want and need from our stakeholders?

The views of 'stakeholders' are incorporated into the Performance Prism. This gives it the ability to overcome the hurdle triggered by multiple stakeholders in PPP evaluation. The facet of *Stakeholder Satisfaction* in the Performance Prism is broader than other PMSs (such as the BSC) that incorporate a limited stakeholder perspective. It mentions not only shareholders and customers, but also suppliers, alliance partners, and even intermediaries (Neely *et al.*, 2001). At the project level, "stakeholders are individuals or organizations that are affected by, or affect the development of, the project" (El-Gohary *et al.*, 2006, p.595). Various parties other than public clients and main concessionaires are involved in PPP projects, such as sponsors, subcontractors, suppliers and facility management organisations (Chinyio and Gameson, 2009). In fact, the key stakeholders of a PPP include government, consumers, investors, employees (e.g., clients, financiers and consultants) and end-users. Considering their perspectives, the *Stakeholder Satisfaction* of the Performance Prism can completely capture and indicate the satisfaction levels of the stakeholders that are critical to the success of a PPP project.

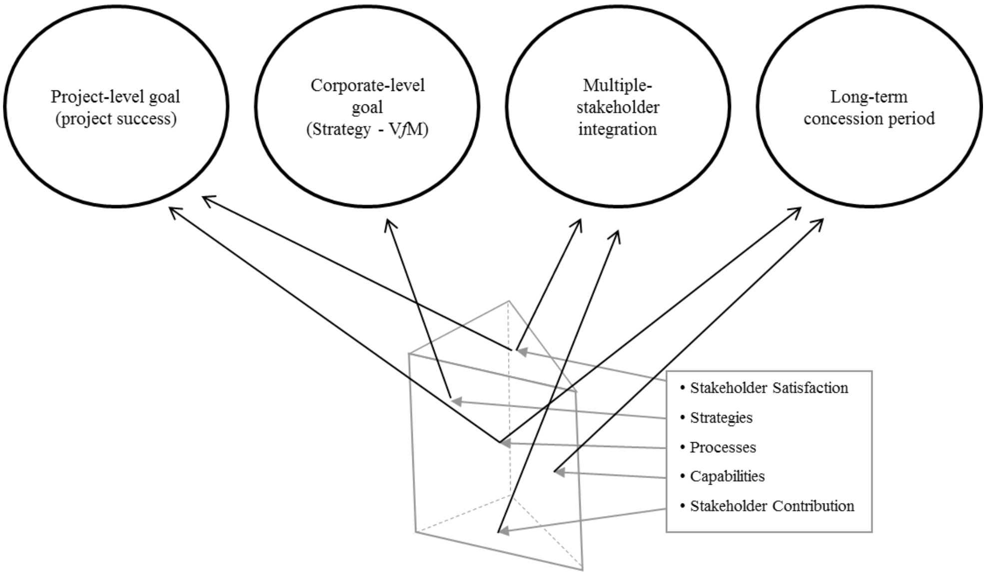
The *Stakeholder Contribution* is a facet used to indicate stakeholders' contribution levels in the organisations. All other PMFs focus only on stakeholder satisfaction, but fail to address the performance of their contribution to the organisation (Neely *et al.*, 2002). According to Neely *et al.* (2001), "not only do organisations have to deliver value to their stakeholders, but also organisations enter into a relationship with their stakeholders, which should involve the stakeholders contributing to the organisation" (p.7). In other words, the performance of an organisation is substantially affected by both stakeholders' satisfaction and their contribution to the organisation (Neely *et al.*, 2002). The measurement of stakeholder contribution is critical to the measurement of PPPs. The SPVs are comprised of a variety of parties, resulting in PPP project managers needing to oversee a wide range of group performances in order to maintain a satisfactory project performance (Yong, 2010). The performance of a PPP is, therefore, associated with not only how project stakeholders satisfy the organisation, but also how adequately such key stakeholders contribute to the organisation. Evaluating PPPs without considering the symbiotic relationship between the stakeholders and the organisation provides project managers with no insight into what contributions should be strengthened in order to improve the whole performance of the project. This is a critical factor in project performance.

Strategy, as mentioned above, is the baseline of performance measurement. It has been acknowledged that V*f*M performs as a benchmark of PPP strategy. Within the framework of the Performance Prism, strategies required to ensure stakeholders' wants and needs have been placed as a facet of the organisation's performance measurement. This facet fits well into PPP performance evaluation because it lets PPP project managers or evaluators clearly understand what strategic objective (V*f*M) the project should move toward or how it should be changed to meet the stakeholders' expectations.

Apart from the aforementioned facets, the *Processes* and *Capabilities* of the Performance Prism can effectively operationalise PPP infrastructure projects as well. It is noted that achieving project success within a long-term concession period is a defining feature of PPPs (Kwak *et al.*, 2009). Project success is often expressed as the 'product success' and 'project management success', where product success is concerned with final product quality while project management success emphasises managing the project development process (Baccarini, 1999). A PPP project possesses a complicated delivery process that is summarised into three main parts; *Initiation and Planning*, *Procurement*, and *Partnership* (i.e., design, construction, operation and maintenance) (European Investment Bank, 2011a). According to Yuan *et al.* (2009), the quality of the final asset of the underlying PPP project can be measured by end users' satisfaction as well as construction and operational indicators. It also has been considered that the *Stakeholder Satisfaction* facet of the Performance Prism can successfully capture the satisfaction levels of the multiple end users of PPPs, and Neely *et al.* (2001) proffer that the *Processes* of the Performance Prism are capable of helping to examine whether the placed processes are effective and efficient in delivering the organisation's long-term strategies. Notably, the 'process' measure is useful for reflecting how a PPP project meets contractual obligations, since it is associated with the performance measures relating to design quality, construction quality, product quality, commercial values and profitability, all of which are crucial components of PPP contract management (Yuan *et al.*, 2009). On the basis of the discussion above, it is reasonable to conclude that the *Processes* facet is able to comprehensively oversee the process performance of a PPP and the Performance Prism has the best prospects in PPP performance measurement in terms of long-term project success.

Business operations in organisations must be supported by certain skills, practical procedures, physical infrastructures and technologies, which are normally referred to as organisational capabilities (Neely *et al.*, 2002). The delivery of a PPP depends on the strong capabilities of the SPV, such as human resources (HR), technologies (i.e., BIM), equipment, management and finance infrastructure (Yong, 2010; Yuan *et al.*, 2009). Take HR and finance infrastructure, for example. Many skilled professionals (e.g., advisors, consultants, engineers and experts) must be hired during the project life-cycle to deal with a series of potential problems and to manage certain activities (e.g., tax, accounting, finance, legal, engineering and environment), and a sound and resilient financing package is the foundation that underpins the project delivery (Chinyio and Gameson, 2009). Essentially, the capabilities are the issues critical to the long-term success of the project and they should be the focus of PPP performance measurement (Yong, 2010). With this in mind, the Performance Prism is robust in this field because it outlines the importance of the organisation's capabilities in performance measurement and considers them as "the fundamental building blocks of the organisation's ability to compete" (Neely *et al.*, 2001, p.7).

The sections above critically demonstrate how the Performance Prism can operate within PPP infrastructure projects. Figure 4.4 vividly summarises and depicts this demonstration. As defined by Neely *et al.* (2001), "the Performance Prism is a framework – a tool – which can be used by management teams to influence their thinking about what the key questions are that they want to address when seeking to manage their business" (p.7). This means that the Performance Prism is not a fixed and prescriptive model, but a framework that can be flexibly adapted to suit performance measurement across many industries.



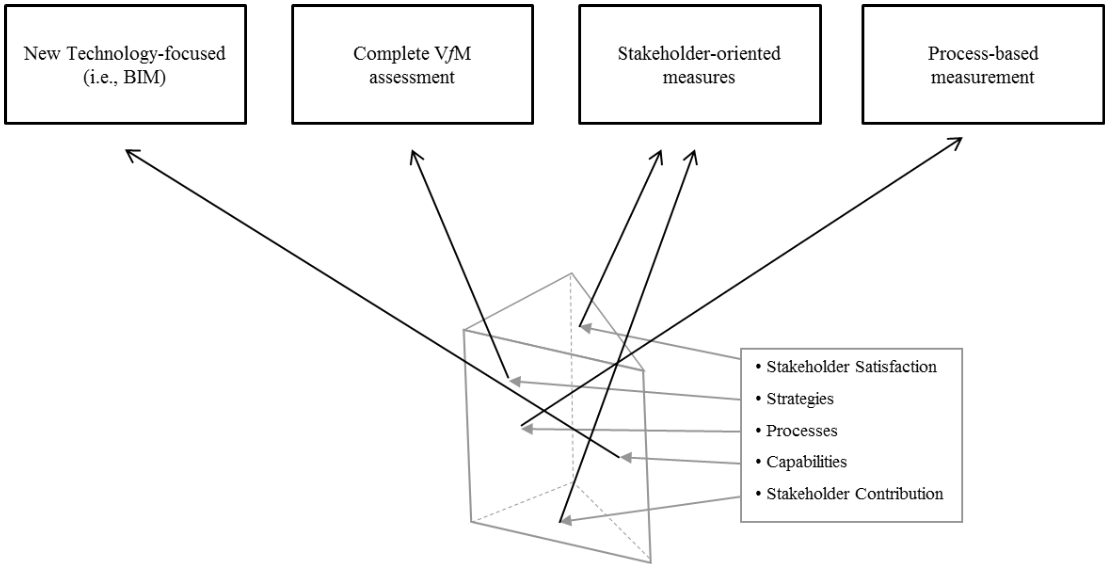
Adapted from: Neely *et al.* (2001)

Figure 4.4 Matching the Performance Prism to PPPs

4.6 Performance Indicators of a Conceptual Framework

According to Figure 4.4, it can be reliably concluded that the Performance Prism is an appropriate, rational and ideal framework to be the theoretical foundation of the conceptual PMF developed as Figure 4.3, since it seeks to enhance the performance measurement by emphasising stakeholder issues, strategies, processes, and capabilities (Neely *et al.*, 2002), all of which are the focuses of the conceptual model. Figure 4.5 illustrates how the Performance Prism underpins the life-cycle/ process-based PMF proposed above.

Due to the inherent perfect match demonstrated above, these facets of the Performance Prism are capable of serving as the performance measurement perspectives of the developed conceptual PMF. According to the process identified from the literature review (Figure 2.5 in Section 2.4.3), the development of relevant KPIs in accordance with the derived measurement perspectives is the final step of the design of a PMS. For that matter, the KPIs were conceptually identified and will be discussed on the basis of the five facets of the Performance Prism, in this section.



Adapted from: Neely *et al.* (2001)

Figure 4.5 Matching the Performance Prism to the developed conceptual model

For the purpose of developing KPIs for PPPs by using the Performance Prism, a guideline was developed as follows:

- *Facet 1 – PPP stakeholder satisfaction*: e.g., “Who are the (key) stakeholders?” and “What do they want and need?” The top management of a PPP franchise/consortium could decide the options and actions, such as identification of key stakeholders and performance indicators.
- *Facet 2 – PPP strategies*: e.g., “What are the long-term and short-term strategies required to ensure that the wants and needs of targeted PPP stakeholders are met?”
- *Facet 3 – PPP delivery processes*: e.g., “What are the PPP processes that have to be put in place in order to allow targeted PPP strategies to be delivered efficiently and effectively?” and “How can the intended process innovations lead to stakeholder satisfaction and overall success?”
- *Facet 4 – SPV capabilities*: e.g., “What are the PPP capabilities required to operate all relevant PPP processes?”, “How can the capabilities be sustained?” and “What are strategies required to ensure adequacy of PPP capabilities?”
- *Facet 5 – PPP stakeholder contributions*: e.g., “What are the roles and responsibilities of the stakeholders of PPP?”, “What are the metrics of

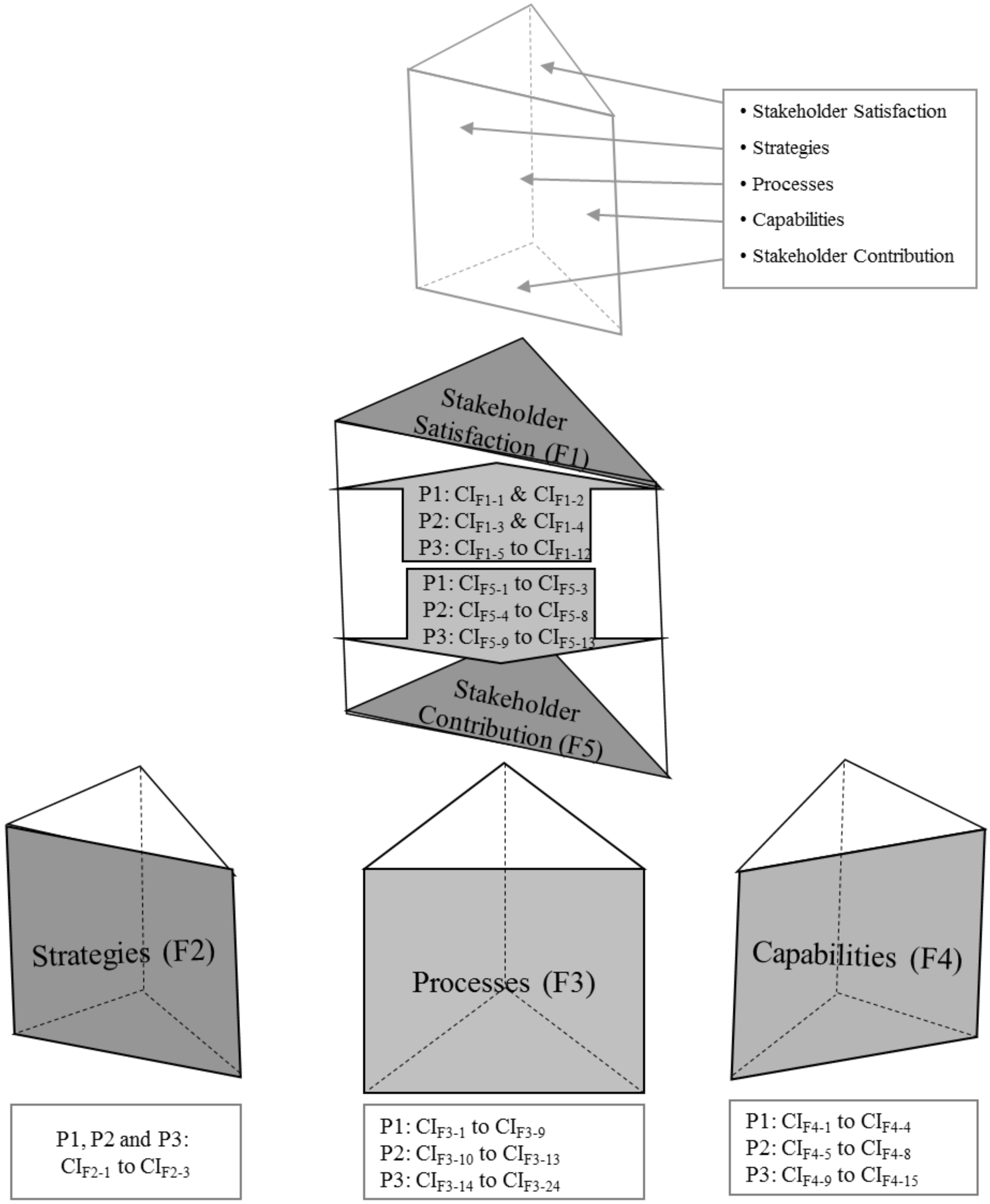
measuring and monitoring stakeholder contributions towards critical success factors (CSFs)?", "What are motivational arrangements and incentive mechanisms for stakeholder contributions?" and "What are the barriers and enablers of stakeholder-led PPP innovations?"

Based on the KPI development guidelines above, a sequence of KPIs can be derived within the configuration of the Performance Prism and the conceptual framework illustrated in Figure 4.3. As these KPIs possess a phase-based nature, they can be viewed as the life-cycle KPIs that are powerful in capturing the performance of a PPP over its entire development process. Figures 4.6 and 4.7, and Appendix D, illustrate and indicate all of these derived KPIs, which are named as core indicators (CIs) within the rest of this thesis.

Stakeholder Satisfaction (F1)

Stakeholder satisfaction is highly important for performance measurement, especially within the context of multiple stakeholders. The Performance Prism commences with the facet of stakeholder satisfaction as satisfying stakeholders' wants and needs, and it is the baseline for the existence of an organisation (Neely *et al.*, 2001; 2002).

Throughout the life-cycle of a PPP project, the SPV exists to satisfy a public client's requirements, which focus on providing a service to the public using private-sector investment (Pongsiri, 2002; Zheng *et al.*, 2008; Chinyio and Gameson, 2009). The public-sector client is actively involved in each of the project's life-cycle phases (Kwak *et al.*, 2009). Therefore, the satisfaction of the public client (CI_{F1-1}, CI_{F1-3} and CI_{F1-5}) must be addressed over a PPP's whole term of life, and the user satisfaction (CI_{F1-12}) essentially needs to be raised when conducting the performance measurement after the infrastructure is operational.



Adapted from: Neely *et al.* (2001; 2002)

Figure 4.6 Core indicators under the Performance Prism (Appendix D)

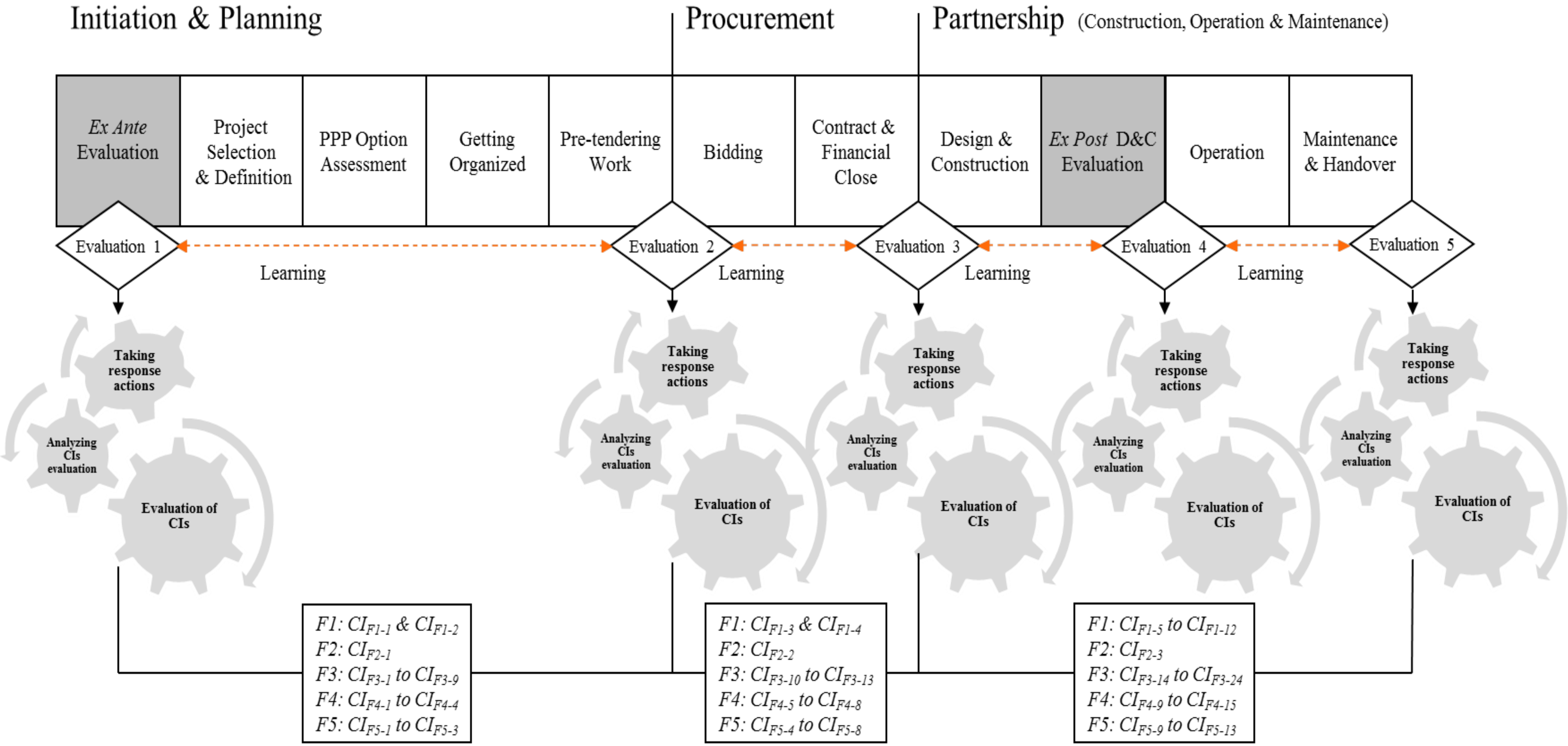


Figure 4.7 Conceptual life-cycle performance measurement system of PPPs

Additionally, the general concessionaire is involved with PPP projects from the *Procurement* phase, during which the finance structuring of PPPs is completed. A number of financial mechanisms can be used to fund PPP projects, such as equity and bank debts, loans and bonds (Chinyio and Gameson, 2009; Yong, 2010; Regan *et al.*, 2011a). With this in mind, general contractor, shareholders and creditors (e.g., banks, insurance/pension corporations and multilateral agencies) can be deemed as the essential stakeholders of PPPs in the *Partnership* phase. Thereby, it is rational to launch the CIs in relation to the satisfaction of the general concession contractor, shareholders and creditors (CI_{F1-7}, CI_{F1-10} and CI_{F1-11}) in the *Partnership* phase. It should be noted that lenders bring discipline to a project by keeping pressure on the contractor to observe loan covenants. Banks are tougher 'taskmasters' with PPPs than government agencies and thus this role is worth highlighting when discussing stakeholders' satisfaction in PPP projects.

After the appointment of a general concession contractor, the subcontractors and suppliers will be engaged to complete the construction of the asset. Main contractors should maintain a good relationship with all other stakeholders in order to ensure satisfactory progress throughout the project's life (National Audit Office, 2001). Kumaraswamy and Anvuur (2008) suggest that the relationship between general contractors and subcontractors, as well as suppliers, plays a more important role in the construction of PPPs than in the case of traditional lump-sum projects. Hence, the contractor's ability to maintain relationships with subcontractors and suppliers of necessary building products to be installed into the asset, and to ensure their satisfaction (CI_{F1-8} and CI_{F1-9}), is a determinant of PPP performance (Davis and Love, 2011).

Over the past decade, in the management research scheme, employees have been acknowledged by researchers as the organisation's key stakeholders (Bourne *et al.*, 2003). In PPP projects, many professional staff, such as advisors, consultants and engineers, must be employed by the SPVs to deal with the problems associated with tax, financing, accounting, legal issues, engineering and the environment (Yong 2010). Their satisfaction levels for many aspects, such as salary, workplace safety and working environment, can significantly affect the project's outcomes. To address this prevailing issue, the CIs of the employee satisfaction construct (CI_{F1-2}, CI_{F1-4} and

$CI_{F1\text{-}6}$) are represented in all PPP phases, as indicated in Appendix D.

Strategies (F2)

Strategy, in any organisation, is not only the base of internal business processes, but also stakeholders' behavioural goals (Neely *et al.*, 2001). Without an appropriate strategy, it is impossible for internal business processes to effectively and efficiently deliver satisfactory services/products to customers, and employees will be confused about what matters and how they should behave to achieve success (Neely *et al.*, 2002; Bourne *et al.*, 2003). Solomon and Young (2007) argue that strategies form the foundations of performance measurement. A common strategy of PPP infrastructure projects, as mentioned above, is the realisation of V*f*M (Akintoye *et al.*, 2003; Zhang 2006b; Yuan *et al.*, 2009). V*f*M has been benchmarked as the principal management philosophy that penetrates throughout the whole life-cycle of PPPs (Treasury Taskforce, 1998; Grimsey and Lewis, 2005; Henjewele *et al.*, 2011).

Broadly speaking, V*f*M is the optimum combination of life-cycle cost and quality (asset quality and service quality) under user requirements and a specified timeframe (Partnership Victoria, 2001). This definition determines that the assessment of V*f*M in PPP performance evaluation should be concerned with project life-cycle costs, as well as quality, within the framework of user satisfaction and the project schedule. In other words, the CIs of V*f*M ($CI_{F2\text{-}1}$ to $CI_{F2\text{-}3}$) ought to constitute project life-cycle costs, physical and service qualities of the asset, project duration and end-user satisfaction. Notably, V*f*M is a concept covering a variety of issues and the measurement facets of the Performance Prism are interconnected; therefore, there are overlaps between the measures identified from the Performance Prism for measuring PPPs. For example, project quality, duration and end-user satisfaction are also the core components of the *Stakeholder Satisfaction* facet and *Process* facet, respectively. As a result, life-cycle cost is the only issue discussed here and the other three indicators are demonstrated in the sections of *Stakeholder Satisfaction* and *Process*.

Life-cycle cost, normally, is the most important factor that must be considered in any PPP before the implementation of the project, and it is complex. This complexity is derived from various factors. According to Sing *et al.* (2013), time, contract, price, human factors and variations to scope are the determinants of the final costs of construction projects. In fact, a project's life-cycle is dynamic and can result in a substantial change in the predetermined budget of the project. However, in PPPs, the examination of the whole-of-life cost is either at the stage of *ex-ante* estimation or at *ex-post* assessment, and there is no mechanism to control and improve the cost performance over the project's life. Thus, the measurement designed for project life-cycle cost performance in the developed PMF is a constant cost assessment that possesses not only the pre-project estimation and post-implementation examination, but also a process-based monitoring (Figure 4.6). The aim of doing so is to capture the dynamic nature of the project life-cycle and provide the key stakeholders with a dynamic insight into the life-cycle cost of the project, so as to hedge cost overruns.

Processes (F3)

To achieve V*f*M in a PPP, it is necessary for both the public sector and the private SPV to group appropriate internal business processes throughout the project's life. Under the framework of the Performance Prism, the measurements of processes are used to identify what internal business processes should be improved to increase the effectiveness of the whole workflow in the organisation (Neely *et al.*, 2002).

Appendix D identifies core process indicators for all phases of a PPP infrastructure project. In the *Initiation and Planning* phase of PPPs, a series of tasks are identified, including macro-environment analysis assessment, definition of service needs and desired output, risk management (identification, analysis and allocation) and project structuring (financing, commercial, technical and engineering) (European Investment Bank, 2011a). The performance quality of these aforementioned activities is a critical metric for evaluating the effectiveness and efficiency of the processes associated with PPP initiation and planning (Yuan *et al.*, 2009; Yong, 2010). Consequently, a set of CIs (CI_{F3-1}, CI_{F3-2}, CI_{F3-3}, CI_{F3-5} and CI_{F3-8}) can be rationally derived. Notably, the CI relating to the feasibility and/or business case study (CI_{F3-4}) (e.g., affordability, bankability, constructability and maintainability) should not be neglected in project *Initiation and Planning* as it has been identified as one of the CSFs for PPPs (Zhang, 2006a, b; European Investment Bank, 2011a). Additionally, it is essential to emphasise the CIs in regard to concession issues (e.g., selection criteria of concessionaire and concession period) (CI_{F3-6} and CI_{F3-7}). There is a widespread consensus that an appropriate concession contractor and a reasonable concession period are critical to PPP project success. Zhang (2004a, b) and Salman *et al.* (2007) conceptually support this argument and identify the importance of appropriate concessionaires and concession periods in the viability of PPP projects.

Bidding is an important function of the *Procurement* phase of PPPs, where activities such as pre-qualification, shortlisting, tender invitation, interaction with bidders, tender evaluation and bidder selection must be conducted step by step (European Investment Bank, 2011a). Yuan *et al.* (2009) argue that a transparent and competitive bidding process is critical to the successful delivery of an infrastructure PPP and therefore the transparency and competitiveness of the bidding procedure must be considered to be a process KPI of PPP projects. With this argument, it is reasonable to derive a CI representing the transparency and competitiveness of the bidding procedure ($CI_{F3\text{-}10}$) for the conceptual life-cycle PMF.

After the completion of tendering/bidding, the PPP contract needs to be finalised under the 'final negotiation' framework. This framework is pivotal and should typically include such key issues as negotiation timetable and how to define and record the remaining problems and matters already agreed upon or settled (European Investment Bank, 2011a). Thus, the core indicator of the comprehensiveness of the final negotiation framework ($CI_{F3\text{-}11}$) is required. Besides, the financial close of a PPP occurs in the *Procurement* phase and it enables the funds (e.g., equity, loans and debts) to start flowing to support the project implementation (Chinyio and Gameson, 2009). The SPVs and public sectors need to carry out a considerable amount of detailed work to reach financial close; therefore, the work organised to reach financial close must be effective and efficient, otherwise the progress of PPPs can be delayed (European Investment Bank, 2011a). Accordingly, the CI in respect of the effectiveness and efficiency of the financial close ($CI_{F\text{-}12}$) is also worthy of being developed within the performance measurement of PPP projects.

PPP projects enter the *Partnership* phase (e.g., design, construction, operation and maintenance) after the award of the contract and the financial close. During this phase, asset design is undoubtedly the first important task. For that matter, the indicator of the appropriateness of the design and the efficiency of the design process must be considered in PPP performance evaluation ($CI_{F3\text{-}15}$). After the design process, the construction of the designed asset is initiated and this process can last for several years, during which the indicators that have been widely used for traditionally procured projects can be adopted to evaluate the effectiveness of the construction process, such as the TCQ and material management ($CI_{F3\text{-}16}$) as well as occupational health and safety ($CI_{F3\text{-}17}$) and environmental impacts ($CI_{F3\text{-}18}$) (Kagioglou *et al.*, 2001; Partnership Victoria, 2001; Zhang, 2006a; Haponava and Al-Jibouri, 2012; Yuan *et al.*, 2012).

A core activity in the *Partnership* phase of a PPP project is contract management, and it is critical to the success of the project. Prior studies suggest that the effectiveness of contract management ($CI_{F3\text{-}19}$) must be considered in PPP evaluations (Zhang 2006a; Yuan *et al.*, 2009). The final phase of a PPP infrastructure project entails operating and maintaining the asset to deliver a required public service within a defined legal and contractual regulatory framework. The compliance of the legal and regulatory framework ($CI_{F3\text{-}14}$), profit and profitability ($CI_{F3\text{-}21}$), and effectiveness of operations and facility management ($CI_{F3\text{-}22}$ and $CI_{F3\text{-}23}$) are attractive issues in the process measurement of PPPs (Yuan *et al.*, 2009). Further, PPPs are being run within the context of multiple stakeholders, and thus the effectiveness of dispute resolution ($CI_{F3\text{-}20}$) and effectiveness of interface management ($CI_{F3\text{-}24}$) are the important process indicators in relation to the *Partnership* phase (Yuan *et al.*, 2009).

It can be noted from Appendix D that the CIs of interface management (IM) ($CI_{F3\text{-}9}$, $CI_{F3\text{-}13}$ and $CI_{F3\text{-}24}$) penetrate the whole life-cycle of a PPP project. The IM can be defined as "the management of communication, coordination, and responsibility across a common boundary between two organizations, phases, or physical entities which are interdependent" (Chan *et al.*, 2005, p.646). It is a set of managerial activities critical to the success of PPPs, particularly those regarding the management of, and coordination between, organisations, the phases of the project life-cycle and the physical entities (Chan *et al.*, 2005). With this, the identification of the CIs in regard to interface management over a project's life is significant and necessary.

Capabilities (F4)

It has been essentially outlined above that the organisational capabilities act as the foundation of the operations of the organisation's business (Neely *et al.*, 2002). In the Performance Prism, the construct of capabilities is the least widely understood and it is established to measure whether the fundamental building blocks of an organisation's competitiveness are strong enough (Neely *et al.*, 2001). The capabilities of the SPVs required to complete PPPs may vary during the phases of the project's life-cycle. This is because of the complexities of a PPP and the phase-based nature of the necessary detailed work designed to ensure the completion of the project delivery.

There is a widespread consensus that employees are one of the most important components in any organisation. Thus, skilled employees (i.e., advisors, consultants and PPP procurement specialists) ($CI_{F4\text{-}1}$, $CI_{F4\text{-}5}$ and $CI_{F4\text{-}9}$) are a basic capability in the SPV over the project's life-cycle. In addition, today's business environment changes dramatically. To maintain competitiveness, "how to enhance an organisation's learning ability" has been an attractive topic in management research (Denton, 1998). For a PPP infrastructure project, the operating environment is more sophisticated than that of a traditional lump-sum project; therefore, an effective and efficient training and learning system (responsible for developing the appropriate training programmes) on the basis of different phases of PPPs is undoubtedly required by both the SPVs and the public authorities during the whole project. The training and learning system is considered to be a necessary supporting infrastructure in the SPVs (Yuan *et al.*, 2009). This is the reason why the CIs of the training and learning system ($CI_{F4\text{-}2}$, $CI_{F4\text{-}6}$ and $CI_{F4\text{-}10}$) were built up from the *Initiation and Planning* phase to the *Partnership* phase.

Developing the CIs of innovation ($CI_{F4\text{-}3}$, $CI_{F4\text{-}4}$, $CI_{F4\text{-}7}$ and $CI_{F4\text{-}14}$) is imperative in all phases of a PPP project, as the organisation's (i.e., the SPVs in PPPs) capability in innovation relates to the project's performance in strategic planning, design, financing, construction, operation and facility maintenance (Shen *et al.*, 2004). This implies that innovation plays a vital role throughout the project life-cycle. In PPPs, financing is completed in the *Procurement* phase and then construction commences. Accordingly, the measure for the SPVs' capabilities in the post-transaction stage (e.g., construction, operation and maintenance) should cover finance infrastructure ($CI_{F4\text{-}11}$), advanced technologies and equipment ($CI_{F4\text{-}13}$) and technology transfer ability

(CI_{F4-15}). The research undertaken by Carrillo *et al.* (2006) explains that, in PPP projects, technology transfer has a substantial impact on the performance of the SPVs in construction. Furthermore, the CIs relevant to project governance (CI_{F4-8} and CI_{F4-12}) need to be placed in both the *Procurement* and *Partnership* phases. The contract of a PPP project includes a range of governance arrangements, such as the practices for monitoring and procedures for decision-making and problem-solving (National Audit Office, 2001). Thus, governance is significant for the successful delivery of a PPP and it can substantially affect the performance of PPP construction, operation and maintenance (Badshah, 1998).

Stakeholder Contribution (F5)

The stakeholder contribution, as opposed to stakeholder satisfaction, is a measure for managing the 'dynamic tension' between stakeholders and the organisation (Neely *et al.*, 2001). As specified above, *Stakeholder Satisfaction* is used to understand what stakeholders require, while the *Stakeholder Contribution* is for measuring what the organisation expectations from its key stakeholders. Take employees, for example; from their organisations, they want a satisfactory salary, job security, safe work environment and recognition. In return, the organisations want their employees to provide positive and valuable suggestions, work efficiently and maintain loyalty (Neely *et al.*, 2001). According to this point of view, the CIs, namely skilled employees' performance/contribution (CI_{F5-3}, CI_{F5-5} and CI_{F5-10}), must be addressed in all project phases of a PPP. These indicators are able to assist in evaluating employees' creativity, productivity and loyalty over a project's life-cycle.

In addition to employee contributions, PPP infrastructure projects should incorporate support from the public client, the concessionaire, subcontractors, suppliers, creditors, and even shareholders (Chinyio and Gameson, 2009). Kwak *et al.* (2009) summarise that a public client's contributions in a PPP encompass the establishment of a favourable investment environment and legal framework during the project's planning and design, the selection of an appropriate concessionaire in the procurement stage, and active involvement with contract management after the project transaction has been completed. Therefore, it is rational to devise the core indicators in association with the establishment of the investment environment and legal framework (CI_{F5-1} and CI_{F5-2}), concessionaire selection (CI_{F5-4}) and willingness to be actively involved ($CI_{F5\text{-}9}$). After PPPs move into the *Partnership* phase, the performances of subcontractors and suppliers emerge to be a critical determinant of the project's success (Chinyio and Gameson, 2009). The lack of the CIs associated with subcontractors' and suppliers' contributions in the *Partnership* phase can lead to the ineffectiveness of the project evaluation. For that matter, $CI_{F5\text{-}11}$ and $CI_{F5\text{-}12}$, namely subcontractors' performance and suppliers' performance, ought to be developed.

In Appendix D, under *Stakeholder Contribution*, the CIs of the willingness of private contractors, shareholders, creditors and users to participate in the PPP ($CI_{F5\text{-}6}$, $CI_{F5\text{-}7}$, $CI_{F5\text{-}8}$ and $CI_{F5\text{-}13}$) have been constructed in the *Procurement* and *Partnership* phases. One of the case studies presented by Neely *et al.* (2001) indicates that the measurement of stakeholder contribution should involve stakeholders' willingness to participate in the business, such as customers' willingness to repeat their business transactions. During the delivery of a PPP, a major task in the project procurement stage is to attract well-qualified and experienced private-sector entities (i.e., banks, facility management organisations and constructors) to be involved with the procurement of the public asset. So their willingness to participate is undeniably a factor that can determine whether the public client can select an appropriate concessionaire and set up a robust finance structure. Most importantly, the final objective of any PPP project is to provide potential users with quality public services and, therefore, it is essential to encourage the end-users to use the asset ($CI_{F5\text{-}13}$). This viewpoint can be supported by the interview with a design manager, which was presented above (Section 4.4.3).

4.7 Chapter Summary

PPPs have been a popular approach in procuring public assets and providing relevant public services since many governments in the world are being subjected to reduced budgets available for infrastructure development. As a result, extensive research about PPPs has been undertaken during the last two decades; however, limited empirical work has been conducted to explore the nature of current PM approaches within the context of social infrastructure PPPs, even though it is highly critical to the development of a new PMS for the organisations involved in procuring the projects. Bearing this in mind, an exploratory study with the aim of empirically interpreting and understanding the PMs that are being used in social PPPs was presented in this chapter.

An interpretivist approach that relies on key informant interviews has been applied for this study. A total of 25 unstructured interviews were conducted with experienced PPP practitioners who had been involved in social infrastructure PPPs across Australia, the UK and the US. It was identified that the PM of PPP design and construction depends on 'traditional' *ex-post* evaluations that focus on TCQ, while qualitative and quantitative KPIs are widely used in a projects' operations. There was a widespread consensus among the respondents that the conventional TCQ approach is too simple to reveal the uncertainties of PPPs and no commonly agreed mechanism is available to capture all critical deliverables and examine whether the key stakeholders' expectations have been met satisfactorily during the delivery of the projects.

On the basis of the identified problematic issues, the respondents proffered that there is a need for a life-cycle PM that strategically emphasises a V*f*M assessment that can evaluate both financial and non-financial benefits to be provided over the project's life-cycle, and it should be introduced into PPPs to replace conventional evaluations. This new PM approach should be a phase-based model with stakeholder-oriented measures and, therefore, it should enable the public and private sectors to essentially oversee all critical tangible and intangible deliverables, and to improve the project's performance cascading down from initiation to maintenance. Additionally, the potential difficulties of implementing a life-cycle PM in PPPs were identified and these include data efficiency and a rational incentive mechanism. Hence, based on the interviews, the BIM and balanced abatement regime were devised as the important components of a life-cycle PM of PPPs. As a result of the findings, a life-cycle PMF was developed for PPPs. It is constituted of a life-cycle V*f*M assessment, stakeholder-oriented KPIs and a systematic review mechanism of operational KPIs, all of which are supported by the BIM technology and a balanced abatement regime. Hence, the proposed PMF is considered to be an effective and efficient tool because it is capable of overcoming the problematic issue of the current incomprehensive evaluation of PPPs. On the basis of the conceptual model, the suitability of the Performance Prism to underpin the proposed conceptual framework was demonstrated and then a sequence of life-cycle CIs was developed.

The exploratory study presented in this chapter is significant for this research. This is because the PMF conceptually proposed has paved a pathway that can direct and guide the subsequent research activities towards the further development and refinement of the life-cycle PMS of PPPs. It particularly provides a solid theoretical base for the survey data analysis that relied on the Confirmatory Factor Analysis, which is known as a theory-driven quantitative technique. In summary, the outputs of this chapter form a base for the researcher to undertake further investigations that will be presented in the following chapters.

CHAPTER 5 CASE STUDIES

5.1 Chapter Introduction

This chapter presents two in-depth case studies of Australian social infrastructure PPP projects (i.e., Project-A and Project-B), which were used to empirically test the feasibility and applicability of the life-cycle performance measurement system (PMS) proposed in Chapter 4 to improve the performance evaluation of 'real-world' projects and refine the PMS to enhance its practicability. The case study of each PPP project is comprised of five parts: (1) a brief description of the project; (2) an interpretation of practice in performance measurement/evaluation for the project; (3) an identification of shortcomings and 'gaps' in current performance evaluation; (4) an analysis concerning how the developed PMS can bridge the 'gaps' of the existing evaluation system; and (5) a further refinement of the developed PPP life-cycle PMS within the context of the case project.

The analytical sections of the two PPP case studies depend upon the information, comments and opinions given from the interviews and documentary sources. The interviews conducted were associated with the key management personnel and practitioners involved in each project, and the documentary sources encompass the 'Project Summary' and 'Project Agreement', which include objective information on the delivery process and performance evaluations of each project. Each interview is made up of three parts: (1) an understanding of current practices in performance evaluation in the particular case project; (2) feasibility and applicability of the developed life-cycle PMS in improving the existing performance evaluation system of the project; and (3) amelioration of the practicability of the developed life-cycle PMS. To put it simply, the findings derived from the interviews and documentary reviews were used to empirically test and refine the developed PMS.

5.2 Case Study of Project-A

This section presents a case study of Project-A, which was procured by using a PPP; therefore, a public authority and a private-sector consortium were involved in the procurement of the public infrastructure asset and provision of its relevant services. The background and performance measurement/evaluation practices of the project will be described and interpreted in subsequent sections.

5.2.1 Description of the Case Project

Project Overview

Project-A is a public hospital located in Australia, encompassing more than 300 beds and 1,000 staff. State-of-the-art facilities are embedded into the hospital, for example, Magnetic Resonance Imaging scanners, ensuring that a comprehensive range of clinical and healthcare services (e.g., pathology, general medical and medical specialities, general surgery and surgical specialities, maternity, intensive care, adult rehabilitation, etc.) will be offered to the local communities.

The project is under a contract with a value of more than AU$340 million, which is co-funded by the Commonwealth and state governments (i.e., AU$170 million from each). The contractual period of Project-A is 20 years, and the operation group (O-A), construction company (C-A) and design firm (D-A) constitute the private consortium that was formed to deliver the project (i.e., Special Purpose Vehicle – SPV). Figure 5.1 illustrates the structure of Project-A.

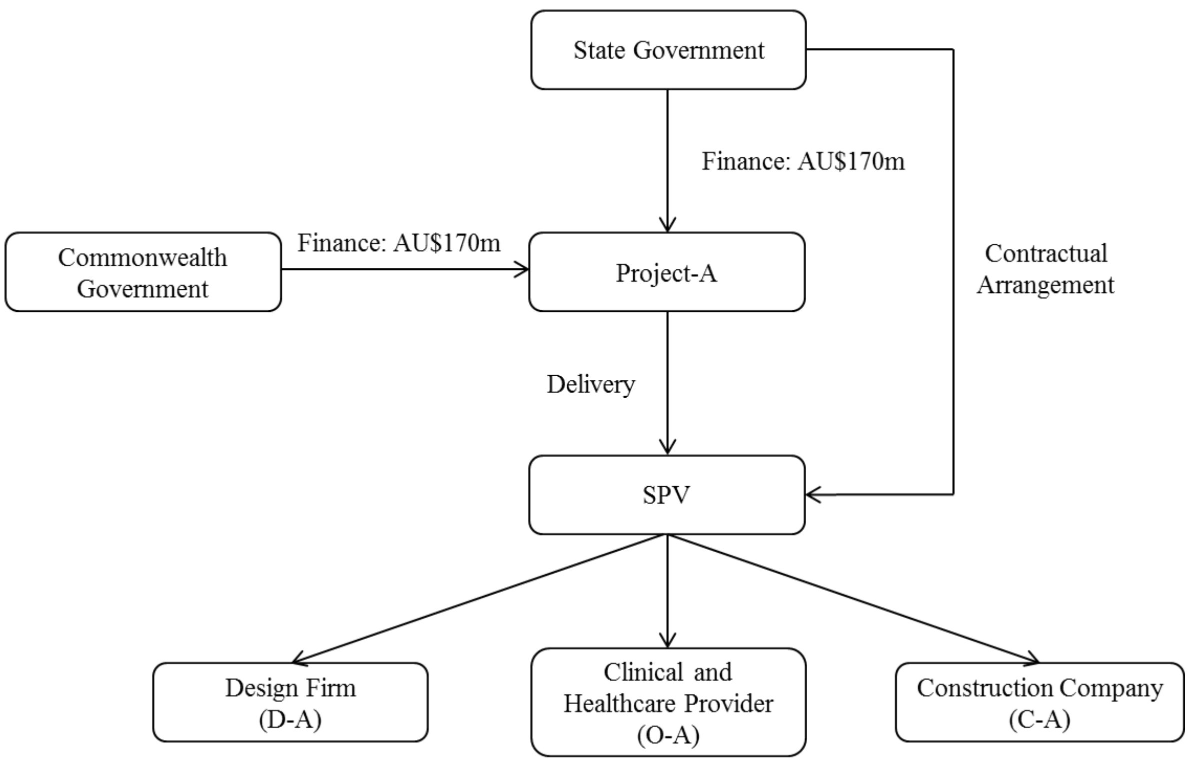


Figure 5.1 Structure of Project-A

The business case of Project-A was completed in the year 2008 and its addendum was finalised in 2010, both of which recommended that a new public hospital would be required to replace existing facilities in order to offer new and expanded services to fulfil the increasingly strong demand for health services along with significant local population growth. The state government then confirmed, in 2010, that a new hospital would be delivered by PPP in order to meet the future regional clinical and healthcare demand and, in 2012, the contract was awarded to an experienced private healthcare provider. As agreed between the public authority and the private concessionaire, Project-A was expected to be completed at the end of 2015 and, therefore, the construction was initiated in the third quarter of 2012.

Project Objectives

During the *Planning* phase of Project-A, a sequence of objectives was developed to offer guidance for project management and procurement. They included:

- To meet the need to enhance and expand health services by:
    1. Providing high quality and safe clinical services;
    2. Increasing access to health services;
    3. Expanding hospital and ambulatory services;
    4. Ensuring a sustainable health workforce;
    5. Providing care in the most appropriate clinical setting; and
    6. Ensuring the sustainability of the finance of the health system.

- To meet the investment objectives of the State, regarding:
    1. Addressing current and future demand for health services;
    2. Delivering the public project via qualified and appropriate private entities to provide V*f*M for the State; and
    3. Improving accessibility to health services.

Selection of Delivery Model under PPP Scheme

Prior to the Expression of Interest (EOI) phase, DBFO (i.e., design-build-finance-operate) and DBOM (i.e., design-build-operate-maintain) had been identified as two preferred procurement approaches for Project-A. Based on the information provided from the EOIs, the state government considered that DBOM surpassed DBFO in the provision of quality outcomes as well as value for money (V*f*M). As a result, DBOM was approved by the government for the delivery of the project, and this meant that the private SPV of the project would be responsible for the design, construction, operation and maintenance of the public asset.

5.2.2 Delivery Process of Project-A

The life-cycle PMS developed in this research is a process-based system. Thus, to examine its feasibility, it is necessary to overview the delivery process of Project-A. The delivery process of Project-A is divided into four phases, including *Inception*, *Procurement*, *Construction* and *Operation* (Table 5.1). It can be noted from the table that the delivery process of the case project is similar to the life-cycle phases defined and determined in the developed PMS, which include *Initiation and Planning*, *Procurement* and *Partnership* (i.e., construction, operation and maintenance). From this it can be inferred that the 'backbone' of the PMS proposed and developed above is rational and can fit 'real-world' social infrastructure PPPs.

Table 5.1 Delivery process and timeframe of Project-A

Phases of Project-A delivery process	**Timeframe**
Inception (Pre-tendering)	
Business case study and planning	From 2008 to 2010
Invitation for the EOI	
EOI evaluation	
Procurement	
Release of the Request for Proposal (RFP)	From May to November 2011
RFP evaluation and nomination of preferred respondent	
Contract close	
Design and Construction	
Commencement of construction works	From 2012 to 2015
Completion of construction works	
Operation and Maintenance	
Commencement of operation	From 2015
Handover	

Source: 'Project Summary' of Project-A, p.13

5.2.3 Practice in Performance Evaluation of Project-A

The practice in performance measurement/evaluation in Project-A was interpreted over a period of several months on the basis of interviews and a sequence of important documentary sources. As mentioned above, this project selected for study was under a DBOM contract; therefore, the interviews conducted were with the project's director and contract advisor representing the involved public authorities, as well as the key management personnel and practitioners from the private sector who were responsible for the design, construction, operation and maintenance (Table 5.2). Each interview was arranged for about 90 minutes, with permission to be digitally recorded. The relevant documentations included the 'Project Summary' and 'Project Service Agreement', both of which explicitly indicate the evaluation and delivery process of the project.

Table 5.2 Information about the respondents in the case study of Project-A

Respondents	**Serial Codes**	**Organisations**
Director in the public authority	D/PA-A	State Government
Service Director	O/FM-A	O-A
Construction Manager	CM-A	C-A
Architect	D/A-A	D-A
Contract Manager in the public authority	CM/PA-A	State Government

The interviews were designed for the purposes of: (1) interpreting and understanding the existing performance measurement/evaluation of Project-A; (2) testing the feasibility and applicability of the developed PMS in ameliorating the deliverable quality within Project-A; and (3) refining the model to enhance its practicability in the 'real-world' context. The respondents involved in the case study of Project-A had been substantially involved with social infrastructure PPPs across Australia and/or Europe, other than Project-A; therefore, they are considered to be experienced PPP practitioners and their viewpoints and opinions are reliable. Throughout the case study, all interviews were semi-structured, with the first and second parts of each interview being undertaken with the following indicative questions:

- Can you tell me any general background information of Project-A and what your major role is in the project?
- How did you evaluate and measure the performance of Project-A?
- What do you consider to be the limitations or gaps of existing performance evaluation system of Project-A?

The performance evaluation in the inception stage of Project-A (i.e., initiation and planning) was undertaken using the process-based concept, in which *ex-ante* evaluation (i.e., strategic assessment and business case) and reviews of business development and the tender decision played critical roles (Figure 5.2). This identification was confirmed by the Director of the public authority (D/PA-A) who oversees the project's progress:

> "We used the concept of Gateway Review to control the performance of the project. So, in the defined stages, strategic assessment for feasibility, such as value for money assessment under the *Public Sector Comparator* (PSC) and a number of qualitative aspects, and then an evaluative review for business case development were conducted, followed by assessments for confirming the defined outputs and checking the tender decision."

After the procurement phase, the contract was awarded to the main concessionaire (O-A) that is responsible for the operation and maintenance of the asset and then the design and construction were initiated, which were sub-contracted to a design firm (D-A) and a building company (C-A), respectively. In Project-A, traditional *ex-post* evaluation that concentrates on time, cost and quality (TCQ), along with the scope, was used to examine the deliverables of the project's design and construction (D&C). In respect to the design stage, the Architect of Project-A expressed that:

> "Unlike engineering and construction, design is difficult to be measured. So we don't have any 'hard' indicators to evaluate the design solution. During this process, we worked collaboratively trying to finalise the brief together and then produce a building which suits everything else. As we had a lot of budget constraints, the cost per square metre was very low. It is impossible

for us to do what we would like to do because we were very restrained with money. So, we just applied a general concept when evaluating the outputs of our design, and it is all about checking if we can meet the client's requirements under the budget and defined timeframe, and in this project, operationally efficient, lean, and smart are the key focuses of the design."

It can be inferred from the architect's points of view that meeting budget and schedule within the predetermined scope requirements was dominant in the evaluation of the design of Project-A. The interview with the Construction Manager (CM-A) also supports this identification of the major role of TCQ assessment in the D&C stages of the project, and he proffered:

"Primarily, the three main components in the design and construction evaluation are obviously time, cost and quality. So, what we have done was to reduce time, control costs and guarantee quality."

In summary, the approach that was used to evaluate the performance of D&C in Project-A is conventional and similar to that of traditional lump-sum projects, where the TCQ is the focus. As claimed by the service Director (O/FM-A) who oversaw the subcontractors as well as the operation and maintenance of Project-A:

"We are measuring each component in the D&C by examining financial expenditure and time performance, and we have also employed external engineering specialists to inspect the quality regularly, in order to ensure the quality, and the state government also inspected the quality by examining service clashes, coordination issues, future access for maintenance, which are the sort of thing that we are also checking."

The contract advisor (CM/PA-A) who supervised the consultant team in the public authority involved in the project confirmed and elaborated that:

"First of all, we focused on the private-sector SPV's design of a building that is appropriate for the Healthcare System of the State. And then, we had focused on their delivery, especially quality. So, we monitor the programme by assessing quality. We monitor their quality assurance (QA) and we monitor our own QA."

After the D&C phase, the hospital would be operated and maintained by the main contracted organisation (O-A), and a series of key performance indicators (KPIs) would be used to measure and monitor the performance of the procured asset. The operation and facility management director (O/FM-A) detailed that:

> "We have KPIs for the operational phase. Some KPIs are about engineering issues, such as electricity availability, and the rest of them are generally around reporting of clinical incidents, access quality of clinical care… The facility is a hospital and, so, most of the KPIs are regarding clinical care. There are also abatements attached to those KPIs. If we get it wrong, the State can take money from us, from the service payment."

The information derived from the documentations of Project-A can supplement the aforementioned findings gained from the interviews. According to the '*Service Agreement*' of Project-A, there are a total of 159 KPIs that were finalised and agreed among the involved parties for the asset's operational performance measurement. Table 5.3 indicates and summarises the indicator categories and their relevant KPIs. It can be identified from the table that the majority of the KPIs designed and used for the project related to the provision of clinical and healthcare services.

Table 5.3 Operational KPIs of Project-A

Categories of KPIs	**Relevant KPIs**
1. Service KPIs	
1.1 Consumer Satisfaction	Overall satisfaction
1.2 Complaint Management	Proportion of complaints responded to within 30 working days; Number of complaints per 1,000 occasions of service; and total number and category of new complaints received per 1,000 occasions of service.

1.3. Governance	Percentage of medical practitioners credentialed with a defined scope of practice; percentage of medical practitioners registered; percentage of nurses and midwives registered; percentage of required allied health and health science practitioners registered; percentage of required staff holding a current Working with Children Check; percentage of required trade staff and contractors registered and insured; percentage of staff holding a current criminal record screening clearance; percentage of required staff having completed mandatory reporting of child sexual abuse training; and percentage of staff identifying themselves as Aboriginal or Torres Strait Islander.
1.4 Access	Availability of back up facilities; Non-availability of critical health services; Unplanned and unexpected readmissions to the facility for the same/related condition on the same or next day; Total hours on Diversion for Emergency Department per month; Total hours on Diversion for Maternity Services per month; Number and proportion of Public Patients who are waitlisted for Elective Activity and have been waiting more than the desired time for their Clinical Urgency Classification; ED patient transfers to tertiary facilities as a percentage of ED Occasions of Services; Inpatient transfers to tertiary facilities as a percentage of Inpatient Separations; Number of patients transferred to another hospital because of unavailability of staff that should have been available to deliver the Services in accordance with the Role Delineation and Activity Profile; and Total number of appropriate adult Patients referred to an ICU.
1.5 Clinical Performance	Hospital-wide clinical performance; Medication safety; Infection control; Aged care; Anaesthetic; Emergency department services; Gastrointestinal endoscopy; Intensive care; Internal medicine; Mental health inpatient; Neonatology; Obstetrics; Oncology; Outpatient care; Paediatrics; Palliative care; Rehabilitation medicine; Stroke; and Surgical.
1.6 Quality indicators	e.g., Number of confidentiality and data protection breaches; Number of reportable Sentinel Events; Compliance with the provision of Medical Records on transfer of patient to another facility … and In-hospital standardised mortality rates.
1.7 Other indicators	e.g., Non-KPI Reports not provided within the specified timeframe; Timely provision of requisite reporting information in relation to monthly reporting of KPIs over the term of the Financial Year … and Submission of a Rectification Plan.
2. Facility KPIs	Facility availability; LARU mandatory requirement indicators; and Asset management indicators;
3. Patient Transfer KPIs	Timely completion: All patients transferred within the Transfer Period; Patients requiring transfer; Number of serious Adverse Events directly related to the Patient Transfer Services; Cancellations of Elective Activity that is scheduled for surgery on first day of the Operational Phase; and Particular Health Services commencing later than the time for commencement of that particular Health Service as identified in the Patient Transfer Plan.

Source: ‘Project/Service Agreement’ of Project-A, pp.286-305

As a result of the aforementioned findings, the system used for evaluating Project-A can be depicted as Figure 5.2 below. It can be noted that the performance evaluation of the case project is a process-based system, which is comprised of the assessments of value for money (V*f*M), general reviews of the business case development and tender decision, evaluation of TCQ, and operational measurement under KPIs.

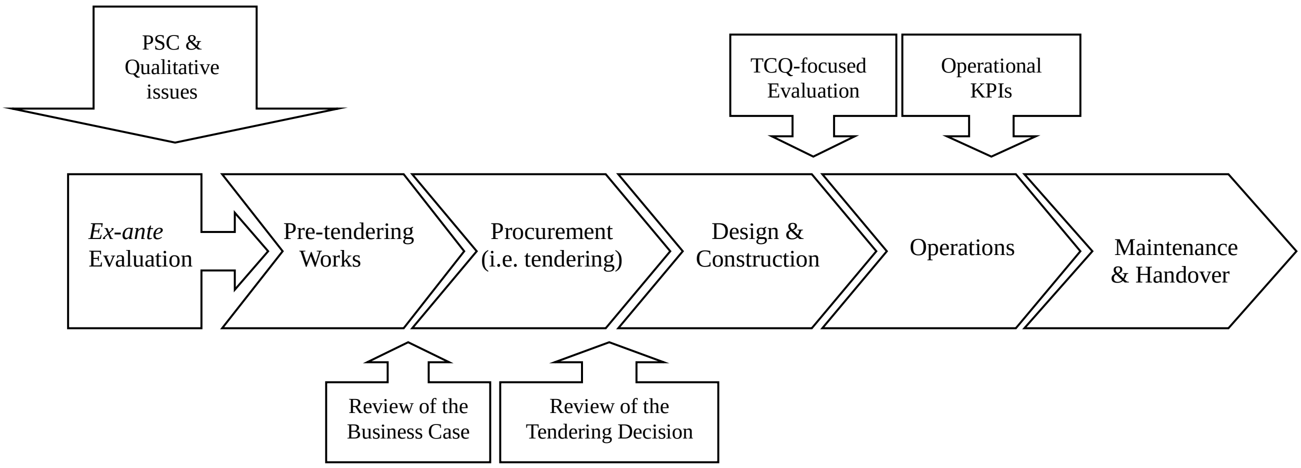


Figure 5.2 Performance evaluation system of Project-A

5.2.4 Shortcomings of Performance Evaluation System in Project-A

Pre-contract Phase

The existing performance evaluation system applied for examination of Project-A by the public authority and private-sector SPV were described above. Although this system expressed the result of a fair performance during the delivery of the project, some problems still had been raised by the key stakeholders listed in Table 5.2. For instance, the Director of the involved public authority of the project (D/PA-A) stated:

> "The track record of our methodology used for evaluation is good. It has performed well with our project over the last five or six years. However, we still have to refine it and certainly are doing that to sort out some problems. In particular, we need to ensure that lessons learned are properly captured. And we will have to make sure they are actually incorporated into the next project. That is what government can get better at, generally. But, there is the lack of a formal and strong learning process to encourage the government to review the project documents. So, what we will have to do is maintain templates so that those templates will be updated at the end of the project by using previous project experience. They need to be maintained

> centrally in order to ensure the most updated templates can be used when the next project comes along. We are constantly refining this internal process."

The public-sector Director's viewpoints imply that no formal and efficient 'learning mechanism' was available during the delivery of Project-A. In essence, an effective and efficient mechanism for internal learning is critical to the successful implementation of a PMS. Conceptually, performance measurement is considered to be a tool for continuous improvements (Sinclair and Zairi, 1995; Mbugua *et al.*, 1999), in which organisational 'learning' maintains a decisive role because 'lessons' learned from the measurement are a prerequisite of the organisation's performance improvement (Cain, 2004; Love *et al.*, 2004). Also, as demonstrated in the previous chapter, 'learning mechanisms' can benefit the key stakeholders of PPPs by providing them with 'lead' information that is extremely useful for 'real-time' performance control. Hence, the lack of a robust internal 'learning' process will substantially bring negative impacts on the performance of the organisation or the whole project. However, apart from the issue about internal 'learning', the Director (D/PA-A) also identified that:

> "Typically, in government, PPP approval process in the Procurement phase sometimes has been protracted, especially for high profile projects, and they often have to go right up to cabinet to get approval. Although we were normally able to get through that process quickly, focusing more on the approval process in evaluation can increase its efficiency. But the control for this important aspect has not been addressed in the current evaluation. And, competition is also important in the project procurement phase, but we have no issue about it during the evaluation process."

The *Procurement* phase of a PPP project, like Project-A, involves a sequence of activities, such as tendering/bidding, awarding of contract, final negotiation, financial close and so on (European Investment Bank, 2011a). The efficiency of passing through these processes can determine the efficiency of the entire delivery process of PPP projects. Despite its importance, this issue has not been substantially addressed in the performance measurement/evaluation of PPPs (Yuan *et al.*, 2009).

Similar to most social infrastructure PPPs in Australia, the V*f*M of Project-A was considered by using the PSC and a few qualitative issues regarding the range and quality of services to be provided by the facility. This identification can be supported by a critical review of the '*Project Summary*', which states that the V*f*M assessment of the project involves quantifiable elements derived from the PSC and the qualitative issues regarding the public services (Table 5.4). Nevertheless, as criticised by both academics and practitioners, the life-cycle perspective cannot be substantially addressed in a V*f*M assessment that relies on the cost-focused PSC and a limited number of qualitative measures regarding service quality, as some wider issues are still being largely neglected (Yong, 2010; European Investment Bank, 2011b), such as the impacts to be generated by the procured facility on the local community. (Please see the findings derived from the exploratory study presented in Chapter 4). In fact, the public-sector Director of Project-A (D/PA-A) recognised that:

> "The V*f*M assessment we used for the project is not perfect. But the track record of this approach was good when it worked with our major projects over the last five to six years. The value for money, you know, incorporates a very holistic consideration of project benefits, not just delivering the required scope of services at the cheapest cost, which is the simplest definition of value for money. It is related to a wide range of benefits to the public, such as economic and social. In addressing them, we are attempting to constantly refine our V*f*M assessment approach."

Table 5.4 The V*f*M assessment of Project-A

Methods	**Main Contents**
Quantitative comparison	PSC: ($000): AU$6,268,756 Private-Sector Delivery ($000): AU$4,960,040 Saving ($000): AU$1,308,715 Saving (%): 20.9%
Qualitative consideration	Quality of Services, Range of Services and Additional Services

Source: 'Project Summary' of Project-A

Partnership Phase (Design, Construction, Operation and Maintenance)

The previous parts of this section have identified the deficiencies in the existing practice in performance evaluation during the pre-contract phase of Project-A. Nevertheless, more problematic issues were identified after interviewing the rest of the key project stakeholders (e.g., O/FM-A, CM-A, D/A-A and CM/PA-A) and reviewing the project's documentations. For example, as illustrated by Figure 5.3, the performance evaluation adopted for measuring the D&C of the project was solely concerned with TCQ, the traditional 'Iron Triangle' in project evaluation. However, the public-sector Director of the project (D/PA-A) expressed:

> "… We expected that an introduction of a private consortium in this case would be an opportunity to drive innovation in design through the whole of life perspective … this may enhance the sustainability of the facility …"

In other words, 'driving innovation in design to enhance facility sustainability' was one of the most important issues expected by the state government during the delivery of Project-A. Nonetheless, as demonstrated in the exploratory study that was presented previously (Section 4.3.2 in Chapter 4), TCQ is too simplistic to capture and reflect qualitative (i.e., intangible) issues, like innovation. Thus, the existing performance evaluation system in Project-A fails in indicating whether the expectations of key stakeholders have been completely met by the private organisation, which has been identified as one of the most fatal problems in an implemented PMS (Kennerley and Neely, 2003). Essentially, there is no formal/systematic mechanism available in the evaluation system of Project-A that can be used to examine the design output. The project's Architect (D/A-A) stated, "We do not have any measures or indicators to evaluate our designs"; however, she agreed that "evaluating design outputs without the support of a formal measurement mechanism may lead to substantial rework or delay the progress over the design process". This architect shared two unforgettable stories that happened during the design process of Project-A to support her own argument:

> "We put the solution to the main contractor on day one after the deadline they set. However, we had to keep changing again and again in the following months, according to their requirements, and the final solution was exactly the same as the first one we submitted on Day One … And, we produced a design with everything - and it is an effective solution - to meet

the predefined clinical objectives. Our client, the project main contractor, was happy about that. Then, we looked through the KPIs provided by the state government to check if we were actually meeting all of their requirements. Eventually, some adjustments had to be made though they are minor only. But if an evaluation mechanism or technique was provided, it would have been much easier for us to communicate with the client and also much more efficient to match our designed solution to the KPIs determined by the government."

In addition to design, the Contract Advisor/Manager (CM/PA-A) also raised criticism towards the project's performance evaluation of the D&C relying on TCQ only. This experienced practitioner of contract management stated that:

> "… The only problem under this evaluation system is we can do nothing to improve the project's performance if the construction progress was delayed by the builder. We have milestones to monitor the construction of this project. When the builder was unable to meet one of these predetermined milestones, basically, we generally just said, 'you are late' or 'you are late by a month'. And they just responded 'yeah, yeah, we are trying our best'. The amount of times we have heard that …"

Essentially, past studies have identified the problematic issues related to conventional TCQ evaluation. For example, Haponava and Al-Jibouri (2010; 2012), criticised traditional *ex-post* evaluation relying on TCQ as being not suitable for a complex construction project because it provides no valuable information about performance improvement that is critical to the success of a project with a long-term life-cycle. Moreover, as claimed by many practitioners in the exploratory study of this research, a measurement concentrating on TCQ ignores a variety of issues that are essential for the organisation, for example, the capabilities of the organisation (i.e., skilled workforce), which is identified as one of the most important aspects that must be considered in an organisational performance measurement by Neely *et al.* (2001; 2002). The Construction Manager (CM-A) described two examples to strengthen this argument within the context of Project-A, and he said:

> "An effective measurement should be able to reflect the risks and problems the organisation is facing and also can reflect lots of intangible issues. But the TCQ-focused assessment failed in doing so because it is not a complete measurement. For example, we faced a shortage of skilled and quality on-site labour before in this project. How can a measurement eyeing on budget, schedule and quality only reflect this problem and help us to minimise it? The other example is that the state government said we might want to expand the hospital. Under the long-term planning by 2020, they would expect to expand the hospital by another 100 beds. So, what we did is we came up with a design which allowed, effectively, half of the ward to be replicated and then built with minimal interruption to the existing facility, and then all of the services which are involved for the hospital are able to be added on - hooked into - to supplement the additional hundred beds. In the existing evaluation, how are these innovative works being reflected?"

Apart from construction, the Service Director (O/FM-A) also expressed his opinions about the existing practice in performance evaluation of the project, and he stated:

> "If I were the director of the state government who is responsible for setting up this contract, I would devise far more engineering KPIs. I would like to make sure that the hospital is well maintained and there was proper asset planning and condition reporting and so on. The government now is focusing too much on clinical care and they have got their clinical care covered, but they don't have the building measurement covered. This is not good for the government. In addition, we are operating the hospital for the next 20 years and so the government should have a mechanism for reviewing and changing operational KPIs. This ensures the facility can accommodate the changes in environments to meet the state's objectives."

It can be inferred from this Director's perspective that the performance evaluation system of Project-A is not only limited in the area of facility maintenance but also provides no mechanism for reviewing the operational KPIs. However, this case project is under the contract form of DBOM with a PPP, whereby operations and maintenance are essential works for the private-sector SPV within a long-term period.

Without the support of a review mechanism, there will be a potential risk in Project-A to be faced by the government that the operational KPIs might not be able to accommodate the dramatic changes in external environment (e.g., population) and then the quality of clinical services will be negatively affected by an ineffective monitoring of the asset's operation. Furthermore, conceptually, an effective measurement mechanism in the maintenance of PPPs is critical, because it is able to enhance the effectiveness of the governance conducted by the public sector (Yuan *et al.*, 2009). As summarised by the Director (O/FM-A), "maintenance is a key thing, and you cannot improve or repair something until you know what is wrong; therefore, you need to measure it to find out, and effective indicators are necessary".

In summary, the features and shortcomings of the performance evaluation system of Project-A can be summarised and depicted as the following diagram (Figure 5.3). This figure illustrates that the performance evaluation/measurement of the case project is a process-based approach. However, it largely neglected a series of critical aspects, which are: (1) the V*f*M assessment on the basis of the PSC is narrow and cannot cover all crucial life-cycle issues (e.g., outcomes – impacts on the public); (2) the measurement for the *Procurement* phase is incomplete, ignoring such important issues as the efficiency of the approval process and the competitiveness of bidding; (3) no mechanism was designed for reviewing the operational KPIs to accommodate the changes in project environment within the long-term contract period; (4) there is a lack of an effective and efficient 'learning mechanism' that is highly useful for absorbing the lessons learned from the measurement mechanisms, which are essential for performance control and improvement of the project; (5) the *ex-post* evaluation of the project's D&C is too simple (i.e., TCQ assessment) to reflect whether the public client's expectations have been met (e.g., innovation in design and sustainability of the asset); and (6) the existing KPIs cover clinical service only and significantly ignore the issues of facility maintenance, which is a major part of the work agreed and is in the contractual arrangements of the project. More importantly, although the practice of the project's evaluation is process-based, it serves as a phase-based review rather than a 'real' measurement. This is because 'process-based' performance evaluation must be supported by an effective and efficient 'learning mechanism'; otherwise, the information derived is not 'led' and thus is not worthy of 'real-time' performance control when the project is still being delivered.

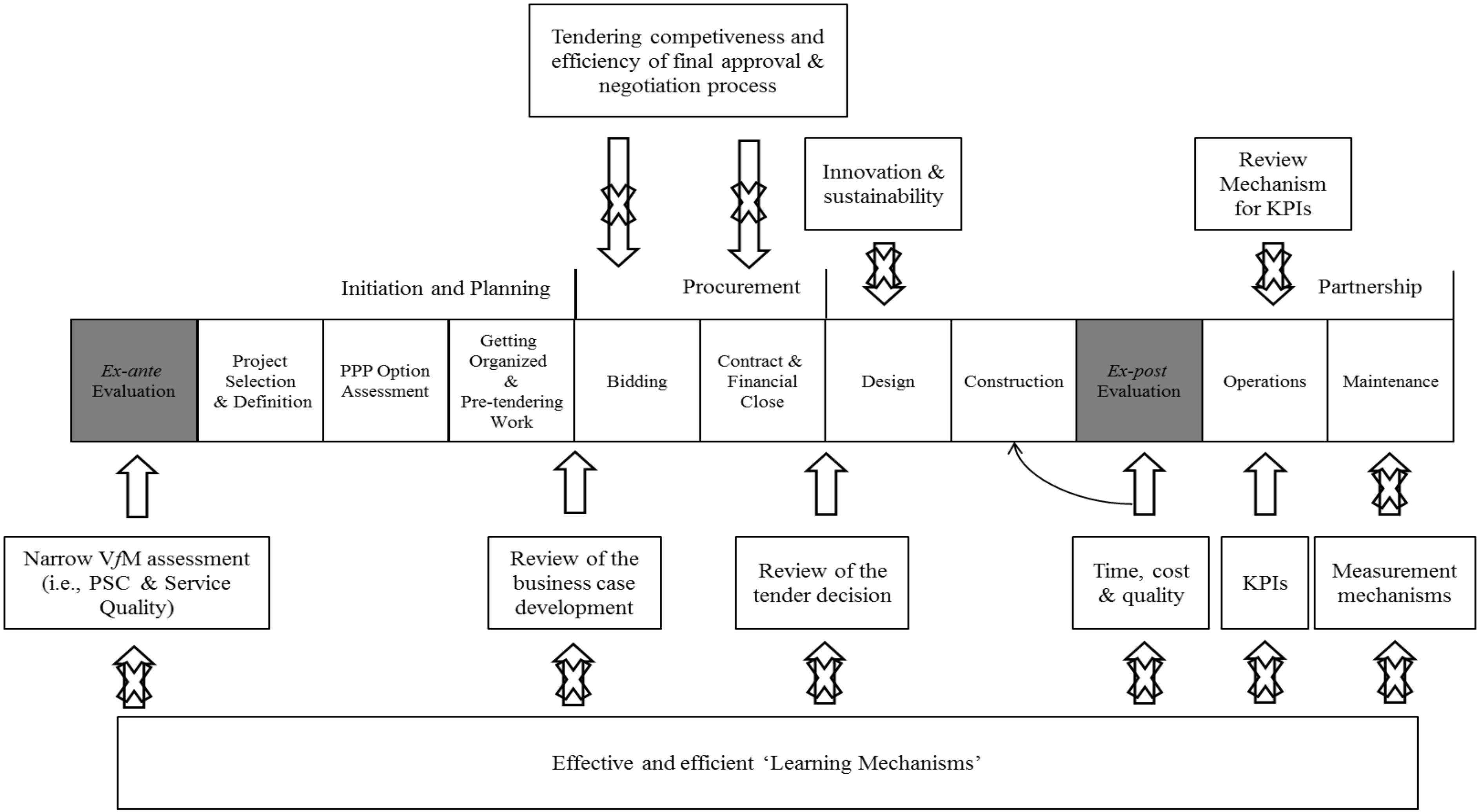


Figure 5.3 Shortcomings of the performance evaluation system of Project-A

5.2.5 Feasibility and Applicability of Life-Cycle PMS in Project-A

The practice in performance evaluation/measurement in Project-A has been studied and interpreted above. This section aims to examine the feasibility and applicability of the proposed life-cycle PMS in bridging the gaps derived above in the context of Project-A, in accordance with the perspectives of key management personnel of the project. With this primary aim, the indicative questions below were used for the second part of the interviews.

- What is your perspective on the necessity to improve the performance evaluation of the project?
- What is your perspective about the feasibility of a life-cycle PMS with stakeholder-oriented KPIs to ameliorate the current performance evaluation system of the project?

To minimise any subjective bias, the life-cycle PMS developed had not been provided for the respondents. However, the definitions of some key concepts that would be mentioned in the interviews were briefly explained before the second part of each interview, including life-cycle/process-based evaluation, stakeholder-oriented KPIs, operational KPI review mechanism and learning mechanism. It has been emphasised previously that all respondents were experienced PPP practitioners who had been involved in the procurement and management of social infrastructure PPPs across Australia for a long period. Thus, they were all clear about such aforementioned concepts after a brief explanation. As identified above, there were a series of shortcomings and limitations in the existing performance evaluation system of Project-A. In fact, all of the key project practitioners who participated in this case study (n=5) argued that a more effective and comprehensive PMS than the existing approach was required because it would be able to provide assistance in improving the life-cycle performance of Project-A. For example, the Construction Manager (CM-A) stated that the existing performance evaluation needed to be improved because a more comprehensive approach could ensure that project success would be measured by what was delivered in terms of the contract. The Service Director (O/FM-A) proffered a similar view that a number of aspects in this project's performance evaluation should be improved and there is no doubt that improvements would be significant for the long-term success of the project, regardless of whether from a procurement point of view or a management perspective.

The life-cycle PMS of PPPs proposed in the previous chapters incorporates the following features: (1) a life-cycle performance measurement with process-based and stakeholder-oriented CIs (i.e., KPIs), which are supported by a continuous review mechanism, as well as Building Information Modelling (BIM), and address all critical success factors (CSFs) in each phase of the PPP (i.e., cascading down from project initiation to maintenance and handover); (2) a life-cycle V*f*M assessment, which considers not only cost factors but also the macro-impacts on the public and or local community/regions; and (3) an emphasis on effective and efficient internal 'learning mechanisms' over the project life-cycle. Based on these characteristics and the shortcomings of current practice in PPP performance evaluations (Section 5.2.4), Figure 5.4 illustrates how the new 'Iron Triangle' addressed in the developed PPP life-cycle PMS can conceptually complement the existing performance evaluation system of the case project and provide assistance in solving the identified problems.

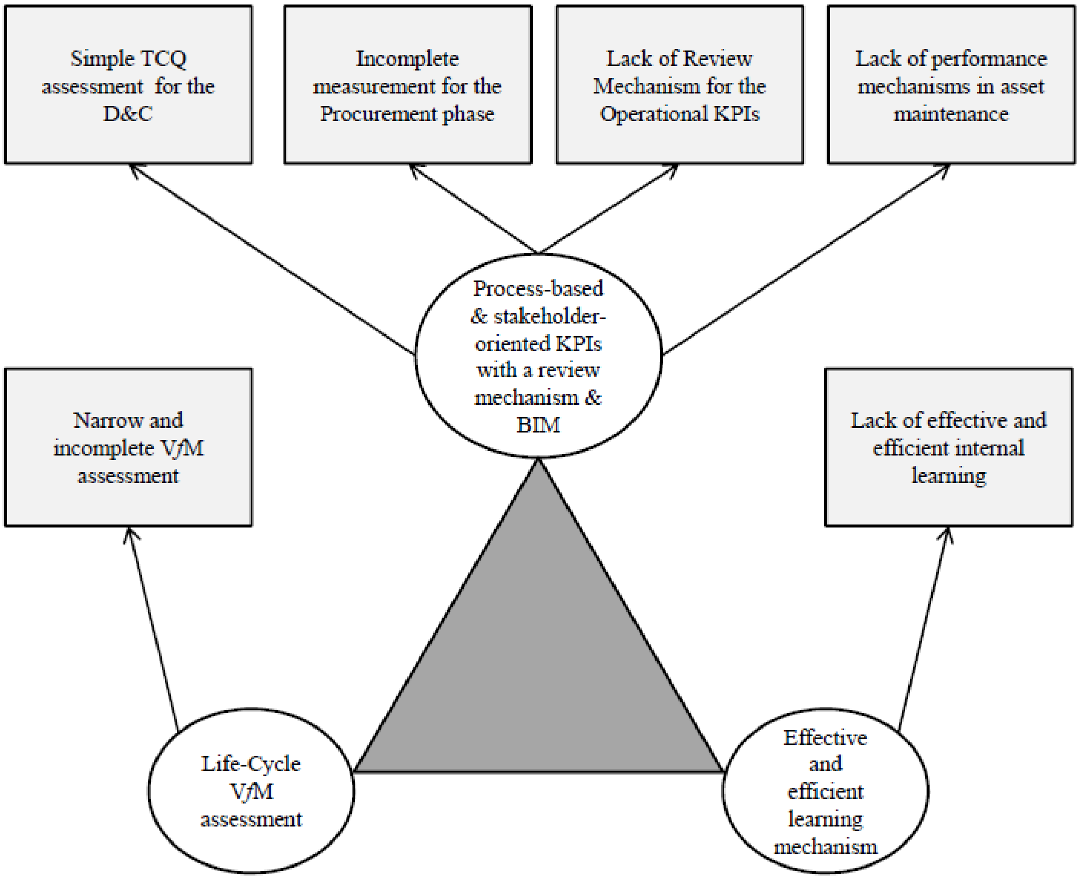


Figure 5.4 Illustration of how the PMS can improve Project-A evaluation

It can be noted from Figure 5.4 that the developed life-cycle PMS could conceptually ameliorate the performance evaluation system of Project-A by addressing its inherent shortcomings in regard to V*f*M assessment, D&C evaluation, facility measurements and internal learning processes. The Director of the involved public authority (D/PA-A) commented that:

> "I think the visibility of the model itself you described is rational and applicable for us. Certainly in our project, we have strong visibility from both a commercial and a technical perspective of exactly the scope of services that are to be delivered… how they're going to be delivered. The unknown issue is actual performance, especially social infrastructure, because we are still in an early stage. But the concept is absolutely transparent and well understood. I do think the model does provide for a very strong datum against what we should currently measure and what we should measure in the future, in both commercial and technical aspects; the

> life-cycle VfM can increase the veracity of the business case, and the stakeholder-oriented KPIs that can help to fully meet our objectives, and the 'learning mechanism' is really what we required and what we are currently developing. Also, the review mechanism for KPIs is useful. In fact, we keep refining things around the precision of our evaluation criteria, consistency of information we request and evaluation requirements."

The Contract Manager/Advisor (CM/PA-A) from the involved public authority also possessed a perspective similar to the Director (D/PA-A), and he contended:

> "As a government consultant, I care about the delivery process, especially in a social infrastructure project, like a hospital, because every part of the process can affect the future service quality. If you are building a railway station, that is fine and output might be more important than the process. So, the measurement concept you raised is exactly what we require. It is feasible and helpful for this project. It could help to understand well the project's life-cycle. A lot of usefulness can be delivered by this model to this project. For example, a broad V*f*M can help us know more if PPPs can provide a broader benefit than public procurements in healthcare provision. Also, the stakeholder-oriented KPIs (i.e., CIs) are very informative for this project because it is a hospital and involves a very complicated stakeholder network. We have to take care of many key stakeholders' expectations and needs. These KPIs could help us be aware of whether the private-sector consortium has met our requirements, stated in the contract."

Apart from the perspective of the public sector, it is necessary to understand the private sector's view about the feasibility of the developed model in dealing with the limitations in the performance evaluation conducted over the Partnership phase of the project. In summary, all of the respondents expressed a positive opinion towards the developed life-cycle PMS. For instance, the Service Director (O/FM-A) claimed that:

> "This is a feasible way for us to improve the performance of this project. For example, at the point when we bid, we don't know a lot. We know the concept and we know unit-based costing. But we don't know what product

will be installed into the asset. When the building is designed, we need to know what product is selected and what energy will be used. So the design parameters are useful. Once it is built, we actually need to measure the building and, after that, we need to do some modifications. So, the phase-based measures would be what we need. And also we keep learning, for our workforce and for our partners to avoid an amount of rework. So effective internal learning is important for us as well. As I said, we need to review the operational KPIs along with the change of time and so the concept of the review mechanism you raised is definitely helpful."

In addition, the Service Director also possessed a positive perspective towards the importance of BIM, not only in the performance evaluation of Project-A but also that of future PPPs. He stated that:

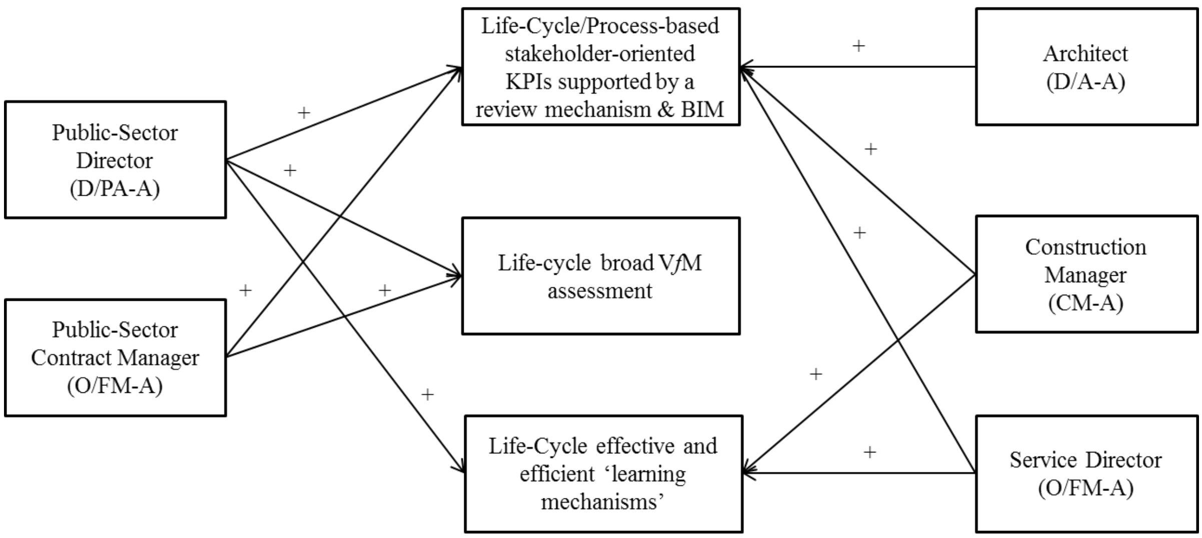
"BIM is the perfect match to the project and even those PPPs that are complex, like a large hospital. It is nice for all of the stakeholders of the project to see what is happening in the building and evaluate if the outputs have already met their expectations. Honestly, such stakeholders can do that or evaluate the project in another way without using BIM. They can carefully read the plan, they can look at the asset list, they can go and witness onsite, or they can take photos of every piece of equipment. But, BIM is a nice and more efficient way for them to get their head around it if they do not know how to read plans, or if they feel it is boring to look at asset lists, and/or if they do not want to take time to visit the site."

The Architect and the Construction Manager contended that the state government and the life-cycle performance measurement will be able to bring about positive effects on the SPV of Project-A as the private-sector consortium has a long-term contractual relationship with the government and intends to understand well the deliverables at each stage over the project's life-cycle. For example, the experienced construction professional (CM-A) specified that:

"From the government's perspective, if they buy out the operator's contract at any point between now and that 20-year end, or they don't renew the

> contract at the end of the 20-year contract, they will have to know what asset they are taking on board. So, it was important for them to understand or keep learning if we are providing them with the right building, what warranties, and what life-cycle analysis was done. So, a process-based evaluation with internal learning will be applicable for them. From the perspective of concessionaire, it is also applicable, especially for the operator, because they want to know if the product we designed and built is meeting the state's expectations, and what maintenance they will have to provide as part of the 20-year contract."

In summary, the key stakeholders from both the public authorities and private SPV in Project-A considered that a life-cycle PMS with an emphasis on the process-based KPIs, as well as a life-cycle V*f*M assessment and 'learning mechanisms', is feasible and applicable for ameliorating the overall performance of the project. This is because the rationale of the developed PMS is capable of effectively and efficiently overcoming the existing limitations of the performance evaluation system of Project-A. Figure 5.5 summarises and illustrates the perspectives of the project's key directors, managers and practitioners regarding the new 'Iron Triangle' emphasised by the life-cycle PMS of PPPs empirically developed in the previous chapters.



Note: '+' represents a positive perspective

Figure 5.5 Respondents' views towards the new 'Iron Triangle' of the PMS

5.2.6 Refining the Developed Life-Cycle PMS under Project-A

The feasibility and applicability of the proposed life-cycle PMS of PPPs has been empirically tested above. To enhance the practicability of the PMS, the key project stakeholders who participated in the case study were asked to propose some KPIs they considered to be important for the phase/works they were overseeing, according to the actual situations of Project-A. Then, a comparison between the CIs that were conceptually derived above and the case-derived KPIs was undertaken to identify what critical KPIs had been ignored in the dataset of the performance measures of the proposed life-cycle PMS (Appendix D). This process is useful for refining the performance measures that were established on the basis of a review of the literature and they form a solid base for a future quantitative study (Haponava and Al-Jibouri, 2012).

During the process of final refinement of the PMS, each respondent was allowed to freely summarise what KPIs needed to be introduced into the project in addition to the existing performance measures. As a consequence, the Director (D/PA-A) of the public authority suggested that:

> "The state government's objectives should be documented properly in the measurement system, and this will guide the business case, procurement and governance. Commonly speaking, value for money is the objective. In the stages prior to the tendering, planning is one thing we are really focused on. It is well known that a dollar spent in planning saves you, or can cost you, far more than you will ever be able to recover once you move down the life of the project. In this project, there was a significant amount of work undertaken in planning. So, KPIs relating to planning must be required. Secondly, in the procurement phase of this project, we assessed price, value for money, the capability of the management team, the capability of their personnel, their track record in project delivery, and commercial aspects. All of those must be balanced and, so, the indicators about the private sector's capabilities are required. As I said early, the approval process and bidding competitiveness are important. So, in the evaluation of the procurement phase of this project, the KPIs to be devised

> should cover the issues that I have summarised. We also expected innovative design to ensure value for money. So, design innovation and asset sustainability must be involved. Finally, for the maintenance and handover, the KPI is really about asset condition, and that is foremost. It is more complicated for this case, because we have got the clinical aspect. But it is fundamentally, first and foremost, about prescribing the (asset) condition."

The Contract Manger of the public sector (CM/PA-A) also proffered his point of view from the contract management angle, and he advised that:

> "In my field of contract management, the patient satisfaction should be addressed. But the mechanism beyond it, and how it works, is something that will need to be thought through quite deeply. It has not been a major part of this PPP project. In the facility maintenance, we also need a mechanism to measure if the building can be expanded to accommodate changes, like the growth of population. Finally, we also need KPIs to be used for managing the handover stage, for example, reliability of financial infrastructure for technology upgrade (i.e., health IT system) and staff team structure. But they have not been documented clearly, either, in this project."

A sequence of KPIs can be identified from the information provided by the two key practitioners above, both of whom are from the public authorities in Project-A. These KPIs include:

- Value for money for the business case and the *Procurement* phase;
- Project planning occurs before the EOI;
- Capabilities of the private-sector SPV;
- Efficiency of approval process during the *Procurement* phase;
- Competitiveness of tendering/bidding;
- Design innovation;
- Asset sustainability;

- End-users' satisfaction in the *Operational* phase;
- Asset conditions and their ability to accommodate future external changes;
- Reliability of financial infrastructure for technological upgrades; and
- Future staff team structure.

In addition to the respondents from the public authorities, the management personnel of the private-sector SPV of Project-A also provided some ideas about the KPIs of each project phase. Firstly, the Construction Manager (CM-A) identified what measures (i.e., KPIs) should be focused upon during the D&C phase of the project, from a builder's perspective, as follows:

> "The main driver for us in the D&C in this project is to make sure that the client gets what they want. So the measures must be about delivering a project which exceeds the client expectations, realising our profit margins as a minimum, completing the project on time or before time, and meeting a quality which is acceptable both to our company and the client at the end of the day. It is also very important for us, under the components of the D&C deliverables, that we track well against the design deliverables, the contract requirements or administration, and the site management in terms of what we deliver onsite. We also should have measures from a design perspective. For example, we have an innovative design about the operating theatres. This innovation should be reflected in the measurement system."

Secondly, the Service Director of Project-A (O/FM-A) claimed that project budget and schedule are the most important KPIs in the D&C, of which cost is the priority. However, the Director listed a series of other KPIs that have been neglected but which are important for the success of Project-A. He proposed that:

> "When we were in the bid phase of this project, we didn't know everything in detail. We had to select not only what model products we would put in but also a partner. We failed in partnering with an organisation we first contacted and this cost us an amount of time. So, the willingness of the partners' or suppliers' participations in your project needs to be measured.

> This will be useful for your future actions when attempting to learn lessons from the project. And, in the operation phase of this project, we should pay attention to the structure of the staff team; for example, how many doctors and nurses are required? This is because 60% of operation expenses are human resources in this project. So, employee structure is a critical measure. And, users' satisfactions are important because we are providing services. In the facility maintenance and management, as I have already mentioned, more engineering indicators relating to building maintenance, like energy consumption, resource usage and asset conditions, are required. We haven't documented well what measures or methods will be applied for maintaining the facilities. I would expect the government to 'put on us' the KPIs about facility management and then I will be 'putting on the team' to make sure that things are maintained. Similar to the operational phase, the structure of the facility management team is important. Finally, the handover is under a strict requirement stated in the contract. It requires a residual life of five years for certain elements of the building. So we have a life-cycle planning that is concerned with the asset's condition monitoring and residual value. So, they should be the 'KPIs' for the handover."

According to the perspectives of the private-sector key stakeholders in Project-A, it is reliable to derive a set of KPIs for each phase of the project's life-cycle, involving:

- Client's satisfaction during the design process;
- Design innovation;
- Contract management/administration during the construction;
- Site management;
- Profitability in the operation;
- Structure of professional staff team for operation and facility management;
- Users' satisfaction levels during the operation;
- Facility maintenance (e.g., conditions, energy consumption, resource usage);
- Asset condition monitoring during the handover stage; and
- Residual value management for the handover (i.e., 5-year residual life).

As a result of the findings above, Table 5.5 summarises the KPIs that were proposed by the respondents within the context of Project-A. Then, a critical comparison was undertaken between the core indicators (i.e., CIs) quantitatively selected in Chapter 6 and all KPIs identified from the study of Project-A (e.g., measures relating to the business case development and tendering decision, operational KPIs and KPIs indicated in Table 5.5) to identify what important and practical indicators have been neglected in the dataset of core indicators of this research (Appendix D) (Figure 5.6).

Table 5.5 Life-cycle KPIs proposed by the respondents from Project-A

Organisations	**Project Stages**	**Key Performance Indicators**
Public authorities	Initiation and Planning	Value for money; project planning
	Procurement	Capabilities of the private-sector SPV; efficiency of approval process; and competitiveness of tendering process
	Design and Construction	Design innovation; asset sustainability
	Operation and Maintenance	End-users' satisfaction
	Handover	Asset's ability to accommodate changes; reliability of financial infrastructure for technical and technological upgrades; and structure of future staff team
Private-sector SPV	Initiation and Planning	N/A
	Procurement	N/A
	Design and Construction	Client's satisfaction; design innovation; contract management; and site management
	Operation and Maintenance	Profitability; structure of professional staff team; users' satisfaction levels; and facility maintenance
	Handover	Asset condition monitoring; residual value management

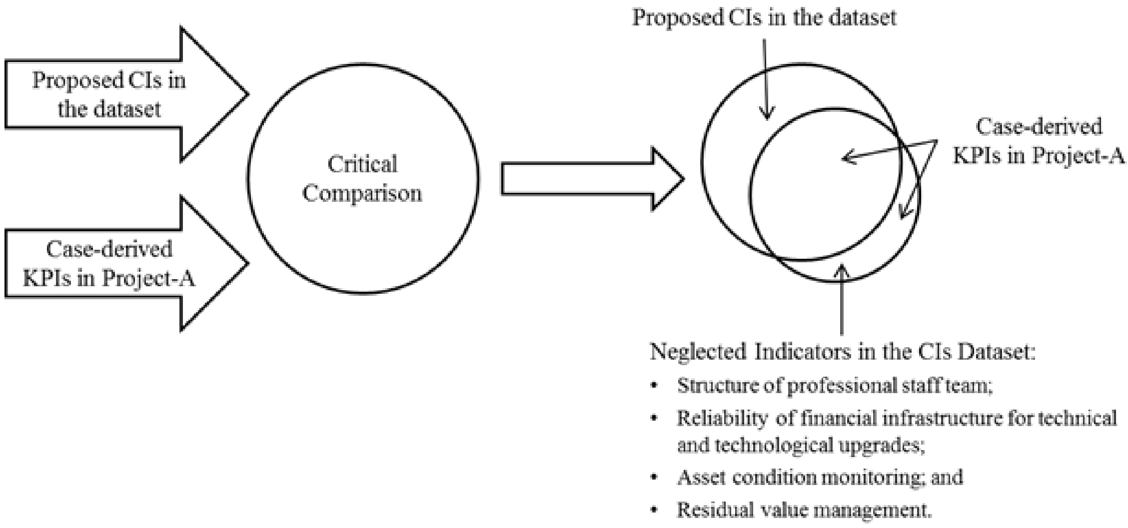


Figure 5.6 Comparison between the proposed CIs and case-derived KPIs

As illustrated by Figure 5.6, the dataset of the CIs established from the exploratory study covers almost all KPIs derived from the case study of Project-A, except: (1) structure of professional staff team; (2) reliability of financial infrastructure for technical and technological upgrades; (3) asset condition monitoring; and (4) residual value management. On the basis of the traditional wisdom, new knowledge or hypotheses cannot be generalised in accordance with the findings derived only from an individual case. Nonetheless, as criticised and corrected by Flyvbjerg (2006), a study of a carefully chosen case has a strong and reliable knowledge that can be "central to scientific development via generalisation as a supplement or alternative to other methods" (p.228). Project-A is a PPP under a procurement model (i.e., DBOM) that is popular in Australia, where the PPP market is considered to be mature and sophisticated. Further, this case was carefully selected by communicating with the senior PPP practitioners of the private organisations that are experienced in partnering the Australian state governments for infrastructure procurement. Thus, it is rational and reliable to renew the dataset of the CIs by adding two extra CIs (e.g., $CI_{F3\text{-}25}$ – Effectiveness of asset residual value management, and $CI_{F4\text{-}16}$ – Appropriateness of the structure of professional staff team) and to update the descriptions of two other CIs (e.g., $CI_{F3\text{-}23}$ and $CI_{F4\text{-}11}$) so as to enhance the practicability of the developed life-cycle PMS. These two changes to CIs are reported in Table 5.6 below.

Table 5.6 Updates of two existing CIs

Codes of the CIs	**Initial Descriptions of the CIs**	**New Descriptions of the CIs**
CI_{F3-23}	Effectiveness of facility maintenance	Effectiveness of facility maintenance and asset condition monitoring
CI_{F4-11}	Reliability of the finance infrastructure	Reliability of the finance infrastructure for project delivery and future technical and technological upgrades for handover

At the end of each interview undertaken during the case study, the respondent had been offered an opportunity to provide his/her general comments and/or suggestions about implementing the life-cycle PMS in Project-A, for example, to report any potential hurdles and/or additional amendments. All respondents (n=5) anticipated that there would be no potential major difficulties/hurdles in operationalising the PMS within the context of Project-A, in accordance with their experience. Nevertheless, the Service Director (O/FM-A) identified a hurdle that may potentially affect the successful implementation of the PMS in the 'real-world' environment of the case project, and he commented that:

> "The borders between some phases are not clear in a 'real-world' project and some of them are even overlapped because of the complexities and uncertainties of the delivery process. For example, this project is what we called a fast-tracked PPP. The way our design and construction partners have gone was following a route, like a continuous design-construct, design-construct, and design-construct and so on. It was a much quicker process but a little more complex. It also added a complexity to measuring the project. So, it is important to have a programme to indicate when the key stakeholders, like the project manager, should initiate an evaluation at each phase, rather than they make a decision intuitively."

The public-sector Contract Manager (CM/PA-A) in Project-A also suggested that, to ensure successful implementation, a sequence of rational and reliable 'evaluation milestones' must be devised when the life-cycle PMS is implemented in a project, and these 'milestones' will serve as the indicators for the project manager or other key management personnel to clearly understand where they are in the process, when they will have to conduct a measurement for the deliverables of each phase, what they have done and what they will have to examine. This experienced Contract Consultant further specified that such aforementioned 'milestones', specifically designed for implementing the life-cycle PMS, must be confirmed between the involved parties and explicitly stated in the contract, as this would not only enable the private SPV to use this new system more strictly, effectively and efficiently, but would also enhance the effectiveness of the governance of the public sector.

5.2.7 Summary of Case Study of Project-A

An in-depth case study of Project-A, which is a social infrastructure PPP (i.e., a public hospital) under a DBOM contract, was undertaken to empirically test the proposed life-cycle PMS. The major aims of the case study were to examine the feasibility and applicability of the PMS and to refine the model so as to enhance its practicability. With this in mind, the background information (i.e., values, structure and objectives) and delivery process of the case project were described and presented, respectively. Furthermore, the performance evaluation system of the case project, as well as its existing shortcomings and limitations, were analysed by using semi-structured interviews with the key management personnel/practitioners of the project team and a review of documentary sources. Based on the interviews, an interpretation of the findings was provided and the PPP life-cycle PMS was refined according to the perspectives of the key practitioners of the project.

5.3 Case Study of Project-B

This section encompasses a case study of the other social infrastructure PPP project (i.e., Project-B), which was procured under a PPP scheme. For that matter, similar to Project-A, both public and private sectors were involved with this study. The case is structured by a description of project background information, interpretation of the existing practice in performance measurement/evaluation of the project, and analysis and discussion of the derived findings.

5.3.1 Description of the Case Project

Project Overview

Project-B is under the custodial infrastructure programme of an Australian state government, which was announced in the year 2009, with the aim of delivering more than 1,600 additional beds across the state's prison system. This project was initiated for procuring a new facility to replace the existing regional prison, which was built in the 1980s and incorporates about 100 beds only.

The business case of Project-B for the redevelopment of a new prison was approved by the State Treasury in 2009, and comprises (Project Summary, p.2):

- 200-bed male medium security prison with capacity to accommodate about 20 maximum security prisoners;
- 60-bed male minimum security sector;
- 40-bed male open minimum security sector; and
- 50-bed female maximum, medium and minimum sector including a 6-bed unit for women with children.

The Cabinet of the state government made a decision and approved the use of a PPP, in 2011, to deliver Project-B, whereby the private sector would design, build, finance and maintain the new prison. In other words, Project-B was procured under a DBFM contract, according to which the Corrective Department of the state government would retain responsibilities in delivering full custodial services and a series of ancillary services, including canteen, kitchen, cleaning (prisoner areas only), education and vocational training, programme delivery, grounds maintenance (partial), health services, laundry, prisoner industries, prisoner visits and waste management (prisoner areas only) (Project Summary, p.6).

After a competitive procurement process, a private-sector SPV that is an independent legal entity was formed, in the year 2012, for the delivery of the project. The value of Project-B is more than AU$200 million, which is privately financed by a capital investment agent (F-B) that is funded by a series of equity investors and creditors (i.e., banks). The contractual period of the project is up to 25 years, during which time the new public asset is to be designed, constructed and maintained by the members of the formed SPV, including a design firm (D-B), the construction contractors (C-B), and a facility maintenance/management group (FMG-B). Figure

5.7 depicts the structure the private SPV formulated to deliver Project-B.

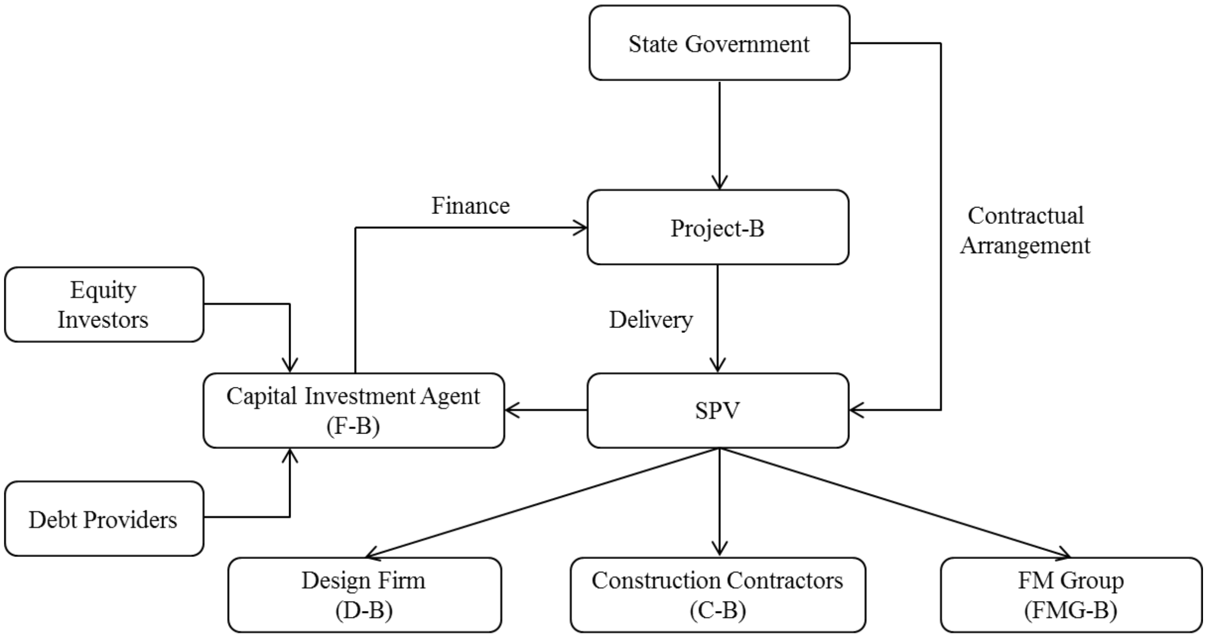


Figure 5.7 Structure of Project-B

The new prison is located close to the existing facility, with an area of 17.2 hectares. After the financial close in the year 2012, the D&C was initiated by the D-B and C-B and it contained two stages, in order to minimise the disruption to operations of the existing facility. These included:

- Stage 1 - design, construction and commissioning of the new prison;
- Stage 2 - demolition of the existing facility and site remediation.

Facility maintenance services would be commenced and handled by the FM-B following the commissioning of the D&C phase over a 25-year operating term. In order to provide a detailed overview of the case project, the objectives and reasons for the delivery model selection of Project-B will be outlined and explained in the following sections.

Project Objectives

Based on the 'Project Summary' of Project-B, a suite of objectives were finalised by the state government at the commencement of the project's planning phase to guide relevant management and procurement activities. Fundamentally, Project-B was expected to achieve the objectives below (Project Summary, p.5):

- Replace the existing facility, which is overcrowded and no longer fit for purpose;
- Reduce overcrowding in metropolitan prisons;
- Provide sufficient prison beds at the facility for local prisoners to remain close to family and remain 'in country';
- Provide safe, secure and contemporary custodial facilities that contribute to community safety and reduce long-term recidivism; and
- Develop modern secure facilities and a technologically supported perimeter security system.

Delivery Model under PPP Scheme

During the procurement option analysis phase, the state government had assessed a variety of delivery models, such as pure public procurement, DBFM and DBFOM. According to the 'Project Summary' (p.6), "each option (was) considered with reference to either the public- or private-sector delivery of components of the project". The reason for the state government's final selection of the DBFM model was because of the following benefits to be provided by that procurement model (Project Summary, pp.6-7):

- An alignment of incentives can improve the efficiency and durability of the asset. As one party is responsible for the design, construction and maintenance, the whole of life performance of the asset is taken into consideration when designing and constructing the asset.
- The provision of private finance provides an increased incentive for on-time delivery of the construction.
- Accountability and performance measures are put in place to ensure that service outcomes for the community meet the high standards specified by government.

- A focus on output specifications and a competitive bidding process for each project provide an incentive for private providers to develop innovative solution in DBFM projects that can then be adopted across the public sector to deliver better and cheaper services more broadly.
- The DBFM model delivers value for money to the tax payers through effective risk transfer by allocating the specific project risks to the party that is best able to manage them.

The main reason for the state government to select DBFM as the delivery model for Project-B was because they expected V*f*M, asset durability, efficiency and productivity, innovation in design, lower costs and quality output from the private sector. For that matter, the benefits to be provided through the involvement of a private-sector partner in infrastructure procurement and public service provision were the 'stimulators' of introducing the DBFM of PPPs into Project-B.

5.3.2 Delivery Process of Project-B

As mentioned previously, the state government had completed a sequence of critical works, such as the business case study and selection of procurement option, before releasing the invitation for the EOI in 2011. After an evaluation of the EOI submissions, the PPP project proceeded to the Request for Proposal (RFP) stage, whereby the short-listed respondents of the EOI were requested to submit fully-costed and complete proposals in 2012. Then, the state government evaluated the received proposals against a range of criteria within both qualitative and quantitative contexts, including organisational structure, stakeholder relationship management, design solution and management, build project management, delivery of facility maintenance (FM) services, and so on. Table 5.7 indicates the delivery process and timeframe of Project-B.

Table 5.7 Delivery process and timeframe of Project-B

Phases of Project-B delivery process	**Timeframe**
Inception (Pre-tendering)	
Business case study and planning	From 2009 to 2011
Invitation for EOI	
Evaluation of the EOI submissions	
Procurement	
Release of the Request for Proposal (RFP)	From January to December 2011
RFP evaluation and appointment of preferred respondent	
Contract and financial close	
Design and Construction	
Commencement of construction	From 2013 to end of 2015
Stage One works completion	
Stage Two works completion	
Facility Maintenance	
Commencement of operation and FM	Since middle 2015
Handover	

Source: 'Project Summary' of Project-B, p.12

5.3.3 Practice in Performance Evaluation of Project-B

One of the focuses in this case study, which relied on interviews and documentary sources (e.g., Project Summary and Service Agreement), was on the practices in performance measurement/evaluation of Project-B. It has been mentioned that the case project was procured by using a DBFM model. Thus, the interviews that were undertaken were associated with the key management personnel of the project team, involving: (1) the director of the involved public authority, who oversaw the entire procurement of the project; (2) the project manager of the private-sector SPV; (3) the construction and engineering manager; (4) the facility maintenance manager; and (5) the design manager. Table 5.8 indicates the information of the respondents and their organisations. Each interview in this case study was arranged to be from 90 to 120 minutes with the respondent's permission to digitally record it. A limitation in this case study was the lack of an interview with the key stakeholder of the Capital Investment Agent of the project (F-B). This was because of the unavailability of the financial manager who declined to participate in the research due to some confidential issues. However, the negative effect from this research limitation was significantly minimised by the Project Manager's (PM-B) abundant knowledge about the financing of Project-B.

Table 5.8 Information about the respondents in the case study of Project-B

Respondents	**Serial Codes**	**Organisations**
Procurement Director in the public authority	PD/PA-B	State Government
Project Manager	PM-B	C-B
Design Manager	DM-B	D-B
Construction and Engineering Manager	CEM-B	C-B
Facility/Asset Manager	F/AM-B	FMG-B

Similar to the study of Project-A, the interviews conducted for the case study of Project-B were semi-structured, and they comprised four parts with the aims of: (1) empirically understanding the current practices in performance evaluation in the project; (2) identifying the deficiencies of the existing performance evaluation of the project; (3) testing the feasibility and applicability of the developed life-cycle PMS in solving the limitations/gaps in the case project's existing evaluation system; and (4) refining the life-cycle PMS developed within the context of the case project. The respondents who participated in this case study were all professionals with 15 to 20 years of experience in procuring social infrastructure PPPs within Australia. This implies that the views and opinions expressed by such respondents are reliable and significant.

At the beginning of each interview, the respondent was provided several minutes in which to describe some background information of the case project and his/her role in it. This helped the respondents to feel relaxed about the interviews and assisted the researcher to become familiar with their responsibilities during the delivery process of the project. Then, the indicative questions shown below were used to understand and interpret the existing practices in performance evaluation of Project-B.

- How did you evaluate the performance of Project-B throughout its life-cycle?
- What do you consider to be the shortcomings and/or limitations in the system/ approach devised to evaluate the performance of Project-B?

To clearly understand the performance evaluation of Project-B, an interview with the Procurement Director of the public authority involved with the project (D/PA-B) was first undertaken. It was identified from the interview that the approach adopted to evaluate Project-B during the stages prior to the '*Partnership*' phase of the project was similar to that of Project-A, which was referred to as a 'Gateway Review', whereby the reviews of the business case development and tender decision had been conducted (Figure 5.8). As this Director stated:

> "The Gateway Review concept was used for this social infrastructure PPP project. So we have a review for the development of the business case and also a review for the decision on the tendering. Before these reviews, we used a Value for Money evaluation, and it depends upon the PSC."

As introduced previously, the financial closes of Project-B was completed in 2011, and then the design and construction were initiated and handled by the private contractors (C-B & D-B). Over the D&C stage of Project-B, the formal measurement mechanisms that were formulated and used to evaluate the project performance were still time, cost and quality. The Project Manager (PM-B) supported this finding:

> "As a private contractor, we talk about time, cost and quality in this project. They are the only performance measures we have in this project. Currently, time is our premium, now we are 44% through the overall duration, but … the design has taken longer to get the approvals that we need. We have had to look at a way to fast-track the building to make sure that we meet the end date. In terms of costs, we are running within the cost limits at this stage and this is good. And, quality - obviously the measure is about once we start building - the quality of the product that we put forward."

The Engineering Manager (EM-B) and the Design Manager (DM-B) of the project explained that there is no difference between the performance evaluation of the D&C in Project-B and that of traditional lump-sum projects; therefore, schedule, budget and quality are the main components. For example, the Design Manager stated that:

> "We fundamentally run the project like a traditional project. Traditional

projects are run in a manner that they run for certainty of outcome, like schedule, budget and client's requirements on product scope and quality."

The views of the three PPP practitioners in the private-sector SPV confirmed that the TCQ-focused evaluation was used for measuring the D&C of Project-B. The Project Manager (PM-B) summarised:

> "… like I said, from a D&C perspective we will close out to make sure that we finish the project on budget, on schedule and on quality. This is a project with more than AU$200 million. So cost is a huge focus and a big job in the performance evaluation. And, quality is making sure that we don't end up with a huge list of defects ..."

Project-B was procured under the timeframe of the DBFM model/contract. Accordingly, an interview with the manager who will be responsible for maintaining the facility was also undertaken to identify whether there are any formal performance measurement mechanisms (i.e., KPIs or performance measures) available for evaluating the facility maintenance. During the interview, the FM Manager (FM-B) said that:

> "The State has a whole lot of abatements or financial risks for us, but they do not document detailed indicators for the FM of this project. What we care about is ensuring that the facility is constantly available for use. For example, we have one cell not occupiable because the toilet is broken. If it is not available for an hour, that is fine. If it is not available for four hours, that is a problem and there is a penalty attached to that. If it is not available for a day - a bigger financial penalty, and it rolls on that way. If a whole prison block is not available because there is a blockage to the sewerage going into that block, it starts costing us a lot of money. And there is also something about the security of the prison, like the perimeter fence or the camera. If a camera is not available for an hour, a week, a month, there are financial penalties attached to that."

The FM Manager's views indicate that maintaining the availability of the facility is the key work of the FM group of the private SPV in Project-B. Table 5.9 below shows the FM services that need to be provided in the case project. Although the areas of FM in Project-B have been outlined explicitly in the 'Project Summary', an in-depth review of the 'Service Agreement' suggests that no formal/systematic KPI or performance measure is stated clearly in the contract of the project.

Based on the information provided by the respondents and the documentary sources, the system devised for measuring the performance of Project-B can be outlined as in the following diagram. Figure 5.8 illustrates that the system devised for measuring the case project over its life-cycle incorporates a V*f*M assessment relying on the PSC, reviews for the business case and tendering, and an *ex-post* TCQ-focused evaluation of the D&C. The Procurement Director (PD/PA-B) summarised that "in the case of this project, we used 'Gateway Review' in the inception and procurement stages and the private sector evaluated the project against time, cost and quality".

Table 5.9 Services provided by the FM Group of the SPV in Project-B

SPV Member Organisation	Detailed Services Provided
FMG-B	• Building maintenance services (e.g., reactive/preventative maintenance and life-cycle replacement). • Limited grounds maintenance services. • Furniture, fittings and equipment maintenance services and whole-of-life replacement of selected items. • Security systems maintenance services and life-cycle replacement (i.e., secure perimeter fence). • Key and lock management services. • Cleaning services (non-prisoner areas only). • Waste management services (non-prisoner areas only). • Pest control services. • Utility management services. • Help desk services.

Source: 'Project Summary' of Project-B, p.5

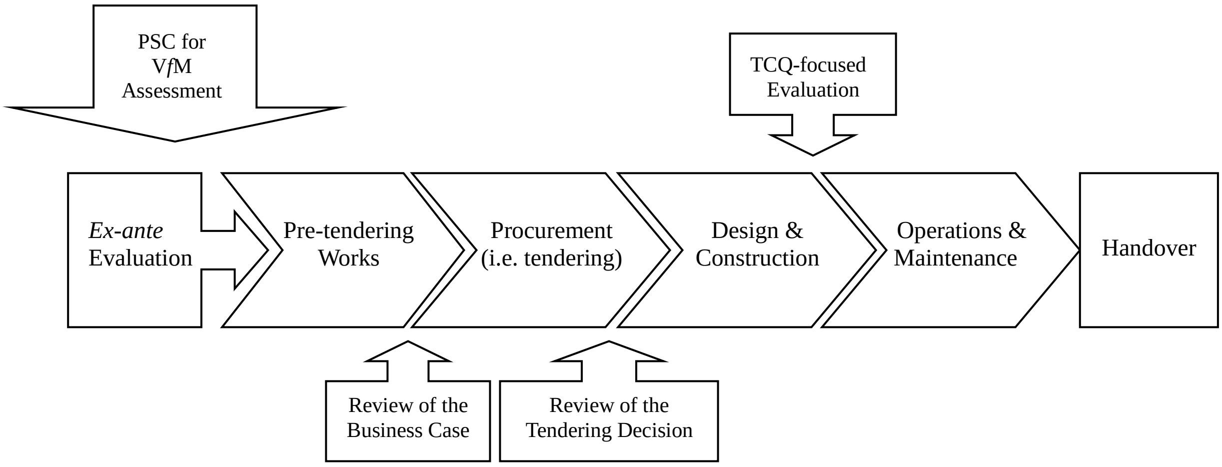


Figure 5.8 Performance evaluation system of Project-B

5.3.4 Shortcomings of Project-B Evaluation System

The practice in performance evaluation of Project-B has been outlined above. All of the respondents (n=5) maintained that there were a range of shortcomings in the project's performance evaluation system and these deficiencies may negatively affect the future success of the project. Likewise, interviews acted as the major research approach in identifying the 'gaps' in performance evaluation in Project-B. According to respondents' views, the deficiencies of the case project's performance evaluation can be summarised as follows: (1) a narrow and quantitative-based V*f*M assessment; (2) an ineffective and inefficient management of information related to the performance evaluation; (3) the lack of an effective and efficient learning process; (4) an incomplete measurement for the '*Procurement*' phase; (5) a simplistic *ex-post* evaluation for the D&C; and (6) the lack of formal performance mechanisms in the stage of facility maintenance.

Pre-contract Phase (Initiation, Planning and Procurement)

The public sector in a PPP has to complete a great amount of essential works, from the project's initiation and planning to financial close, including the business case, project definition and procurement option, tendering and final negotiation, all of which can determine the quality of the deliverables and even the success of the whole project (European Investment Bank, 2011a). Nevertheless, only a review of the business case and tendering decision was implemented in the existing performance evaluation of Project-B, and other critical aspects (e.g., competitiveness of tendering and efficiency of approval process and final negotiation) have been largely ignored. These limitations were identified by the Procurement Director of the public authority of Project-B (D/PA-B) and he specified, as follows:

> "Performance measurement is used for improvement. In the case of this project, improving is first about bidding efficiency and the efficiency of the whole procurement. It sometimes took us a little bit long to pass each approval and final negotiation process. And, competition is really an aspect we expected in the Procurement phase. But this is missed in the project's performance evaluation and we should have a mechanism to examine if the competitiveness of bidding can achieve the level we expected."

Additionally, in Project-B, the management of evaluation information was weak and the 'internal learning' was ineffective and inefficient in capturing the lessons learned from the evaluation results. As stated by the Procurement Director (DA/PA-B):

> "Consistency of information is critical to the precision of our evaluation and governance. The information that is required to be provided by the respondents of the private organisations must be structured well to make it easier for our evaluation team. Typically for this large project, a lot of information needs to be provided. So, we do require an effective technique to generate consistent and ordered information and support us to locate useful information. We also require an internal process to properly capture lessons learned from the information produced from the evaluation. But the existing learning process needs to be improved, and we are refining it."

It can be summarised from the above that the performance measurement mechanism implemented for the inception stages of Project-B (pre-contract phase) was limited in reflecting the 'efficiency of the approval process in the *Procurement* phase' as well as the 'competitiveness of the bidding'. Moreover, there was a lack of technology to support the existing performance measurement mechanism, not only to generate consistent information useful for measuring the project but also to assist the evaluation team to access it efficiently. Also, similar to the situation of Project-A, the internal learning process of Project-B was too weak to completely absorb the lessons generated from evaluating the information provided by the relevant respondents (i.e., involved key organisations) in the project.

An important task that must be completed by a state government during the pre-contract stage of a PPP is an evaluation of V*f*M. In the case of Project-B, the V*f*M assessment completely depended upon the PSC. The 'Project Summary' indicates that the state's evaluation framework for Project-B was based on the PSC, which generated a net present cost that was used for comparison with the net present costs of the bids received in order to determine the V*f*M analysis. Table 5.10 presents the PSC-focused V*f*M assessment of Project-B.

Table 5.10 The V*f*M assessment of Project-B

State's Risk Adjusted PSC (AU$'000)	SPV's Risk Adjusted Proposal (AU$'000)	Savings (AU$'000)	Saving Percentage
$452,590	$372,312	$80,278	17.7%

Source: 'Project Summary' of Project-B, p.14

As shown by the table above, the state government estimated that a 17.7% saving would be attained as a consequence of a competitive design and construction cost and competitive whole-of-life maintenance and refurbishment costs under the DBFM model. Although the quantitative results estimated by the government indicate V*f*M for the state, the assessment relying on the PSC largely neglected a sequence of benefits that can be provided by the involvement of the private entities in Project-B. This identification is supported by the 'Project Summary', which emphasises that the PSC-focused V*f*M assessment "does not recognise a range of other significant value for money benefits provided by the proposal" of the private SPV. These benefits include (Project Summary, p.14):

- the provision of a commercial laundry that will provide additional prisoner employment and revenue generation opportunities for the project;
- additional education and training facilities, including a training kitchen for male prisoners;
- additional programme facilities that will allow more prisoners to attend personal development, offending behaviour and release preparation programmes to help them adjust to prison life and to enable a successful

transition into the community upon release; and

- additional operational and administrative facilities that will improve amenities for staff at the new prison.

To put it simply, the V*f*M assessment of Project-B was too narrow to shed light on all benefits to be provided by the DBFM model under the PPP scheme. According to the European Investment Bank (2011b), PPPs are able to provide both financial and non-financial benefits (e.g., accelerated delivery, enhanced delivery and wider social impacts – labour market and environmental impacts), however, the PSC fails in covering all of these issues. As stated by the Procurement Director of Project-B (D/PA-B), "I think the PSC gave us good results but we will continue refining it, of course, because it is true that the PSC does not embrace all critical issues of PPPs in this project". This implies that the public sector involved in Project-B considered that a wider V*f*M assessment is required for a social infrastructure PPP project.

Partnership Phase (Design, Construction and Maintenance)

Performance measurement is a process of determining how well the objectives and strategies of the organisation have been achieved (Kagioglou *et al.*, 2001). For that matter, comprehensively measuring the performance of a PPP is a challenge because it possesses a complex stakeholder network, comprised of the public and private entities, and it is difficult to completely examine whether the key stakeholders' expectations and objectives have been satisfied (Zhou *et al.*, 2013). According to Yuan *et al.* (2009) and Mladenovic *et al.* (2013), the systems devised for measuring PPPs need to be sophisticated in order to capture a project's inherent complexities and uncertainties resulting from an involvement of multiple key stakeholders under a long-term contractual arrangement between the public and private sectors. These arguments can be strengthened by the public-sector Director (D/PA-B) who was overseeing the procurement of Project-B, and he stated that:

> "We selected PPP for this project for a number of reasons. One, the track record for on-time and on-budget is an important consideration, obviously. But, in this case - a very significant facility - we felt it is the opportunity to drive innovation in design through the whole-of-life perspective in PPPs to

> realise value for money… We are not just thinking about the completed design and construction but the responsibility for maintaining the facility over 25 years. So we suggested to get the facility manager involved in the design and expected there is a whole-of-life aspect to the design."

From the Director's statement, it can be inferred that the state government expected to achieve V*f*M for tax payers in Project-B through not only an on-time or on-budget delivery but also an enhanced innovation in design. This critical finding can also be supported by the project's 'Project Summary', which indicates that the "potential benefits expected by the government involve an increased incentive for delivering the project under the pre-defined schedule and budget and enhancing innovative design that considers the whole-of-life performance of the asset". Considering the perspectives presented above, an effective and efficient PMS implemented for Project-B should be able to capture all such aforementioned aspects (e.g., innovation) and assist in determining whether they have been realised. Nevertheless, the approach that was adopted to evaluate the performance of Project-B from the design stage to the maintenance stage was simplistic; a TCQ-focused *ex-post* evaluation.

Ex-post evaluation depending on the conventional 'Iron Triangle' (e.g., time, cost and quality) is criticised as a simple and narrow measurement that provides no insight into all deliverables (i.e., tangible and intangible issues) of a construction project (Haponava and Al-Jibouri, 2012). In the case of Project-B, the TCQ evaluation failed in examining how well the state's expectations had been satisfied. This shortcoming was identified by the Design Manager of the project (DM-B) and he criticised that:

> "Well, essentially, design is less measurable than many other facets. Engineering is much more measurable, finance is highly measurable, but design is not. We should measure it in a much broader band rather than evaluate it using a method for engineering, especially in a PPP where we have various objectives to meet."

The Project Manager (PM-B) also expressed his critical opinions towards the TCQ evaluation in Project-B, and these are quoted as follows:

> "This project is financed by both equity investors and debt providers, such as an infrastructure investment group, banks and other financiers. They are looking at evaluation and always say 'well, you are not drawing down and your revenue uptake is behind'. As I said, time and cost are extremely important in this project. The financiers always became nervous when they found we did not spend enough money. They thought this means we were not making enough progress and there were problems in our management. But (in fact) a lot of things correlate with it. Under this evaluation system, they have no idea where a problem came from, design or somewhere else."

The views of the Design Manager and Project Manager in Project-B imply that the TCQ evaluation has been considered to be an incomplete and unreliable approach for measuring the deliverables of the D&C stage of the project, as it is not robust in: (1) indicating how well the key stakeholders' expectations have been met; and (2) providing assistance in identifying where the problems originate in the project during the delivery process. Thus, as criticised by the Project Manager (PM-B), "an ex-post evaluation for time, cost and quality is not useful for continuous performance improvement of this social infrastructure PPP project".

In the case study of Project-A above, an important finding empirically derived from the respondent's views was the existence of a lack of formal performance measurement mechanism in measuring the FM works. Likewise, for the facility maintenance and management of Project-B, no performance measure was provided. The FM Manager (FM-B) acknowledged this significant gap and considered that KPIs for FM are essential for the life-cycle success of the project. He stated that:

> "We are maintaining the availability of the facility. If failed in doing so, we would get abatement. But the current system cannot help us improve our performance in FM to avoid the risks in the unavailability of the facility."

Using the key practitioners' views above, Figure 5.9 illustrates the 'shortcomings' of the performance evaluation of Project-B. It is noted from this diagram that the existing performance evaluation system of the case project possesses a range of 'limitations', involving V*f*M assessment that relies on PSC only, incomplete measurement for the *Procurement* phase, simplistic *ex-post* evaluation for the D&C, and the lack of an FM performance mechanism. These deficiencies were deemed as being the 'factors' that may substantially affect the success of the project by all respondents, and their opinions about the feasibility and applicability of the developed life-cycle PMS in fulfilling these identified measurement 'gaps' will be presented in the following section.

5.3.5 Feasibility and Applicability of Life-Cycle PMS in Project-B

This section focuses on demonstrating and determining whether the developed life-cycle PMS is a feasible and applicable way for Project-B to improve the effectiveness of its performance evaluation system. To achieve this, interviews using the indicative questions below were conducted:

- What are your opinions about the necessity of improving the performance evaluation of the project?
- What do you think about the feasibility and applicability of a life-cycle PMS with stakeholder-oriented KPIs to ameliorate the project's performance evaluation system?

This followed the same route as the study of Project-A, whereby the subjective bias towards the developed PMS was minimised by not providing the respondents with the developed PMS. Nonetheless, a range of key concepts, such as life-cycle V*f*M assessment, process-based and stakeholder-oriented KPIs, and learning mechanism, was explained at the beginning of each interview. Similar to the key stakeholders involved in the Project-A study, the respondents who participated in the study of Project-B were also experienced in the delivery of social infrastructure PPP projects in Australia. Hence, they all understood well the meanings of such concepts.

In the second part of the interview, all respondents (n=4) recognised the necessity of making a substantial change in the existing performance evaluation system of Project-B owing to its inability to deliver performance improvements over the project's life-cycle. For example, the Project Manager (PM-B) maintained that a study of how to improve the performance evaluation of this project was needed because a series of limitations could be found, and improvements would be helpful for future projects. Also, the Procurement Director (D/PA-B) of the project stated that change was necessary for this case project's evaluation because the current system was not robust in capturing all areas critical to the life-cycle success of the project.

As addressed above, three components were integrated with the developed PPP life-cycle PMS: (1) a sequence of process-based and stakeholder-oriented CIs, underpinned by a continuous review mechanism and BIM; (2) a wider life-cycle V*f*M assessment, taking into account both financial and non-financial critical issues (i.e., sustainability and potential social impacts on the public); and (3) whole-of-life effective and efficient 'learning mechanisms'. These three 'facets' are synergised and already have been referred to as the new 'Iron Triangle' in the Project-A case study. By considering the findings identified from the views of the key stakeholders of Project-B, Figure 5.10 illustrates how the life-cycle PMS is able to contribute to improving this case project's performance evaluation system, whereby the new 'Iron Triangle' assists to resolve the following problematic issues: (1) a purely quantitative V*f*M assessment; (2) inefficient evaluation information management; (3) ineffective and inefficient internal learning process; (4) incomplete measurement for the Procurement process (i.e., tendering); (5) a simplistic *ex-post* evaluation for the D&C (TCQ); and (6) the lack of an FM performance mechanism.

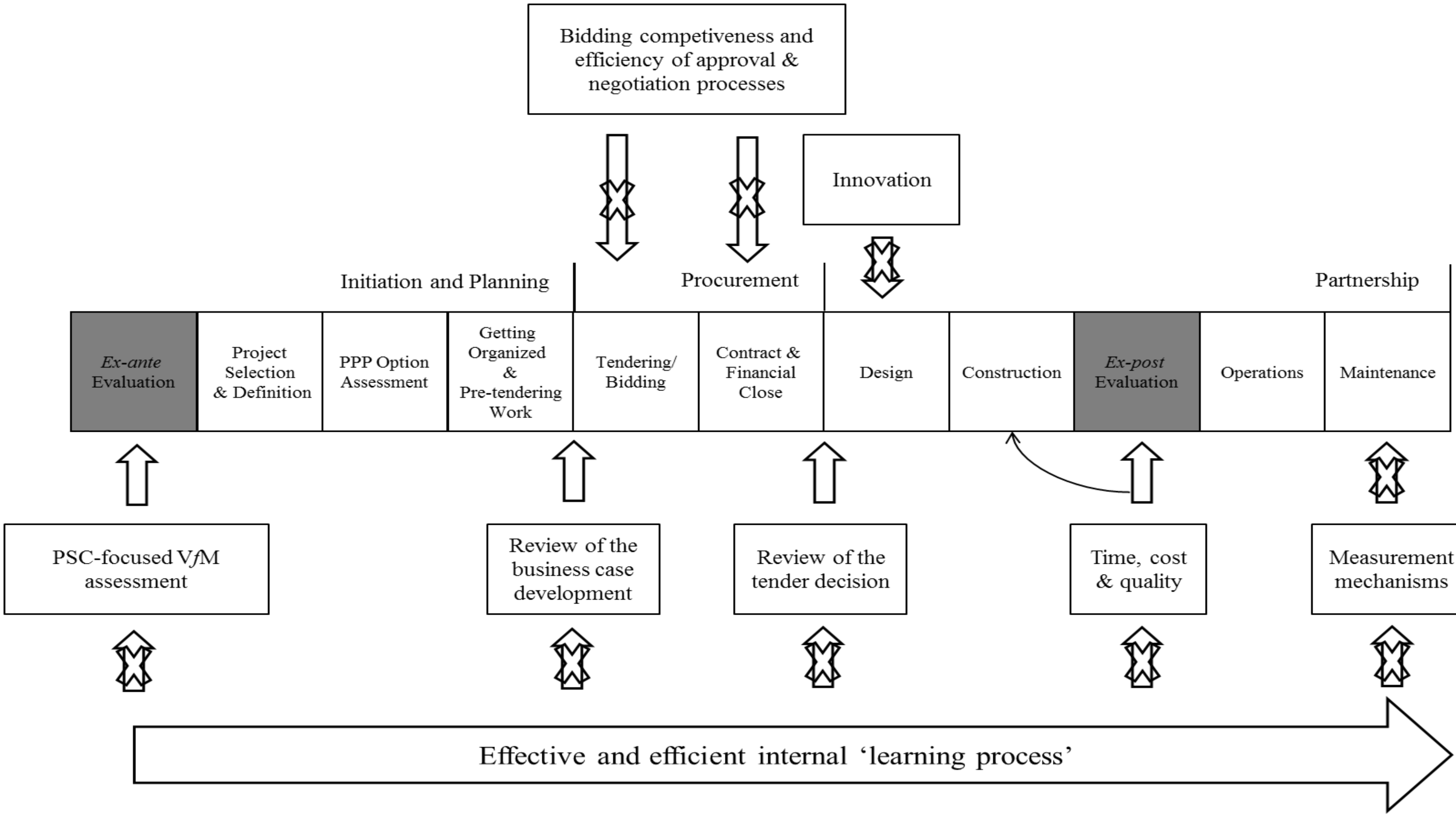


Figure 5.9 Shortcomings of the performance evaluation system of Project-B

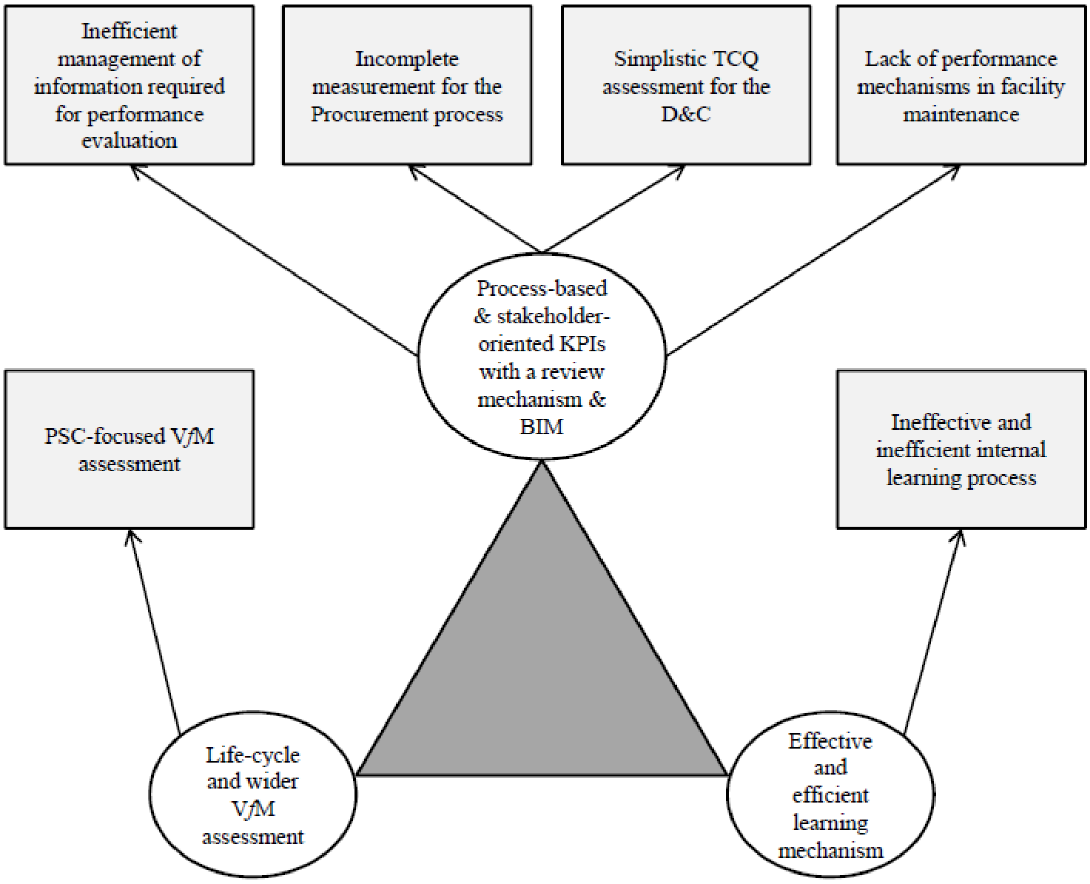


Figure 5.10 Illustration of how the life-cycle PMS can improve Project-B evaluation

The respondents' perspectives empirically support the aforementioned identification. In essence, all respondents commented that the rationale and concept that underpin the life-cycle PMS are rational and, therefore, the developed system is feasible and applicable for bridging the 'gaps' of the existing performance evaluation system of Project-B. The Procurement Director (D/PA-B) of the project believed that:

> "The life-cycle performance measurement makes sense. A wider value for money assessment is definitely applicable for this project. We had PSC assessment only in this project and we will get refined of course … I believe that the concept of stakeholder-oriented performance measures will ensure more effective and practical KPIs for the state government. As I said, we expected bidding competitiveness and innovative design in this project; however, the existing performance evaluation system cannot tell us if our expectation has been met. But the proposed model is helpful in these areas as it is stakeholder-oriented. In fact, the process-based measurement with

KPIs is a little bit similar to our 'Gateway Review' but more sophisticated. So it is undoubtedly feasible to capture more issues critical to the project success. And, I do think the life-cycle learning mechanism is useful and this is also what we are doing our best to realise."

The life-cycle PMS, essentially, can solve the problematic issues related not only to the V*f*M assessment and the measurements for the *Procurement* phase, but also to the management of the information required for evaluating a PPP. This is because the PMS is underpinned by BIM, which is a technology-focused methodology robust in efficiently producing reliable data and enhancing the efficiency of data access (Love *et al.*, 2013; 2014b). The advantage of BIM was acknowledged by the Procurement Director (PD/PA-B) and he maintained that BIM has a promising future in PPP procurement. Even though it has been used only in the design development of Project-B, it is now being substantially incorporated into two other new PPPs of the state government from the projects' commencements to closures. This Director proffered that:

> "BIM has helped the design of this project. There is a new PPP hospital in the process now that substantially incorporates the BIM Model and it is probably one of the first projects, even internationally, where BIM is being used from the initiation to facility maintenance … It is the next generation of PPP projects that will see using BIM not only design and construction but also facility maintenance and management."

The Design Manager (DM-B) confirmed that BIM has provided Project-B with huge benefits because of its asset tagging, as well as real-time data, and *LOD 300* (i.e., level of development 300) was used. Therefore, a mechanical structure was brought into a three dimensional model that was powerful in generating essential data of the project. He specified that:

> "We obviously used the full BIM model in our projects, like the one you are studying. In fact, it has already been used practically in a variety of fields of the delivery of our PPPs, in addition to the design development. For example, in this project, we used LOD 300 and it helped to enhance our

productivity and efficiency … in a new PPP public hospital, LOD 500 is now being used and this is one of the first BIM 500 in this state. It is undoubted that BIM can increase our efficiency and productivity in accessing the data required to evaluate, monitor and control the project's performance during the whole delivery process. Honestly, we have extraordinary experience with BIM in the delivery of this project. This is because we got less coordination onsite by literally inserting structural steel and also by inputting the ductwork, as long as that information that is put in is accurate. I can anticipate that BIM will be fully embedded within the next decade and will be seamless in the delivery of infrastructure projects, particularly PPPs."

Other respondents from the private-sector SPV provided their positive opinions on the life-cycle PMS as well. They maintained that the developed PMS is able to surpass the conventional 'Iron Triangle' *ex-post* evaluation, which has been criticised as a product-oriented simple review (Haponava and Al-Jibouri, 2012). Specifically, the Project Manager (PM-B) expressed his views from a construction practitioner's angle, which are quoted as follows:

"The life-cycle performance evaluation is absolutely applicable to improve this project. In fact, we took the life-cycle perspective into consideration when designing and constructing this facility. When we bid for this project, we worked through with the consultants, FM group and financiers to answer 'what does that do over the life-cycle of the project?' because there are obviously rules about the end of the 25 year period and there must be a minimum amount left on the life of a product. So we worked a lot during the design and construction to enhance the durability and sustainability of the asset and reduce the project's life-cycle costs to meet the state's requirements. We should have the performance measures in terms of what we actually contributed to produce the product over the design and construction process. So the process-based KPIs are absolutely useful."

In addition to the Project Manager, the FM Manager (FM-B) acknowledged the feasibility and applicability of the developed PMS for Project-B, and he contended:

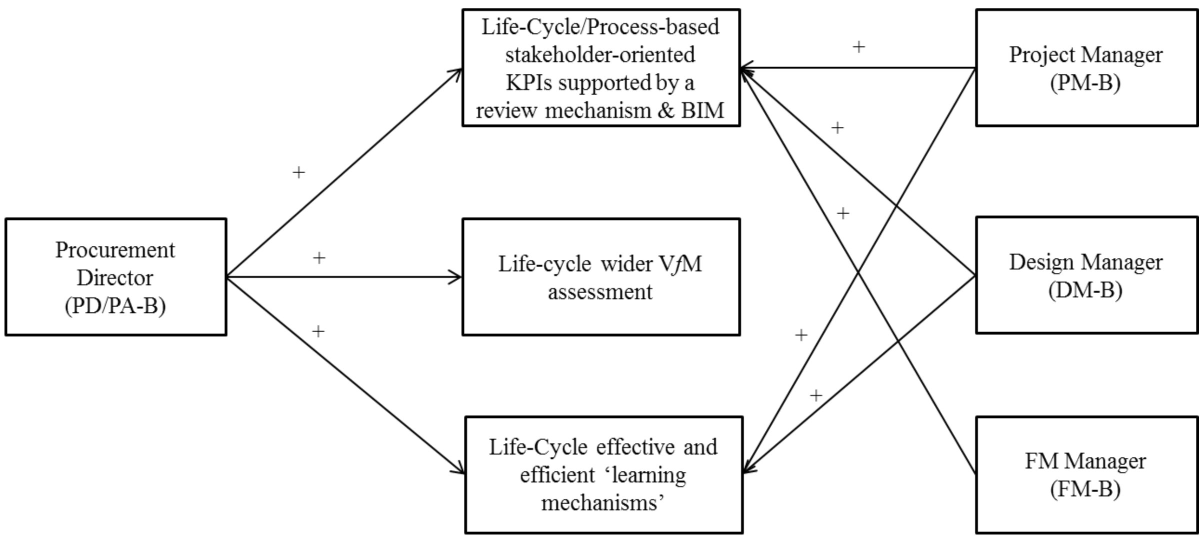
> "The process-based measurement of the model makes good sense, because it makes us understand how each critical issue impacts on the project team. This is very important for the FM Group as we will have to maintain the facility for the next 25 years and the performance measures against the embedding process and procedures can help to mitigate risks in the long term and ensure a higher performance of the FM."

Essentially, the Design Manager (DM-B) also possessed a positive view towards the process-based and stakeholder-oriented KPIs of the life-cycle PMS; however, one of his statements implied that the internal 'learning mechanism' is a more necessary component of the PMS other than such performance indicators. This practitioner stated:

> "Having a sequence of performance indicators, especially for FM service, is all well and good. This means most of the works are going to be pretty black and white. But the reasons for not meeting KPIs are still based on a whole series of 'grey'. Take the toilets, for example. We have had 15 broken toilet pans this year, and this is much higher than we expected. Why is that? Is it because, all of a sudden, that prisoner is actually doing something or something else? So, KPIs are all well and good but we need to also know what caused a failure in meeting a KPI. This requires certain skills and processes to learn the lessons from the evaluation of KPIs. Otherwise, problems will come up again and again. The first two years we didn't have any broken ones and then we had something like 30 out of 45 toilets in that building were broken."

According to the Design Manager's views, it is reliable to identify and conclude that an effective and efficient 'learning mechanism' maintains a decisive role in performance measurement/evaluation as it serves as a foundation for performance improvement and risk mitigation. Buckler (1996) argues that continuous improvement cannot be achieved without learning about the 'problems'. Notably, the Design Manager is not the only respondent of the private SPV of Project-B who recognised the importance of the internal learning mechanism in PPP performance measurement. The Project Manager (PM-B) also identified that the complexities of this PPP generate a plethora of issues when evaluating the D&C and FM, and they tend to be lessons that the private consortium needs to learn because these will be useful for the future and/or next project. Essentially, this viewpoint also implies and proves that an effective 'learning mechanism' is pivotal for the performance evaluation system of Project-B.

The information obtained from the interviews above indicates that the respondents from both public and private sectors recognised the significance of the life-cycle PMS. Such key project stakeholders considered that the developed PMS with its emphasis of the new 'Iron Triangle' is feasible, applicable and robust in coping with the limitations of the performance evaluation of Project-B, and it is capable of assisting to improve the project's life-cycle performance (Figure 5.11).



Note: '+' represents a positive perspective

Figure 5.11 Respondents' views towards the new Iron Triangle of the PMS

5.3.6 Refining the Developed Life-Cycle PMS under Project-B

The developed life-cycle PMS of PPPs has been tested again through the study of Project-B. Relevant empirical evidence also indicates that it is a feasible and applicable system that can operationalise 'real-world' infrastructure PPPs and substantially improve a project's performance evaluation system. Similar to the study of Project-A, the key stakeholders involved in the case study of Project-B were asked to propose a series of KPIs for the project's Initiation and Planning, Procurement, D&C and FM stages in accordance with the actual situations of Project-B. As argued above (Section 5.2.6), this is an essential process that is valuable for refining the dataset of the core indicators (CIs) of the PPP life-cycle PMS (i.e., Appendix D) to enhance the model's practicability.

Throughout the process of proposing KPIs, each respondent was allowed to list the critical KPIs that had been ignored in the delivery of Project-B, without any interruption. The Procurement Director (PD/PA-A) proposed a set of neglected KPIs from the public sector's perspective, and his proposition is reported below:

> "At the moment, we have no criteria about assessing and increasing bidding competition, but it is important. If you are getting six or seven bids for a PPP in this state, it is pretty good going. So bidding competitiveness would be an important KPI. The Procurement is probably not established well now … you know… approval processes were protracted. We may need a measure to indicate if the procurement process is pretty efficient. And, I said, we keep refining our evaluation, ensuring consistency of information that we request from the private organisations and making sure they are structured, ordered and concise for our project evaluators. So a KPI for management of evaluation information is required. For the D&C, we hope the private sector can complete the project on time and on budget and drive innovation in design. We do get the facility manager to be involved in the design development to ensure a whole-of-life aspect. So design innovation, like an involvement of the whole-of--life aspect, should be devised. And, for the FM and Handover, this project is easy and all things are around availability of the facility, and KPIs are about asset conditions and its residual value."

According to the statement of this public-sector director, a range of KPIs is able to be derived and summarised as follows:

- Competitiveness of bidding;
- Efficiency of approval process during the *Procurement* phase;
- Design innovation (e.g., involvement of life-cycle perspective); and

- Asset's conditions and residual value.

The key stakeholders from the private SPV also expressed their ideas about which KPIs had been ignored in the performance evaluation system of Project-B but were critical to the project's success. For example, the Project Manager (PM-B) proposed:

> "For design and construction, KPIs should look at what it actually costs us to install or buy and install products. We might be able to put a lot of cheap products in, but it might take us twice as long to build. Then that is twice as long that I have to have officers onsite, that I have to have staff, and that I have to cover with my insurance. All of these correlate to financial costs. So, an evaluation of the D&C is not just a simple check about if the project is on time and on budget, but <u>should include a determination of the most cost-effective option for products.</u> The hot water generation is a really good example. We looked at solar, we looked at thermal, and we looked at absolutely every option. One performed better in capital costs, while one performed better in maintenance costs. When you combined the two of them, then one stood out over the other, and the comparison was done again and again because we are doing it over a long period of time and we will have to consider the FM aspect. And, the <u>construction KPI is to make sure that the planned target can be met. If we are not doing it following the way that it was planned, have I found a better and innovative way to do it and improve efficiencies</u>? A lot of these things are the lessons we should learn from the evaluation system."

In essence, the Project Manager provided an implication to improve the measures used for evaluating the D&C of PPPs, rather than listing a series of detailed KPIs. It can be interpreted and inferred from the Manager's statement that the KPIs of the D&C in Project-B need to help in examining whether the decision for the option of the products to be installed is appropriate (i.e., cost effective, durable and sustainable) and if the planning for construction is innovative in driving efficiency. Further, the Design Manager (DM-B) provided more details about what measures should be added into Project-B to improve the measurement for the project's D&C stage, and he proposed:

> "Design is not as measurable as engineering. It should be measured in a wider band, like measuring people. We should measure if people are happy (satisfied), but happiness (satisfaction) is a hard one to measure. The people I am talking about are not only prisoners, but also staff, who will often spend more time in the prison. Staff may work at an institution for up to 20 to 25 years. If people are not happy (satisfied) with their facility, they will treat it more harshly, which means the maintenance goes up. In this project, we should also measure design based on the criteria like if the building will be dynamic, flexible and adaptable to be able to cope with 20 years. And also we will have to think about the Handover stage in the design - like the asset's ability for accommodating technology changes (i.e., sustainability). We attempted to make this government facility with a design life of 50 years plus."

Bearing the perspectives of the Project Manager and Design Manager in mind, a group of critical KPIs of D&C that were neglected during the delivery of Project-B can be derived as follows:

- Proper design (asset's durability, sustainability, flexibility and adaptability);
- Determination of most cost-effective option for the products to be installed;
- Construction innovation; and
- End-users' satisfaction (e.g., staff and prisoners).

Apart from the KPIs of design and construction, the FM Manager (FM-B) suggested that the KPIs for the FM of this project are straightforward and they should be in regard to the estate maintenance and facility management, such as maintenance of buildings, FF&E (i.e., furniture, fixtures and equipment) and security systems, as well as cleaning services, waste management, utility management, and so on. The objective information presented in the project's documentation can complement the subjective opinions provided by the FM Manager and assists in tailoring a series of FM KPIs. According to the 'Schedule 13' (Service Specifications) of the 'Project Agreement' of Project-B, the facility maintenance provided by the FM Group of the SPV (coded as FMG-B in Figure 5.7) encompasses the following services: (1) estate maintenance services (e.g., building, external areas, FF&E, security system, schedule estate, building management IT hardware and software, and statutory testing for building fabric, utility and electrical services); (2) graffiti management; (3) key and lock management; (4) facilities management services (e.g., cleaning services, waste management services, pest control services, utility management services and FM help desk services); and (5) environmental management services (pp. 8-51). Additionally, this experienced FM practitioner also argued that:

> "More qualitative indicators should be added. I am talking about the measures for the intangible issues, like stakeholder engagement. I think they are absolutely critical. You can build a great facility and do it on budget and in the time frame and then have the stakeholders moving into it and be nothing like what they wanted, or envisaged."

By combining the subjective and objective information provided, the KPIs with respect to the facility maintenance of Project-B are identified and summarised below:

- Effectiveness of asset maintenance, and facility and environmental management
- Stakeholder engagement

As a consequence of the findings derived in this section, Table 5.11 reports all KPIs that were proposed by the respondents for Project-B. Following the process of the study of Project-A, a critical comparison is illustrated as Figure 5.12, which was undertaken between the core indicators (CIs) presented in Appendix D and the KPIs derived from the case study of Project-B (e.g., the existing performance measures that had already been used in the project - Figure 5.8 - and the KPIs proposed by the respondents in Table 5.11). This aims to examine whether any critical KPIs have been ignored in the CIs dataset (Appendix D) and to enhance the practicability of the developed PMS.

Table 5.11 Life-cycle KPIs proposed by the respondents from Project-B

Organisations	**Project Stages**	**Key Performance Indicators**
Public authority	Initiation and Planning	Nil
	Procurement	Competitiveness of bidding; Efficiency of approval process
	Design and Construction	Design innovation; Effectiveness and efficiency of evaluation information management
	FM under asset operation	End-users' satisfaction; Effectiveness and efficiency of evaluation information management
	Handover	Asset conditions; Effectiveness and efficiency of evaluation information management
Private-sector SPV	Initiation and Planning	N/A
	Procurement	N/A
	Design and Construction	Proper design (asset's durability, sustainability, flexibility and adaptability); Determination of most cost-effective option for the products to be installed; Construction innovation
	FM under asset operation	End-users' satisfaction (for design); Effectiveness of asset maintenance, facility and environmental management
	Handover	Nil

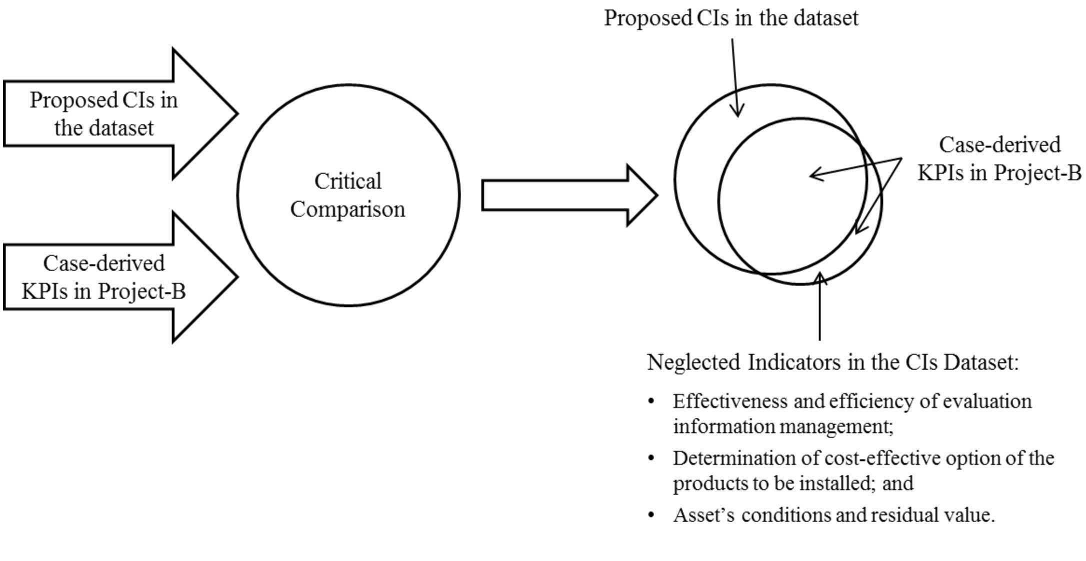


Figure 5.12 Comparison between the proposed CIs and case-derived KPIs

It can be identified from the comparison that the CIs dataset embraces the majority of the KPIs derived from the study of Project-B, excluding 'effectiveness and efficiency of evaluation information management', 'determination of cost-effective option of the products to be installed', and 'asset's conditions and residual value'. As has been addressed in the case study of Project-A, the findings generated from an individual, carefully selected case study are valuable and significant for knowledge or hypothesis generalisation (Flyvbjerg, 2006). Project-B was procured by using the DBFM model that is prevalent across Australia. Similar to the Project-A study, this case was carefully chosen by communicating with the key management personnel of the involved public authority, as well as the legal advisor and communication manager of the private SPV. All of these senior managers considered that Project-B would be suitable for the nature of this research because the involved organisations play leading roles in the delivery of social infrastructure PPPs within Australia and the information provided would be exceptional and significant. Therefore, the CIs dataset of the developed life-cycle PMS of PPPs can be expanded by adding the aforementioned case-derived KPIs. Notably, one of the KPIs derived from Project-B (i.e., asset's conditions and residual value) has already been addressed in the study of Project-A. As a result, only two case-derived KPIs of Project-B were added into the CIs dataset (Appendix D), those being 'public sector's capability in managing evaluation information' (CI_{F4-17}) and private 'SPV's capability in determination of cost-effectiveness of products to be installed into the asset' (CI_{F4-18}).

After testing and refining the developed PMS, each respondent was asked to provide some general comments on the life-cycle model. This assisted the researcher to identify whether there would be any potential difficulty in implementing the life-cycle model within a 'real-world' context. Essentially, no respondent raised a substantial hurdle to an implementation of the developed PPP life-cycle PMS. As commented by the FM Manager (FM-B), "I am not able to anticipate any huge potential hurdle if this model is implemented in a 'real-world' PPP, like this project; however, its implementation must be finalised in the pre-bid phase and the evaluation phases need to be clearly defined - for example, who does what, when it happens, and what will be done in post-evaluation - and this requires effective information and technology for support, especially in the FM". The Procurement Director (PD/PA-B) also possessed a similar viewpoint and summarised that information consistency and efficiency is critical to the successful implementation of the life-cycle PMS in Project-B because of an involvement of various organisations.

5.3.7 Summary of Case Study of Project-B

This section presented an in-depth case study of a prison project procured under the usual scope of a DBFM model for PPPs in Australia. Over this case study, the project's performance evaluation system and its deficiencies were interpreted. Then, testing was undertaken to empirically examine whether the developed PPP life-cycle PMS was feasible and applicable in dealing with the identified evaluation limitations. The empirical evidence proves the feasibility and applicability of the developed model. At the end of the case study, a sequence of KPIs was identified, in the context of the case project, to enhance the practicability of the life-cycle PMS.

5.4 Comparisons of Two Case-Study Findings

Two in-depth case studies of Australian social infrastructure PPP projects (e.g., a public hospital and a prison) have been conducted in the prior sections (Sections 5.2 and 5.3) of this chapter. Based on the information provided above, these two projects share a selection of common points in the practices of their performance evaluations, such as a V*f*M assessment that largely relies on the PSC, a general 'Gateway Review' for the business case development and tendering decision, a TCQ-focused *ex-post* evaluation, and so on. Tables 5.12 and 5.13, below, critically compare the key practical issues of the performance evaluations of the two case projects as well as their systems' shortcomings and limitations, and explicitly indicate how the developed life-cycle PMS of PPPs is capable of substantially bridging the 'gaps' of the case projects' performance evaluation systems. This section serves as a summary, with an emphasis of clearly indicating the findings and identifications derived from the case studies.

Table 5.12 Comparison between performance evaluations of Projects A and B

Components of Performance Evaluation Systems	**Project-A**	**Project-B**
V*f*M assessment	PSC and qualitative issues	PSC-focused only
Pre-tendering measurement	Review of the business case development	Review of the business case development
Procurement measurement	Review of tendering decision	Review of tendering decision
D&C evaluation	Time, cost and quality	Time, cost and quality
Operational measurement	KPIs of clinical services	N/A
Facility maintenance and management	No formal measurement mechanism available	No formal measurement mechanism available

More importantly, as emphasised above, a case study is powerful not only in problem identification but also for model refinement (Flyvbjerg, 2006). Thereby, the developed PMS of PPPs was refined in this chapter by renewing its CIs dataset according to the findings derived from the case projects. Then a renewed and updated dataset of the CIs was developed, based on the two detailed case studies (Appendix E), which acted as a solid conceptual base for the quantitative studies to be presented in Chapter 6.

Table 5.13 Contributions of the life-cycle PMS to case projects' performance evaluations

Case Projects	**Shortcomings and Limitations of the Performance Evaluation Systems of the Case Projects**						
	Narrow V*f*M assessment	Incomplete measurement for the *Procurement* phase	Simplistic *ex-post* evaluation for the D&C of the projects	Lack of review mechanism for the operational KPIs	Lack of performance measurement mechanism in the FM	Ineffective and inefficient learning mechanism over the project's life-cycle	Ineffective management of performance evaluation information
(I) 'Gaps' in the Performance Evaluation Systems of the Case Projects							
Project-A	√	√	√	√	√	√	
Project-B	√	√	√		√	√	√
(II) Contribution of the Developed Life-Cycle PMS to Improving the Case Projects							
Project-A	×	×	×	×	×	×	
Project-B	×	×	×		×	×	×

Note: "×" in part (II) means that the developed life-cycle PMS can contribute to removing the shortcomings of the projects' performance evaluations.

5.5 Chapter Summary

This chapter presented two case studies of social infrastructure PPP projects; a public hospital and a prison, both in Australia, which were procured by using the DBOM and DBFM models, respectively. The purpose of these two case studies was to empirically test the feasibility and applicability of the proposed PPP life-cycle PMS within the context of 'real-world' projects, and to enhance its practicability.

With this primary purpose, the background information, objectives and delivery processes of the case projects were described. After a description of the general information, the semi-structured interviews and reviews of documentary sources (e.g., Project Summary and Project Agreement) were conducted to interpret the practices in the performance evaluations of the case projects and to examine whether the developed PMS would be feasible and applicable in contributing to dealing with the shortcomings and limitations of the approaches adopted to evaluate the projects. The empirical findings identified from the interviews and project documentations proved that the developed life-cycle PMS could enable substantial improvement of the performance evaluation systems of the two case projects. In addition to the empirical testing, the detailed case studies were also undertaken with the aim of refining the proposed life-cycle PMS via the critical comparisons relying on the case-based KPIs proposed by the interview respondents. This process was useful for enhancing the practicability of the PPP life-cycle PMS by 'polishing' its dataset of CIs.

In summary, the life-cycle PMS developed in this research has been considered to be feasible and applicable for future PPPs. In the next chapter, the main components of the proposed life-cycle PMS (i.e., propositions derived from the exploratory study and case studies) will be quantitatively tested by the confirmatory factor analysis that relies on the survey data.

CHAPTER 6 LIFE-CYCLE CORE INDICATORS AND MACROECONOMIC KEY PERFORMANCE INDICATORS

6.1 Chapter Introduction

The feasibility and applicability of the life-cycle performance measurement system (PMS) of PPPs that was conceptualised from the exploratory interviews have been tested by the case studies. In this chapter, a quantitative study is presented with the aim of validating the main components of the developed PMS (e.g., five performance measurement perspectives and their relevant life-cycle core indicators). Statistical tools, involving Cronbach's alpha, item-total statistics, and Confirmatory Factory Analysis (CFA), are used to analyse the data collected from a questionnaire survey.

After running the survey-based statistical tests, the performance measures that are specifically for assessing the macroeconomic environment were derived according to the comments that were raised by the respondents of the survey. A total of eight macroeconomic key performance indicators (KPIs) were determined and then validated through the application of a vector error correction (VEC) model. Under the constructed VEC model, the Granger causality tests, variance decomposition and analysis of generalised impulse response function were conducted, and are reported in this chapter.

6.2 Quantitative Analysis for the Observed Items

This section quantitatively tests the five performance perspectives and phase-based core indicators (CIs) of the PPP life-cycle PMS that were developed and examined in Chapters 4 and 5. The six topics of this section are the pilot survey, sample information, reliability tests, a comprehensive analysis using CFA and discussion of the implications.

6.2.1 Pilot Questionnaire Survey

As noted in Chapter 3, a pilot questionnaire survey was conducted and distributed to 28 experienced PPP practitioners across Australia to pre-test the effectiveness of the research instrument. A total of 25 responses were received, which equates to a response rate of 89%. The respondents who returned the questionnaire included procurement directors (20%) and financial advisors (26%) in the public sector as well as architects (12%), construction managers (19%), operation managers (12%) and facility managers (11%) in the private sector. The majority of respondents (n=23) considered that the questionnaire was comprehensive and straightforward to answer, and only minor modification was undertaken for the research instrument.

Each of the completed pre-test questionnaire surveys was given an identification number to ensure anonymity. Responses to each question were coded prior to data entry. A database was created in the SPSS Version 21. Responses were entered into it by the researcher, and the responses to the open-ended question of the final part of the questionnaire were transcribed verbatim into a spreadsheet.

6.2.2 Sample Information of the Survey

During the period of data collection, as mentioned in Chapter 3 (Methodology), a total of 368 questionnaires were distributed to PPP practitioners in both the public and private sectors, of which 141 responses were received. However, six of the received responses had to be discarded because of incompleteness. It is accepted knowledge that completeness of data is a prerequisite of structural equation modelling (SEM) and Confirmatory Factory Analysis (CFA). Therefore, 135 valid datasets were entered into the SPSS for modelling and related analyses. Table 6.1 indicates some basic information of the sample, in which 63 of the respondents were from the public sector while the remaining 72 respondents were involved with the delivery of social infrastructure PPP projects as key private-sector stakeholders. Ideally, CFA of structural equation modelling requires a larger sample size; however, a number of studies have used CFA with a sample smaller than 200, for example, Islam and Faniran (2005), Chinda and Mohamed (2008), Aibinu *et al.* (2011), Yuan *et al.* (2012) and Rajeh (2014). According to Bagozzi and Yi (2012), SEM typically, preferably, needs a sample above 200; however, a sample size within the range of 100 to 200 can still be acceptable. Molwus *et al.* (2013) support this perspective and argue that a sample size between 100 and 400 is considered to be large enough for SEM.

Among the 135 valid responses, 23% of the respondents possessed more than 20years of experience in delivering PPP projects, and 36% and 33% of the respondents had 11-15 and 6-10 years of experience, respectively. In summary, more than 92% of the respondents possessed over five years of experience in the delivery of PPPs, while only a small proportion of the respondents (i.e., 8%) had under five years of experience in PPP markets. Moreover, 84% of the respondents had participated in at least three social infrastructure PPPs, and approximately 33% had been essentially involved with more than five social PPPs. The majority of the respondents in the survey are experienced practitioners; therefore, the reliability of their opinions and perspectives can be assumed (Chartered Institute of Building – CIOB, 2013).

Table 6.1 Sample information of the questionnaire survey

Groups of sample	Questionnaires sent	Questionnaires received	Response rates (%)
Public sector:			
Business case study	40	26	65.00%
Procurement	71	22	30.99%
Contract Management	62	15	24.19%
Private sector:			
Design	46	13	28.26%
Construction	59	20	33.90%
Operations	51	18	35.29%
Maintenance	39	21	53.85%
Total:	368	135	36.68%

6.2.3 Reliability Tests for the Observed Items

Prior to a detailed analysis of the data, each construct/item contained in the research instrument (i.e., questionnaire) was tested for reliability. Nunnally (1978) states that "in the early stages of research on predictor tests or hypothesised measures of a construct, one saves time and energy by working with instruments that have modest reliability" (p.245). Thus, the reliability of the instrument was evaluated by using Cronbach's (1951) alpha (α), which has been widely applied to assess the reliability of items incorporated in research instruments. This coefficient, α, estimates the proportion of the variance of the responses, which are owing to the common factors. A satisfactory test result supports the argument that the data are interpretable (Cronbach, 1951). Mathematically, the α value is obtained through an analysis of the diagonal matrix of the correlations between the items.

A value of α greater than 0.70 indicates a reliable measurement instrument for the data that are used for fundamental research (Cronbach, 1951; Nunnally, 1978; Scott, 1981). SPSS version 21 was used to calculate the correlation matrix of responses to the ordinal scale questions, which was adopted for calculating the α level for each construct of the questionnaire survey. Further, the corrected item-total statistics were used with Cronbach's alpha throughout a reliability test to identify which items should be discarded in the subsequent quantitative modelling. According to Nunnally and Bernstein (1994), the items that are being observed in a research instrument (i.e., questionnaire) should be discarded if the values of their corrected item-total statistics cannot exceed 0.30.

Appendix F summarises that the Cronbach's alpha values of a total of 76 items were 0.96, while the corrected item-total correlation statistics were within the interval between 0.06 and 0.80. Based on these results, four items, namely CI_{F1-1}, CI_{F3-2}, CI_{F3-14} and CI_{F5-4}, had to be excluded from the life-cycle PMS as a consequence of their corrected item-total statistics, which were below the acceptance threshold value of 0.30. Then, the reliability test was undertaken again, after deleting the aforementioned items, and the empirical evidence indicates that the modified instrument, with 72 observed items, possesses a higher α value (i.e., 0.97) and increased item-total statistics (i.e., from 0.36 to 0.81).

The α levels for the survey data collected for this research indicate a high degree of internal consistency (i.e., measures are related to the same construct), which is necessary for the validity of the construct (Tabachnick and Fidell, 1996). This suggests that the questionnaire that was used for the survey was a reliable research instrument and the data are worthy of a comprehensive analysis.

6.2.4 Confirmatory Factor Analysis

After conducting the reliability tests and deleting several unacceptable items, CFA was undertaken for a total of 72 items. Conceptually, CFA is a theory-driven factor analysis technique that is within the scheme of SEM and, therefore, its formulation is driven by the theoretical linkages between the observed and unobserved variables

(Schreiber *et al.*, 2006). Within the configuration of the life-cycle PMS (Figures 4.6 and 4.7), the five measurement perspectives and their relevant CIs are viewed as the observed variables, while the outputs/deliverables of each PPP phase are considered to be the unobserved variables. With this in mind, the purpose of the use of CFA in this research is for testing whether the measures of a construct are consistent with such aforementioned conceptual propositions in regard to the nature of the measurement perspectives and CIs of PPPs.

Initially, the CFA-hypothesised model was constructed to estimate a covariance matrix of the survey population in comparison with an observed covariance matrix (Figure 6.1). Accordingly, the formulated model was applied to examine whether the observed items (i.e., five performance measurement perspectives and their associated CIs) were significant or could significantly contribute to the performance of a PPP project. Then, the items with comparatively low 'factor loadings' were eliminated to modify the initially hypothesised model and develop an optimal one.

The hypothesised model can capture the features of the developed PPP life-cycle PMS, whereby the phase-based CIs are proposed according to the five measurement perspectives that were assumed to be causally significant to the performance of a PPP project. The path arrows and the coefficients in Figure 6.1 are viewed as the causal effects in terms of the contributions of the observed items to the outputs of each phase and the project's entire life-cycle performance. The AMOS version 21 package was used in this research, for the model estimation, and relevant empirical results are summarised in Appendix G.

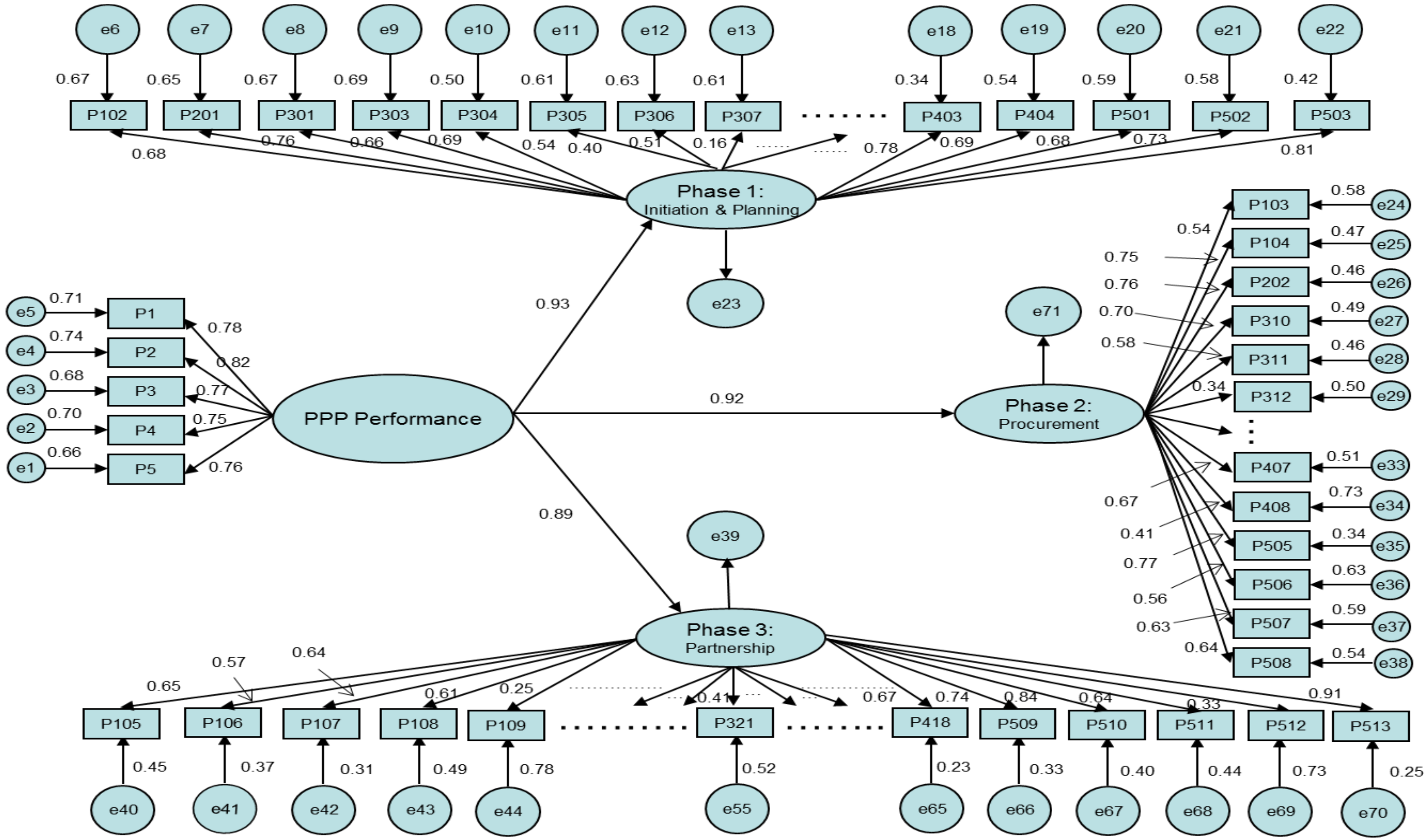


Figure 6.1 Initially-hypothesised model for the CFA of this research

According to Figure 6.1 and Appendix G, it can be identified that the coefficients of the five measurement perspectives (e.g., F1: Key Stakeholder Satisfaction; F2: Strategy – Value for Money; F3: Project Delivery Process; F4: Capabilities of the involved public authorities and private-sector entities; and F5: Key Stakeholder Contribution) emphasised by the *Performance Prism* proposed by Neely *et al.* (2001; 2002) are 0.78, 0.82, 0.77, 0.75 and 0.76, respectively, all of which are significant under 5% significance level. These statistically indicate that such proposed perspectives are significant to measuring the performance of PPP projects.

Apart from the findings relating to the five measurement perspectives, a sequence of critical implications can be drawn from the generated empirical evidence regarding the 67 CIs. Under the pre-contract phases (i.e., Phase 1: Initiation and Planning; Phase 2: Procurement – Tendering/bidding), the coefficients of most of the derived CIs are larger than 0.50 and are significant (under 5% significance level), which means that such observed CIs are significant for the performance measurement of PPPs (Yuan *et al.*, 2012). Nonetheless, four items, namely P305 (i.e., CI_{F3-5}), P307 (i.e., CI_{F3-7}), P312 (i.e., CI_{F3-12}) and P408 (i.e., CI_{F4-8}), were identified as insignificant indicators because they possessed comparatively low 'factor loadings' (i.e., coefficients) (i.e., 0.40, 0.16, 0.34 and 0.41, respectively).

As indicated above, most respondents involved in this survey were PPP practitioners based in Australia, where the PPP industry is acknowledged to be sophisticated and mature (Hodge, 2004). Essentially, PPP has become an integral part of both the federal and state governments' procurement strategies in Australia (Regan *et al*., 2011a). For that matter, Australian PPP projects are normally procured by strictly following a well-developed guideline and process (Infrastructure Australia, 2008), which not only delivers the projects efficiently but also enhances the use of PPPs across Australia. As a consequence, the state governments and an array of private-sector entities within Australia are experienced in procuring and delivering infrastructure projects via PPPs, and they are familiar with solving such process issues as financing options and design of an appropriate concession period, and/or how to organise and govern well the tendering and efficiently achieve financial close. This may explain why the performance indicators relating to the PPP project's finance option (CI_{F3-5}), concession period (CI_{F3-7}) and financial close efficiency

(CI_{F3-12}), and the government's governance ability for the procurement phase (CI_{F4-8}) were considered to be insignificant by the respondents of this survey.

In addition, the results of CFA indicate that the coefficients of the majority of the CIs proposed under Phase 3 (i.e., Partnership phase) of PPPs can exceed 0.50, except P109 (CI_{F1-9}), P321 (CI_{F3-21}) and P512 (CI_{F5-12}), which are associated with the coefficient values of 0.25, 0.41 and 0.33, respectively. This suggests that the effects of building product suppliers can be ignored in an evaluation of PPP performance. A possible reason for this situation is due to the stability of the Australian construction materials market. The private consortia of PPPs have rarely faced the challenge of unavailability or shortage of essential raw building materials during the delivery of their projects. This identification is supported by the statistical data published by the Australian Bureau of Statistics (ABS) (2014d), which indicates that the market of building materials in Australia is stable, even though the overall price level is on the rise. More importantly, Figure 6.1 and Appendix G indicate 'project profitability' as an insignificant indicator. In Australia, the delivery of social infrastructure PPPs, particularly such projects as public hospitals, schools and prisons, normally uses the availability-based model, where the private entities are paid monthly by the state governments for maintenance of the facilities rather than by the profits yielded from asset operations. For that matter, both the public and private sectors in social infrastructure PPPs are concerned with effectively and efficiently delivering the projects with quality outputs and outcomes, rather than enhancing the profits generated by the assets (Yong, 2010). In other words, 'project profitability' as a performance measurement indicator is not as important in Australian PPPs as in the projects of other countries where the operational-based PPP model plays a major role. This may explain the insignificance of 'project profitability' in this survey.

After eliminating the seven insignificant indicators (i.e., CI_{F1-9}, CI_{F3-5}, CI_{F3-7}, CI_{F3-12}, CI_{F3-21}, CI_{F4-8} and CI_{F5-12}), an optimal model was constructed and is illustrated by Figure 6.2. The estimates of the optimal model are reported in Appendix H, in which the values of 'factor loadings' of all observed items (i.e., five performance measurement perspectives and 60 CIs) are larger than 0.50 and also significantly correlated to the performance of PPPs at a 5% significance level.

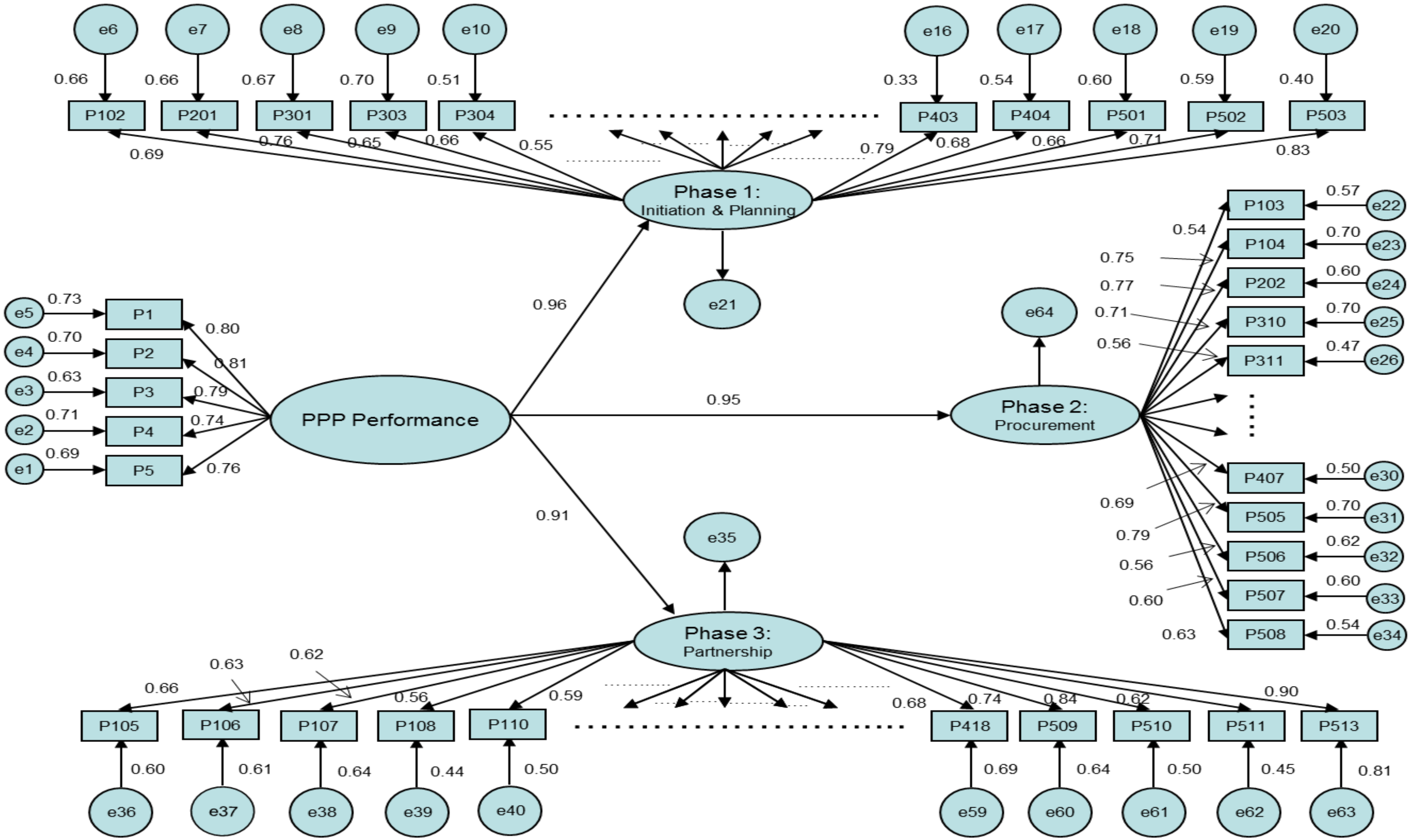


Figure 6.2 Optimally-revised model for the CFA of this research

To examine the model, three Goodness-of-Fit Indexes (GFIs) were used, including the *Chi-squared* (x^2) statistic, the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA). Theoretically, the GFIs, particularly x^2, CFI and RMSEA, are widely-used and valuable for indicating how well the constructed structural model fits a set of observations (Sanders *et al.*, 2006; Yuan *et al.*, 2012). Table 6.2 below shows the benchmark values of such aforementioned GFIs. In other words, the constructed structural model (Figure 6.2) is deemed as a 'fitted' model if its GFIs are beyond/within the intervals of the benchmark values.

Table 6.2 Benchmark values of the GFIs

Goodness-of-Fit Indexes	**Benchmark Values**
x^2	$1 \leq x^2/Df \leq 5$
CFI	≥ 0.90
RMSEA	$0.05 \leq$ good model fit ≤ 0.1

The empirical evidence relating to the three GFIs of the constructed optimal model (Figure 6.2) are summarised as follows: 2.32 (*Chi-squared* statistic), 0.92 (CFI) and 0.076 (RMSEA). These indicate a good model fit. On the basis of the results derived above, it can be found that all of the five proposed measurement perspectives are significant for the performance measurement of PPPs, while 60 indicators out of the 71 proposed CIs 'passed' the quantitative tests that relied on CFA. Therefore, the null hypotheses proposed in Chapter 3 (i.e., $F^1 - H_0$: The five measurement perspectives are not significant for measuring PPPs; and $F^2 - H_0$: The conceptually derived indicators are not significant for measuring PPPs) are rejected. The empirical findings confirmed the main proposition, that the stakeholder-oriented measurement perspectives and their relevant measures (i.e., CIs) are significant for future PPP performance measurements, which was conceptually proposed from the exploratory study and qualitatively examined by the case studies (Chapters 4 and *5*).

6.3 Discussion of Implications

The empirical evidence generated from CFA provides a sequence of implications for discussion. As indicated by Appendix H, the coefficients of the CIs relating to the

PPP strategies (i.e., V*f*M) are comparatively high during the projects' life-cycles (Phase 1 to Phase 3), ranging from 0.75 to 0.77. This empirically confirms the view that V*f*M is a long-term strategic goal pursued by the key stakeholders of PPP projects. Additionally, the average values of the coefficients of the CIs specific to the involved organisations' capabilities and key stakeholders' contributions are even higher than those of the CIs related to stakeholders' satisfaction and project delivery processes, especially in the *Procurement* and *Partnership* phases. This confirms Neely *et al*.'s (2002) perspective that the organisation's capabilities (e.g., management experience, innovation, and advanced technologies and knowledge) and key stakeholders' contributions can substantially determine organisational success and are, therefore, necessary for the organisation's performance measurement. It also indicates that the public authorities should have to conduct an assessment, not only of the proposals submitted by the private consortia during the *Procurement* phase (i.e., tendering/bidding), but also of their capabilities. Despite their importance, as addressed in Chapters 4 and 5, these critical issues currently are being largely ignored in an evaluation of PPP performance.

It is also noted from Figure 6.2 that the coefficients of the three project phases of the PPP can reach 0.96 (*Initiation and Planning* phase), 0.95 (*Procurement* phase) and 0.91 (*Partnership* phase), respectively. These values, on the one hand, indicate that the outputs of all three PPP phases are significantly correlated to the successful delivery of the project. On the other hand, the coefficients of Phases 1 and 2 are even larger than that of Phase 3. According to the traditional perspective of project evaluation, the outputs produced from the *Partnership* phase of a PPP should be the most important for the success of the project. This is also why the traditional *ex-post* evaluation that solely focuses on construction outputs (i.e., time, cost and quality) is still being widely used for evaluating PPPs. However, the empirical results above suggest that the quality of the deliverables yielded from pre-contracting works (i.e., the business case study, V*f*M assessment and tendering or bidding) in a PPP are as critical as those of the public asset's design, construction, operation and maintenance. This provides project key stakeholders with a strong hint that PPP performance evaluation should be wider and should embrace all essential aspects of the project other than just the construction. Thus, the assumed view that the phase-based measurement should be promoted to replace traditional *ex-post* evaluation can be empirically and essentially confirmed.

As addressed in Chapter 3, the final section of the questionnaire (Appendix J) that was based on an open-ended question was designed to provide the respondents with an opportunity to proffer some additional comments or ideas in regard to the performance evaluation of PPPs. Notably, a group of the respondents (n=13: 11.3%) suggested that the CI regarding the macro-environmental assessment (CI_{F3-1}) should be detailed in terms of macroeconomic conditions, which maintain a crucial role in the successful delivery of PPP projects, especially in Australia. Therefore, an econometric study with the aim of identifying macroeconomic KPIs for PPPs was undertaken for this research and will be presented in Section 6.5.

6.4 Summary of the Survey-based Analysis

A study that relies on the data derived from a questionnaire survey (the research instrument that is available in Appendix J) was conducted, and reported in this section, with the aim of empirically testing the five performance measurement perspective and a sequence of CIs, both of which were conceptually derived in Chapter 4. To ensure internal consistency, reliability tests relying on Cronbach's alpha and corrected item-total statistics had been undertaken prior to the main analysis of the data. On the basis of the results of these pre-tests, four observed items had to be discarded due to their unacceptable values of item-total statistics.

After performing the reliability tests, CFA was performed to identify whether the proposed measurement perspectives and their relevant CIs were significant for measuring the performance of PPPs. By examining the 'factor loadings' of the observed items, it was identified that all measurement perspectives are significantly correlated to PPP performance, while 56 CIs are considered to be significant indicators. In addition, the fit of the 'optimal model' that is comprised of the five perspectives and 56 tested CIs was examined by using a series of GFIs, such as the *Chi-squared* statistic, CFI and RMSEA, all of which indicated that the model is a good fit and reliable.

In summary, this section has presented a quantitative study of the main components of the proposed PPP life-cycle PMS. Based on the findings derived from the survey data, the null hypotheses launched in the methodological chapter can be declined and the major assumed points of view that were raised from the exploratory study have been confirmed. Further, the outcome of this survey-based study serves as the fundamental basis for the subsequent econometric investigation.

6.5 Macroeconomic Analysis with KPIs

The derived CIs have been quantitatively validated and selected through the use of CFA, as described in the previous section. It has been identified from the empirical evidence that the 'comprehensiveness of macro-environmental assessment' (e.g., political, economic, social and legal) ($CI_{F3\text{-}1}$) is a significant process CI in the life-cycle performance evaluation of PPPs. In most developed countries with open economies, such as Australia, the UK and the USA, the political, social and legal environments are stable and reliable for construction investments (i.e., PPPs). This is in contrast to the economic atmosphere, which is dynamic and can be influenced by not only domestic but also global disturbances (Liu and London, 2013). Therefore, this section derives and empirically tests a sequence of macroeconomic KPIs that can be used to evaluate the suitability of the macroeconomic conditions in which a PPP will be implemented.

6.5.1 Macroeconomic Assessment in PPP Evaluation

The macroeconomic environment is critical to the success of infrastructure projects, especially for a PPP that is under an operational model whereby the involved private entities are profit pursuers. Cheung *et al.* (2012) argue that a stable and favourable macroeconomic condition is the 'cornerstone' for minimising risks and maximising the return of investment for a PPP project. This is because an 'unfavourable' macroeconomic environment can depress the private sector's ability to finance, or become involved in the delivery of, a public infrastructure asset, and this will further negatively affect the competitiveness of the bidding process, which has been identified as one of the critical success factors (CSFs) of PPPs (Jefferies *et al.*, 2002; Li *et al.*, 2005). According to the European Investment Bank (2011a), an assessment of the macroeconomic environment is an essential part of an *ex-ante* evaluation in PPPs, which is an important step in the procurement process of any project. For that matter, as indicated by Figure 4.3 in Chapter 4, *ex-ant*e evaluation serves as one of the pivotal components in the conceptual life-cycle PMS developed for PPPs by this research.

A critical review of the normative literature suggests that most PPP studies that are concerned with *ex-ante* evaluation focus on the Value for Money (V*f*M) assessment that relies on the *Public Sector Comparator* (PSC) (e.g., Quiggin, 2004; Grimsey and Lewis, 2005; Blanc-Brude *et al.*, 2006; Coulson, 2008). As introduced previously, the PSC has been applied widely, across the world, to determine whether a proposed PPP can provide better V*f*M than other conventional procurement methods. Essentially, it is a comparison between the costs of proposed PPP projects and the benchmark cost, which is a financial estimation of the cost of the specific service using public procurement. Indeed, past studies of PPP *ex-ante* evaluation have concentrated largely on a project's cost performance. However, according to the European Commission (2001), *ex-ante* evaluation must be comprehensive, and assessment of the economic environment is of primary importance. Despite this, limited attention has been paid by researchers to develop or refine the core issues of this critical area (Barretta and Ruggiero, 2008).

In addressing the aforementioned knowledge 'gap' to enhance the practicability of the developed PPP life-cycle PMS, a set of macroeconomic KPIs that were conceptually derived from the literature will be validated using a VEC model. These KPIs can be viewed as the sub-KPIs of the tested process CI that relates to 'macro-environmental assessment' and they are useful for examining whether the future macroeconomic environment will be suitable for procuring infrastructure assets through an application of PPPs. Such developed KPIs can assist governments and other key stakeholders to undertake an effective *ex-ante* evaluation of their upcoming infrastructure projects.

6.5.2 KPIs for Macroeconomic Environment Assessment in PPPs

Public-Private Partnership is a form of investment by the private sector in public asset delivery (European Investment Bank, 2004; Public-Private Infrastructure Advisory Facility, 2014). Akintoye and Skitmore (1994) propose that investment is a derived demand, and the investment of private-sector parties in construction is determined by construction price, domestic economic performance (i.e., Gross National Product – GNP/Gross Domestic Product – GDP), interest rate, purchasing power of the population (i.e., unemployment level), and profitability (i.e., manufacturing price), all of which are able to be indicated as the function shown by Equation 6.1:

$$Q^d = f(P, Y, r, U^e, M^p) \qquad \text{(Eq. 6.1)}$$

where Q^d is the construction investment (*demand*); P is construction prices; Y represents the GNP; r stands for interest rate; U^e is the unemployment rate; and M^P represents manufacturing price. In other words, the endogenous factors of Eq. 6.1 are the macroeconomic KPIs that can be used to estimate whether the macroeconomic environment is appropriate for a potential construction investment. In neoclassical economics, these factors are normally referred to as the 'causal factors' (Fan *et al.*, 2010), and their significant impacts on construction investment have been demonstrated by past research such as Hillebrandt (1985), Akintoye and Skitmore (1994) and Tse and Ganesan (1997). Since PPPs are construction projects in nature, the indicators displayed in Eq. 6.1 are also considered to be suitable for PPP projects.

It is accepted that PPP projects are more complex and sophisticated than traditional lump-sum construction projects, particularly in their financial structure (Merna and Lamb, 2009). "PPPs are highly leveraged in listed or private firms and rely on capital markets for both equity and debt capital" (Regan *et al.*, 2011a, p.7). Most PPP infrastructure projects are financed via bank loans, equity, bonds, and/or private placements (Yong, 2010). Therefore, any changes in money and capital markets can have a substantial impact on the investment decisions of PPPs. Indeed, the impacts of changes in the money market on PPPs can be evaluated by examining the interest rate, which has been indicated in Eq. 6.1. To capture the effect of the capital market on PPPs, a KPI relating to stock and bond market conditions should be involved in an *ex-ante* macroeconomic assessment. Furthermore, Regan *et al.* (2011a) suggest that the collapse of the global economy had a substantial effect on the development of new and existing PPP infrastructure projects. Thus, the turbulence of the global economic climate is worthy of being included as an exogenous factor in the macroeconomic assessment of a PPP *ex-ante* evaluation.

Infrastructure normally refers to a technical structure that supports and underpins the growth of a society (e.g., roads, bridges, water and power supplies, schools, hospitals and prisons) (Infrastructure Australia, 2012). As suggested by neoclassical economic theory, expansion of a society is positively related to population growth (Kormendi and Meguire, 1986). Hence, the growth of population should be considered in the investment decision-making process of infrastructure development. A report issued by the Victorian Auditor-General (2013) supports this point of view and states that the growth of population is an important indicator of the demand for infrastructure. In the construction literature, several studies (e.g., Tang *et al.*, 1990; Goh, 1996; 1999; Fan *et al.*, 2010; Jiang and Liu, 2011) have attempted to incorporate 'population' as a macroeconomic indicator into the modelling of residential construction demand, and they have discovered a significant relationship between population and residential construction investment.

On the basis of the discussion and demonstration above, the KPIs derived for the PPP macroeconomic assessment can be summarised as follows: 'construction price level (P^c) ($MKPI_1$)', 'domestic economic conditions (E^d) ($MKPI_2$)', 'money market conditions (R) ($MKPI_3$)', 'level of unemployment (U^e) ($MKPI_4$)', 'profitability (PRO) ($MKPI_5$)', 'capital market conditions (MC^c)' ($MKPI_6$), 'population growth (POP) ($MKPI_7$)' and 'global economic climate (E^g) ($MKPI_8$)'. To validate these proposed KPIs, a set of econometric techniques will be used in the following sections.

6.5.3 VEC Model

The econometric technique selected by this research to validate the macroeconomic KPIs, as introduced in Chapter 3, is the VEC model. The VEC model is capable of capturing and quantifying the causalities as well as the long-term relationships between the endogenous variables (Engle and Granger, 1987). This implies that it possesses a strong applicability to the estimation of construction investment owing to a consideration of, not only an equilibrium relationship, but also a 'short-term' causal linkage (Jiang and Liu, 2011). PPPs are the construction projects with long-term contractual arrangements between public and private sectors (Kwak *et al.*, 2009), and the KPIs identified for their evaluation must be causally and significantly related to both short-term outputs and long-term outcomes of the projects (Chan and Chan, 2004). Based on this view, the VEC model is suitable for the validation of the derived KPIs.

As identified above, 'global economic turbulence' needs to be considered to be an exogenous factor in the macroeconomic assessment of an *ex-ante* evaluation of a PPP. To capture the effect of this derived factor on the decision-making involved in PPP investments, a dummy variable was inserted into Eq. 3.5 as an exogenous variable, and then a VEC-D model was developed as Eq. 3.6 (Chapter 3). On the basis of the derived macroeconomic KPIs, the VEC-D model can be rewritten as follows:

$$\Delta Q^{PPP} = \alpha ecm_{t-1} + \sum_{i=1}^{p}\Gamma_{1,i}\Delta Q^{PPP}_{t-i} + \sum_{i=1}^{p}\Gamma_{2,i}\Delta P^{c}_{t-i} + \sum_{i=1}^{p}\Gamma_{3,i}\Delta E^{d}_{t-i} + \sum_{i=1}^{p}\Gamma_{4,i}\Delta r_{t-i}$$
$$+ \sum_{i=1}^{p}\Gamma_{5,i}\Delta U^{e}_{t-i} + \sum_{i=1}^{p}\Gamma_{6,i}\Delta PRO_{t-i} + \sum_{i=1}^{p}\Gamma_{7,i}\Delta MC^{c}_{t-i} + \sum_{i=1}^{p}\Gamma_{8,i}\Delta POP_{t-i} + \delta E^{d}_{t} + \varepsilon_{t} \quad \text{(Eq. 6.2)}$$

Here Q^{PPP} is the private-sector investment in infrastructure using PPPs; and δ is the coefficient of the exogenous variable (i.e., dummy variable). Notably, the VEC-D model is an acceptable technique for empirically estimating the impacts of global economic turbulence (Jiang and Liu, 2011; Liu and London, 2013; Liu *et al.*, 2015a) on both the supply and demand sides of the construction sector; however, it has been rarely used to particularly investigate the issues of infrastructure project evaluation. Moreover, the purpose of introducing a dummy variable into the VEC model is for quantifying the impact resulting from any disturbances in the global economic climate. This research will mainly focus on examining how the 2008 Global Financial Crisis (GFC) has affected construction investment within the context of PPPs, because the GFC is the most representative event that has recently caused such disturbance to the world.

6.5.4 Data Collection for Econometric Modelling

Data used for the estimation of the VEC-D model were derived from the following sources: the Australian Bureau of Statistics (ABS), Reserve Bank of Australia (RBA) and Australian Stock Exchange (ASX). The selected data series cover the period from the third quarter of 1997 (1997Q3) to the fourth quarter of 2014 (2014Q4). The reason for selecting this sample period is the lack of earlier data on construction prices and the absence of the most up-to-date data on population size at the national level in Australia. This observed period also covers the impact of the GFC, from 2008 onwards.

Investment, as defined above, is a derived demand. So the private-sector investment in infrastructure using PPPs can be measured by the value of the engineering construction work commenced by the private sector for the public sector within Australia. This type of data is identified from the ABS and is compiled from the infrastructure works (e.g., waste water treatment facility, availability-based roads, stadiums, etc.) procured by PPPs (ABS, 2014b). Additionally, the *Output Producer Price Indexes* (PPIs) of infrastructure construction works and the manufacturing sector are used to reflect the Australian construction price and profitability. Both of these types of data are compiled and published by the ABS, indicating changes in the prices of products as they leave the production process (ABS, 2014d). Manufacturing price is an appropriate proxy for the profitability of the private sector's construction investment, and this view was explained well by Hillebrandt (1985) and Akintoye and Skinmore (1994).

Domestic economic performance, interest rates, unemployment and population growth can be captured by using the data on the Australian GDP, real interest rates, unemployment rates and estimated resident population, respectively, all of which are issued by the RBA (2014a,b) and ABS (2014a,c). Finally, the *Stock Price Indexes* provided by the ASX (2014) were extracted to measure capital market conditions. Prior studies have found that there is a long-term convergence between stock and bond returns (e.g., Fama and Gibbons, 1982; Stivers and Sun, 2002). Thus, the *Stock Price Index* is an ideal indicator of capital market changes. All data used for the estimation of this econometric study were transformed to natural logarithms to reduce heteroscedasticity, which may negatively affect the results (Brooks, 2002)

6.5.5 Analysis and Discussion or the Empirical Evidence

Unit Root Tests and Co-integration Tests

The data entered into econometric models must be stationary; otherwise, a spurious regression may occur (Granger and Newbold, 1974). To test the stationariness of the selected data, the Unit Root Tests were run for each variable by using the Augmented Dickey-Fuller (ADF) test, which was developed by Dickey and Fuller (1979) in the 1970s. Table 6.3 reports the results of the ADF tests, which indicate that the selected data series are integrated in the order one, i.e., I (1). This means that the data used in this research are not stationary at level, but are stationary at first difference. To avoid spurious regression, the VEC model was formulated on the first-difference data.

Table 6.3 Results of the ADF Unit Root Tests

	ADF Unit Root Tests			
	Level		First difference	
KPIs	*T*-stat	*P*-values	*T*-stat	*P*-values
Q^{PPP}	-1.39	0.86	-4.81	0.00^{***}
P^{c}	-2.77	0.21	-2.14	0.03^{**}
GDP	-2.51	0.32	-2.11	0.03^{**}
R	-0.68	0.41	-5.09	0.00^{***}
U^{e}	-1.30	0.88	-4.81	0.00^{***}
PRO	-2.17	0.50	-5.24	0.00^{***}
CM^{c}	-2.55	0.30	-5.26	0.00^{***}
POP	-1.37	0.86	-4.39	0.00^{***}

Notes:

P-values denote the probability values, with

** representing the rejection of null hypothesis at the 0.95 significance level; and

*** denoting the rejection of null hypothesis at the 0.99 significance level.

Apart from the Unit Root Tests, testing for the co-integration relationship between the variables is necessary for constructing a VEC model. The co-integration test that is particularly suitable for the VEC model was proposed by Johansen and Juselius (1990), and it contains *five* representative models: (1) Model 1 represents all data series that have a zero mean; (2) Model 2 represents deterministic data that have an intercept but no trend in the co-integration equations (CE); (3) Model 3 suggests that data possess a linear trend and there is an intercept but no trend in the CE; (4) Model

4 suggests that a linear trend is in the data, and both intercept and trend are in the CE; and (5) Model 5 represents data that have a quadratic trend where there is an intercept but no trend in the CE.

Hui and Yue (2006) argue that Models 1 and 5 of Johansen and Juselius's (1990) co-integration test have limited application in the 'real world'; therefore, this research concentrates on Models 2, 3 and 4. There is a widely accepted assumption that long-run equilibrium demand probably has no trend (Wong *et al.*, 2007; Liu *et al.*, 2015a). Hence, Model 3 is used in the co-integration test conducted in this research. Based on a variety of statistics and criterion (e.g., sequential modified likelihood ratio test statistic – LR, final prediction error – FPE, Schwarz information criterion – SC, and Hannan-Quinn information criteria – HQ), a 4-lag length was selected for the co-integration tests, as well as for the VEC-D model. Table 6.4 reports the results of the co-integration tests and 'one' co-integration relationship can be identified by using the *Trace* and *Max-eigenvalue* tests, indicating that there is a long-run equilibrium relationship existing between the variables.

Table 6.4 Results of the co-integration tests

Variables	Lagged difference	Results (Trace test)	Results (Max-eigenvalue test)
Q^{PPP}, P^c, GDP, R, U^e, PRO, CM^c, POP	4	1	1

Dummy Variable Specification

A dummy has been inserted into Eq. 6.2 to capture the impact of global economic turbulence on a PPP project investment. It has been acknowledged that a challenge of creating a dummy variable is to identify the 'event window' length. According to Huang and Liu (2010), the announcements publicly released by the RBA are valuable for illuminating this problematic issue within the Australian context, as the central bank is sensitive to changes in the domestic and global economic climate.

The dummy variable discussed in this research is against the year 2008, when the GFC began. It can be noted that the US financial crisis sent shockwaves throughout the world in 2008. To hedge the rapid spread of the GFC, the Australian government launched an economic stimulus package in September 2008 (RBA 2008; Australian

Treasury 2009), indicating that the GFC began affecting Australia in 2008Q3. As a result, the cash rates in Australia dropped dramatically from 7.25% to 3.0% between September 2008 and September 2009 (RBA, 2014b). However, in October 2009, the Australian cash rates were increased by 25 basis points by the RBA due to the resuming growth of both the global and Australian domestic economies (RBA, 2009). This decision suggests that the impact of the GFC on Australia had faded by the fourth quarter of 2009. With these identifications, the values of 2008Q3, 2008Q4, 2009Q1, 2009Q2 and 2009Q3 were set as *1* and all others were set as *0* of others in the dummy time series.

Estimates of the VEC-D Model and Empirical Findings

The VEC model with a dummy variable can be constructed after conducting the tests above. Table 6.5 indicates the estimates of the VEC model. Under the developed model, the *Granger causality* test can be run for the endogenous variables (see Table 6.6 for the test results). By applying *Wald* tests and joint *F*-tests, the null hypothesis that the independent variables (i.e., the proposed KPIs) do not significantly influence the Granger causality and the dependant variable (infrastructure investment under PPPs) is rejected at the 0.90, 0.95 and 0.99 significance levels.

Table 6.6 shows that all proposed KPIs that are involved as endogenous variables of the developed VEC-D model can affect the Granger causality of PPP infrastructure investments. Theoretically and essentially, the Granger causality is not a 'real' causal relationship, but a 'predictive causality'. This means that the Granger causality test is designed to identify whether a time series (*x*) (independent variable) can be used to forecast another time series (*y*) (dependant variable). With this perspective, it can be concluded that the KPIs presented in Table 6.6 are significant for an evaluation of the macroeconomic environment in which a PPP project will be operating.

Apart from the KPIs in Table 6.6, it is noted that the *F*-statistic of the coefficient of the exogenous dummy variable relating to PPP infrastructure investment (Q^{PPP}) is not significant (Table 6.5). However, the dummy coefficients associated with domestic economic conditions (*GDP*), money market conditions (*R*), unemployment (U^e), profitability (*PRO*) and capital market conditions (CM^c) are significant at

0.90, 0.95 and 0.99 significance levels. This implies that turbulence within the global economic climate can have substantial impacts on the domestic economic system, money and capital markets, construction investment profitability and purchasing power of a population (unemployment level). All of these economic variables, in turn, significantly affect a private-sector entity's decision-making in relation to an infrastructure investment. In summary, GDP, interest rate, unemployment rate, manufacturing price and stock price are the transmission mechanisms of the global economic disturbance to PPP markets. This empirical finding conforms with the conceptual study undertaken by Regan *et al.* (2011a). Thus, the developed KPI of the global economy can also be considered to be critical to the *ex-ante* evaluation of PPPs. More importantly, while the dummy variable coefficients related to *GDP*, *R*, *PRO* and CM^c are negative, the dummy coefficient of U^e is positive. This leads to a rational identification that a global economic turbulence can significantly depress a domestic economic system and result in a growth in local unemployment. From this stance, an unstable global economic atmosphere can act as a 'warning' signal for governments that intend to procure infrastructure assets with PPPs.

Table 6.5 Estimates of the formulated VEC-D model

Variables	ΔQ_t^{PPP}	ΔP_t^c	ΔGDP	ΔR_t	ΔU_t^e	ΔPRO_t	ΔCM_t^c	ΔPOP_t
Q_{t-1}^{PPP}	1.00	……	……	....	……	……	……	……
P_{t-1}^c	- 7.11 (-3.54***)	……	……	……	……	……	……	……
GDP_{t-1}	71.55 (10.95***)	……	……	……	……	……	……	……
R_{t-1}	- 5.80 (-7.84***)	……	……	……	……	……	……	……
U_{t-1}^e	20.06 (10.15***)	……	……	……	……	……	……	……
PRO_{t-1}	- 14.77 (-6.07***)	……	……	……	……	……	……	……
CM_{t-1}^c	5.07 (8.41***)	……	……	……	……	……	……	……
POP_{t-1}	5.91 (4.97***)	……	……	……	……	……	……	……
C	330.20	……	……	……	……	……	……	……
CointEq1	- 0.94 (-3.45***)	……	……	……	……	……	……	……
Dummy	0.18 (0.50)	-0.04 (-0.45)	–1.01 (-1.41*)	-1.16 (-2.64***)	1.04 (1.98*)	-1.03 (-2.34**)	-2.23 (-3.04***)	-1.05 (-0.89)
Error correction	*t-1*	*t-2*		*t-3*		*t-4*		
ΔQ^{PPP}	0.64 (1.69)	0.14 (0.41)		0.03 (0.08)		0.11 (0.56)		
ΔP^c	- 40.28 (4.46***)	- 8.03 (0.76)		- 29.03 (-2.12***)		- 44.08 (-3.82***)		
ΔGDP	109.49 (5.71***)	75.75 (3.82***)		87.39 (4.41***)		32.39 (2.49**)		
ΔR	- 10.96 (-4.75***)	- 6.50 (-3.52***)		- 3.95 (-2.83***)		- 2.77 (-2.75***)		
ΔU^e	- 15.96 (-2.75***)	- 20.46 (3.97***)		- 8.32 (-1.87*)		1.67 (0.54)		
ΔPRO	0.23 (0.04)	8.14 (1.81*)		11.26 (2.27**)		5.46 (1.11)		
ΔCM^c	1.56 (0.86)	3.07 (1.92*)		1.32 (0.88)		- 0.15 (-0.11)		
ΔPOP	14.92 (1.15)	7.20 (0.77)		25.64 (2.57**)		25.75 (2.59**)		
R-squared	0.84	Sum sq. resids	0.05					
S.E. equation	0.07	Log likelihood	120.56					

Notes: *T*-statistic in ( ):

* denotes *t*-statistics significant at 0.90 significance level; ** denotes *t*-statistics significant at 0.95 significance level; and *** denotes *t*-statistics significant at 0.99 significance level.

Table 6.6 Results of the Granger causality tests

Dependant variable	Directions	*Chi*-squares	*P*-values	Results
Q^{PPP}	$P^c \rightarrow Q^{PPP}$	32.12	0.00***	*Y*
	$GDP \rightarrow Q^{PPP}$	35.32	0.00***	*Y*
	$R \rightarrow Q^{PPP}$	23.45	0.00***	*Y*
	$U^e \rightarrow Q^{PPP}$	17.88	0.00***	*Y*
	$PRO \rightarrow Q^{PPP}$	8.66	0.07*	*Y*
	$CM^c \rightarrow Q^{PPP}$	10.20	0.04**	*Y*
	$POP \rightarrow Q^{PPP}$	12.65	0.01***	*Y*

Notes:

* represents the rejection of null hypothesis at the 0.90 significance level;

** represents the rejection of null hypothesis at the 0.95 significance level;

*** represents the rejection of null hypothesis at the 0.99 significance level; and

Y stands for the existence of Granger causality.

To further investigate the contribution levels of the developed KPIs to PPP investment, a variance decomposition (VDC) was used in this research. As introduced in Chapter 3, a VDC is applied to interpret the amount of information about how each endogenous variable contributes to the forecasting of other variables in auto-regression. Through an estimation of relative variance contribution (RVC), the VDC helps in indicating the values of the contributions of the shocks on a variable to the forecast error variance of other variables.

The RVC generated from the VDCs of Q^{PPP} are presented in Table 6.7 and also are illustrated in Figure 6.3, both of which indicate that the proposed KPIs explain 8-20% of the variability within the PPP market. It can be identified from this finding that investment in PPPs is endogenous to the auto-regressive system comprised of the developed KPIs. Notably, the construction price, GDP, interest rate and unemployment rate account for a substantial amount of the forecast error variances of PPP investment within the 12-quarter periods of Table 6.7, i.e., maximum values of 20.24%, 18.39%, 13.88% and 10.63%, respectively. This empirical evidence suggests that the construction price level, domestic economic conditions, money market conditions and unemployment level are the most critical KPIs in PPP *ex-ante* evaluation, and they should be the highest priority of the PPP macroeconomic assessment conducted by the public sector.

Table 6.7 RVCs of the VDCs of Q^{PPP} (PPP infrastructure investment)

Periods	Q^{PPP}	P^c	GDP	R	U^e	PRO	CM^c	POP
1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	63.19	4.12	14.36	0.06	1.73	13.14	1.70	1.71
3	43.18	13.99	13.19	4.67	8.15	9.50	5.60	1.71
4	36.67	12.50	13.02	8.10	9.09	8.13	7.54	4.94
5	32.24	17.53	12.40	7.06	8.42	7.21	10.04	5.09
6	26.03	14.84	18.39	11.55	8.70	7.30	8.82	4.36
7	23.31	16.53	17.29	13.88	9.83	7.60	7.80	3.76
8	21.50	17.48	16.26	13.82	10.24	7.01	8.80	4.88
9	21.09	17.24	15.84	13.48	10.63	6.83	9.29	5.60
10	20.64	17.54	16.16	13.17	10.49	7.34	9.11	6.53
11	20.18	18.22	15.94	13.20	10.22	7.56	8.86	7.82
12	20.01	20.24	15.57	12.81	10.14	7.74	8.69	7.80

Figure 6.3 Variance decomposition results of Q^{PPP}

Although the Granger causality test and VDCs are able to specify the causal linkages and contribution levels in the framework of a VEC model, they failed in indicating the dynamic relationships between the observed endogenous variables. Nevertheless, the macroeconomic environment is dynamic, meaning that an analysis of the dynamic interactions between the variables in economic studies is required (Liu and Liu, 2012; Sing *et al.*, 2015). Liu and London (2013) further maintain that it is necessary for the investors and/or key stakeholders of a construction investment (i.e., a PPP project) to understand how economic indicators can dynamically affect the project outcomes within a specific period of time (i.e., positively or negatively), as this can benefit the decision-makers by providing them with useful information to justify what actions will be taken to respond well to future changes in the macroeconomic environment. Bearing this perspective in mind, the *Generalized Impulse Response Function* (GIRF) was also used to identify the dynamic linkages between a PPP infrastructure investment and the derived macro-KPIs, and the following diagram (Figure 6.4) illustrates the results generated from the GIRF.

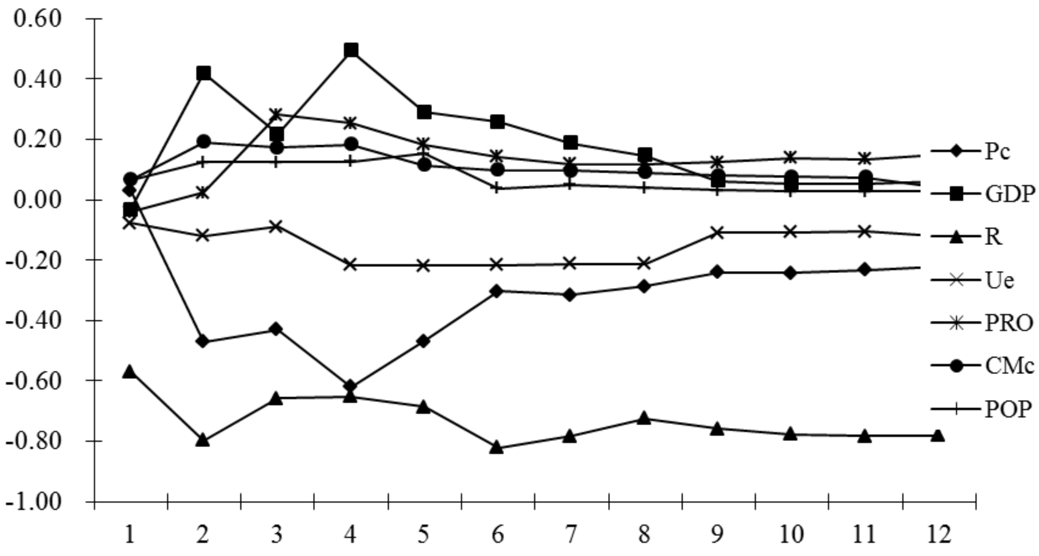


Figure 6.4 Responses of the PPP Investment to the shocks of the derived KPIs

Figure 6.4 indicates that a standard deviation of GDP, profitability, capital market and population growth can bring about a positive effect on infrastructure investment, ranging from about 10% to 16% on average, within 12 observed periods (i.e., 8 quarters). This means that there are positively significant relationships between these four KPIs and the PPP investment during a specific period of time. For instance, it may be suitable for the key stakeholders (i.e., governments) to procure an infrastructure asset by using PPPs if the results of their *ex-ante* macroeconomic assessment indicate that there will be a promising ‘future’ for the domestic GDP or capital market, or a significant growth of local population. By contrast, the responses of a PPP investment to the standard deviation shocks of the other three endogenous variables (i.e., construction prices, interest rates and unemployment) are negative (i.e., 30% on average). This finding provides for a clear implication that the ‘reverse’ linkages exist between a PPP investment and such aforementioned variables. Mindful of this, in the cases of an increase in construction costs (i.e., rises in construction material prices and/or interest rates) or a decrease in purchasing power at the national level (i.e., an increase in the unemployment rate), the private-sector entities' demand for investing in the delivery of public infrastructure assets may be substantially depressed. Under an 'unfavourable' macroeconomic environment, governments need to carefully consider and assess whether PPPs will be a suitable approach for procuring their infrastructure assets, since a substantial decrease in investment demand for the private sector to participate in the provision of public services may significantly reduce the competitiveness of the bidding for proposed projects, which will in turn have an impact on the selection of an appropriate concessionaire and increase the risk of unsuccessful project delivery (KPMG, 2010).

6.5.6 Summary of the Econometric Study

A sequence of KPIs for the *ex-ante* assessment of the macroeconomic environment was conceptually derived within the context of PPP infrastructure projects. The proposed KPIs have been empirically validated by a VEC-D model. According to the results of the Granger causality tests, the KPIs developed as the endogenous variables of the VEC-D model can affect the Granger-causality of PPP infrastructure investment. This means that such KPIs are critical to a macroeconomic assessment in an *ex-ante* evaluation of a PPP. Also, the estimates of the VEC-D model further suggest that the coefficient of the dummy variable of PPP investment is insignificant, but it is significant to the other five endogenous variables (i.e., GDP, interest rate, unemployment rate, manufacturing price – profitability, and stock price) at 0.90, 0.95 and 0.99 significance levels. This finding indicates that there is an indirect relationship between the PPP market and the global economic climate, and the fluctuations of the global economic system can influence PPP investment through these noted variables. Hence, it is confirmed that the condition of the global economy is a KPI that is important for *ex-ante* evaluation of PPPs.

By using the variance decomposition, this research also identified that the developed KPIs can significantly explain 8-20% of the variability within the PPP market. Further, the construction price level, domestic economic conditions, money market conditions and unemployment level are the most critical KPIs in the *ex-ante* evaluations of PPP infrastructure projects. Finally, the IRF was applied to analyse the dynamic interactions between the observed variables. An analysis of the IRF results provides the key stakeholders with useful information to make decisions about what actions should be taken to respond well to the dynamic changes in the macroeconomic environment in which the proposed infrastructure projects will be implemented.

It can be perceived from the previous empirical evidence that both the domestic and global economic climates, the total purchasing power of a population (unemployment level), and the conditions of construction, money and capital markets play vital roles in PPP *ex-ante* macroeconomic evaluations. This finding is consistent with the knowledge that the success of a PPP project heavily depends on the performance of the national and industrial economic climates as well as a sound financial structure (Yuan *et al.*, 2009; Regan *et al.*, 2011a; Cheung *et al.*, 2012). Accordingly, the KPIs derived in this section are practical and they are able to provide the public sector with assistance in conducting a comprehensive and effective *ex-ante* evaluation for the whole macroeconomic environment in which a PPP project will be implemented.

The macroeconomic environment is dynamic and can bring substantial impacts to bear on infrastructure projects within a long-term context; therefore, governments should consider whether a PPP is a suitable method for procuring an infrastructure asset when the macro-environment is not favourable. However, macroeconomic assessment does not form the entirety of a PPP *ex-ante* evaluation, but only a significant part of it. Deciding what type of procurement should be applied is a complex process; therefore, it is difficult and not rational to make a judgement on the use of PPPs or not depending only on a macroeconomic assessment. Decision-makers in the public sectors that will embark on infrastructure development need to examine all vital issues under an effective framework to identify which procurement style, and then what kind of contract, is the most appropriate choice for the project. After developing the macroeconomic KPIs, the CIs dataset was renewed again and is presented in Appendix I.

6.6 Chapter Summary

This chapter presented two quantitative studies for a sequence of observed items. These included five performance measurement perspectives, process-based CIs and macroeconomic KPIs, all of which were synergised under a life-cycle PMS that were conceptualised from the exploratory study and examined by the case studies. Two types of dataset were used for these studies; the survey-based data and secondary published data at a macro level.

On the basis of the nature of the data collected, a set of statistical techniques (e.g., Cronbach's alpha, item-total statistics, CFA and GFIs) were used to analyse the data derived from the survey. The empirical evidence indicated the reliability of the research instrument (questionnaire) and confirmed the significances of the proposed five performance measurement perspectives as well as their 60 CIs. Moreover, the values of GFIs show that the model constructed for CFA possesses a good model fit and, therefore, the findings are reliable.

Econometric modelling was undertaken after conducting the survey-based analysis. Under the constructed VEC-D model, the Granger causality tests, VDCs and GIRF were applied to validate a series of conceptually-derived macroeconomic KPIs, which are considered to be the sub-indicators of the tested process CI relating to a macro-environmental assessment. The results yielded from such aforementioned tests indicated that all derived macro-KPIs are significant and, therefore, they are worth inclusion in an *ex-ante* evaluation of PPPs, which acts as an essential part of the developed life-cycle PMS.

The findings of the quantitative studies presented in this chapter empirically confirm that the main assumptions raised in the exploratory study are valuable and significant. As a result, the CIs dataset (Appendix D) could be renewed and a new dataset with the validated CIs and macro-KPIs was created (Appendix I). Based on the outputs of the quantitative studies, it is reliable to conclude that the life-cycle PMS is a promising, reliable and feasible system for measuring the performance of PPPs. A further discussion about the developed life-cycle model of performance measurement of PPPs will be presented in the next chapter.

CHAPTER 7 A LIFE-CYCLE MODEL FOR PPP PERFORMANCE MEASUREMENT

7.1 Chapter Introduction

The main components of the theoretical life-cycle performance measurement system (PMS) for PPPs have been empirically tested and refined in previous chapters. In this chapter, a refined PMS for PPPs will be introduced, with the aim of describing how the derived research findings have contributed to the final 'version' of the life-cycle model of PPP performance measurement. Moreover, a discussion about how the fully-developed PMS can benefit future PPPs is provided. Additionally, this chapter also demonstrates how Building Information Modelling (BIM) is able to 'future-proof' PPPs through the lens of life-cycle performance measurement. Some information identified from the interviews of the two case studies will be used to strengthen the argument.

7.2 PPP Life-Cycle Performance Measurement Model

The major components of the conceptual model proposed from the qualitative exploratory study have been quantitatively validated through the use of Confirmatory Factor Analysis (CFA) and econometric modelling, and then the feasibility and practicability of the whole model was empirically tested and refined by undertaking two PPP case studies. The components include: (1) five performance measurement perspectives; (2) a sequence of phase-based core indicators (CIs); and (3) *eight* macroeconomic key performance indicators (KPIs). As demonstrated in the preceding chapters, the CIs were derived in accordance with the five performance measurement perspectives, and the macro-KPIs act as the sub-indicators of one of the tested CIs (i.e., CI_{F3-1}: Comprehensiveness of macro-environmental analysis).

On the basis of the empirical findings and the relationships between the components that have been tested, a life-cycle model of performance measurement (PM) can be finalised within the context of PPPs. This finally-confirmed PMS assembles the CIs and the macroeconomic KPIs under each PPP phase (i.e., initiation, planning, procurement, design and construction, operations, and maintenance and handover), and they are technologically and technically supported by an operational review mechanism and BIM, as well as being theoretically underpinned by the *Performance*

Prism originally proposed by Neely *et al.* (2001; 2022) (Figure 7.1).

The final version of the life-cycle model, as indicated by the case studies, addressed a completely new 'Iron Triangle' (i.e., process-based CIs, a life-cycle V*f*M assessment, and effective and efficient whole-life learning mechanism). Hence, this PMS can substantially improve the performance of PPPs by covering all issues critical to the success of the projects. Figure 7.2 explicitly illustrates how the developed PMS will be able to benefit PPPs if the management teams of the projects (i.e., governments and private entities) can shift their evaluation approaches from conventional *ex-ante* and *ex-post* evaluations to a life-cycle stakeholder-oriented performance measurement system.

As can be noted in Figure 7.2 below, a new concept of V*f*M assessment will positively contribute to enhancing the values generated from the assets in a PPP. The V*f*M assessments in most procured Australian PPPs were normally determined by the *Public Sector Comparator* (PSC). There is a widespread consensus that V*f*M assessments conducted for PPPs should embrace whole-of-life issues; however, the PSC is not an 'authentic' life-cycle analysis because qualitative issues and the impacts of the assets on the public are largely neglected. Thus, the wider life-cycle V*f*M assessment that was addressed by the developed PMS can bridge this 'gap' and significantly ameliorate the veracity of the business cases for future PPPs. This will also provide governments with a broader concept regarding V*f*M and guide them to pursue a more complete attainment of project success (e.g., both product success and project management success) within the long-term context (Baccarini, 1999).

The process/phase-based CIs are able to effectively capture and reflect the situations of the public assets' initiation, planning, design, construction, operations and maintenance. In other words, such CIs will benefit governments by ameliorating their efficiency in decision-making in regard to the options for infrastructure procurement while, at the same time, assisting private entity partners to effectively and efficiently monitor their deliverables and completely meet the key stakeholders' expectations over the projects' life-cycles. As a consequence, the quality (e.g., physical quality and service quality) and sustainability of the procured facility will be substantially enhanced, leading to an increase in the end-users' satisfaction and a decrease in risks that can result in the underachievement of V*f*M and project long-term success. Moreover, the systematic performance measurement mechanisms for 'organisational learning' and continuous review of the CIs associated with the assets' operations can facilitate the PPP projects in accommodating intensive changes in both internal and external environments, thus enhancing the whole-of-life suitability of the CIs and the sustainability of the procured facility. From this stance, increased end-user satisfaction may occur, which, in turn, will be significant to the realisation of V*f*M and the project's long-term success.

In summary, the main components of the developed PMS can ensure the continuous value of the asset throughout its life-cycle during the delivery of a PPP project into the future. Apart from such aforementioned 'soft' issues, the PMS also possesses a 'hard' and technologically-based component; BIM. Although the importance and advantages of BIM and its promising future have been recognised by the two case studies of this research, a detailed demonstration about how BIM will substantially bring positive effects to the delivery of future PPPs has not been provided. In essence, the issue with regard to the relationship between BIM and the life-cycle performance measurement of PPPs has received very limited attention in the literature. Against this contextual backdrop, a critical discussion is provided in the subsequent sections, with the aim of examining the role of BIM in 'future proofing' the public assets procured by PPPs from the perspective of life-cycle performance measurement that emphasises the use of process-based measures (i.e., core indicators).

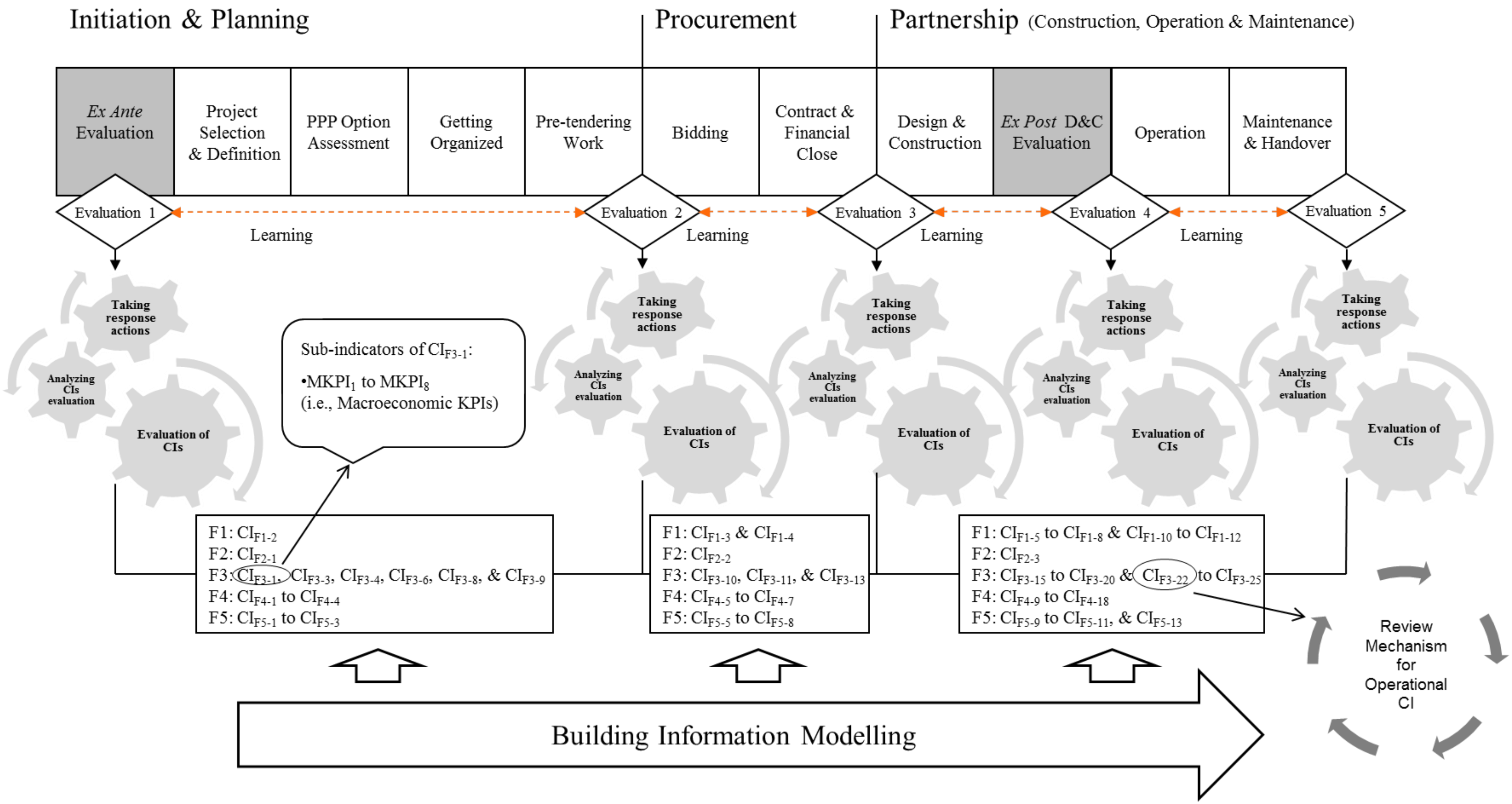
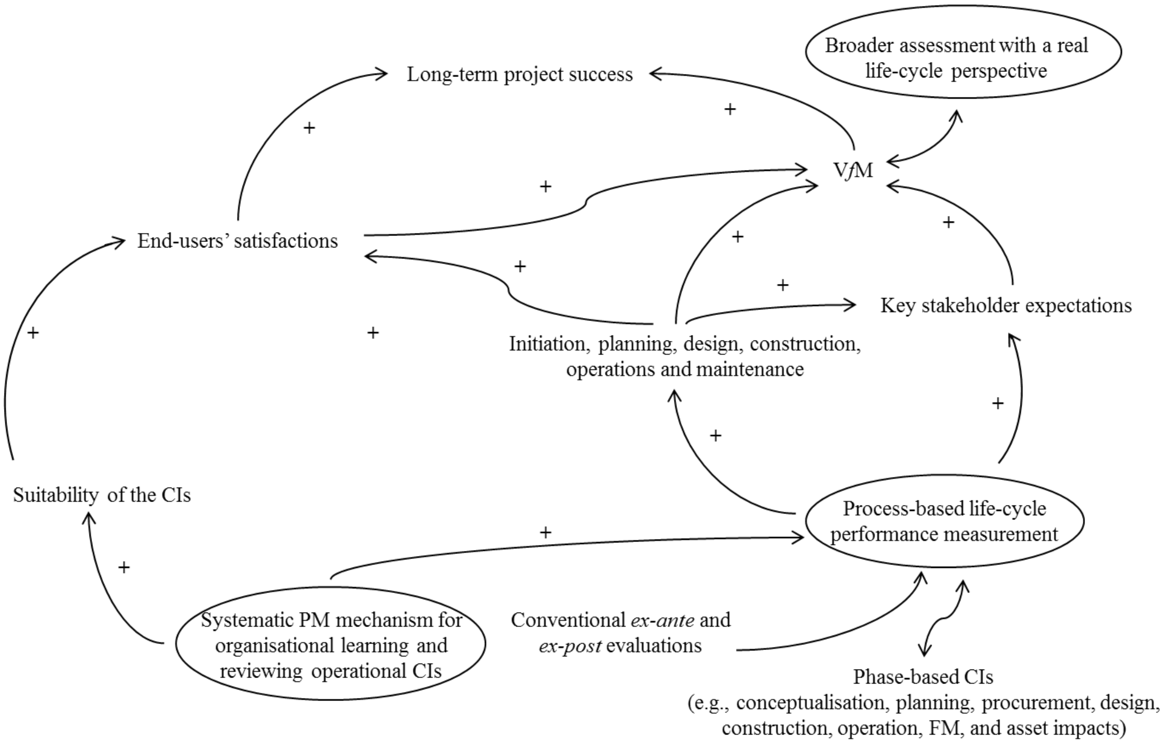


Figure 7.1 Life-cycle model of performance measurement of PPPs



Note: "+" represents the positive effects

Figure 7.2 Roadmaps of the developed life-cycle model in benefiting PPPs

7.3 Information Efficiency and Performance Measurement

Consistent performance measurement throughout the project's life-cycle in a PPP can ensure the effectiveness and efficiency of the project's delivery and satisfy key stakeholders' needs (Yuan *et al.*, 2009). Nevertheless, as suggested by the findings that were derived from the exploratory study and the case studies of this research, ensuring 'information efficiency' is a major difficulty in successfully implementing a life-cycle performance measurement system within a 'real-world' PPP project.

Performance measurement can be defined as the process of determining how well the organisations and/or individuals achieve their strategies and objectives (Kagioglou *et al.*, 2001). Kennerley and Neely (2003) also argue that performance measurement is useful for assessing the success of the organisation. Considering these definitions, Gunasekaran and Kobu (2007) identified that performance measurement provides organisations with assistance in determining organisational successes and key stakeholders' satisfactions It also allows them to examine the efficiency and effectiveness of their internal business processes and to identify whether the predetermined and expected outputs and outcomes have been achieved, in order to ensure the appropriateness of each decision and realise performance improvements.

To fulfil the aforementioned tasks, having access to 'information' plays a decisive role in determining the success of a PMS (Neely *et al*., 1999; Latiffi *et al.*, 2009). Love and Holt (2000) also proffer that a successful PMS in construction must be consistently underpinned by useful information in relation to the asset's planning, design, construction, operations and maintenance, which incorporates a set of technological issues. PPPs are complex construction projects because their delivery is associated with public sectors and a variety of private organisations within a long contractual period (Zheng *et al*., 2008). Thus, effective and efficient coordination among the key project stakeholders (e.g., client, designer, builder, subcontractor, operator and facility management group) in a PPP is vital for the successful delivery of the project. In such a complex and diversified stakeholder environment, the information that is needed for measuring the performance of a PPP can be distorted; therefore, 'information efficiency' is more critical to an effective measurement system for PPPs than for projects procured by conventional approaches.

Information efficiency is normally referred to as the efficiency of the process relating to the storage, access, filtering and sharing of the essential information. In addressing 'information efficiency' within a PPP, BIM is considered to be an ideal and efficient platform to enable performance measurement throughout an asset's life-cycle (Sacks *et al*., 2010; Taylor and Bernstein, 2009; Love *et al*., 2013).

7.4 Future Proofing Public-Private Partnerships

To deal with the potential risk resulting from the provision of efficient information, the life-cycle PMS was developed and equipped with BIM, which is technologically-focused and deemed as being able not only to offer digital representation of physical and functional characteristics but also to provide the key stakeholders with the ability to make decisions based on an effective application of, and efficient access to, complete and integrated information during the delivery and evaluation of PPPs. Mindful of this, the use of BIM is necessary for PPPs so as to ensure that the procured assets are 'future-proofed'. Future proofing in construction is defined as the ability of an asset to continue to be of value into the future, and it has been a topic critical to both the public and private sectors in PPPs because the involved governments and private entities are obligated to ensure that taxpayers receive value for money (V*f*M) over a long period of time.

PPPs conceptually provide an ideal environment for implementing BIM because the private sectors are responsible for procuring the asset (e.g., design, construction, operation and maintenance). In the case of an SPV, for example, they would initially develop a business case for the use of BIM. In developing this business case, the benefits of enabling BIM for asset and facilities management (FM) will need to be demonstrated. The benefits of BIM for each of the stages of a PPP are identified in Table 7.1.

Table 7.1 CIs of a PPP and BIM to facilitate performance measurement

Project Phases	**Core Indicators (CIs) in the Dataset (Appendix I)**	**BIM Activities and Tools**	**BIM Benefits**
Initiation and Planning	*For example*: • Appropriateness of value for money assessment; • Macro-environmental assessment; • Risk identification, analysis and allocation; • Feasibility/business-case study; • Concessionaire selection criteria; • Legal, commercial, technical and engineering structures; and • Interface management	• Visual walkthroughs; • Space calculations; • Space inventory; • Accurate designation of an assets total space; and • 5D BIM which includes: i. Functional analysis and cost benchmarking ii. Creation of depreciation reports iii. Preliminary construction programme iv. Life cycle costing analysis	• Improved financial forecasting; • Improved ability to develop the project brief according to stakeholder needs; • Greater access to information enabling earlier input into feasibility, planning, design, cost and environmental assessment; • Early contractor involvement; • Development of COBie definition for asset management; • Stabilisation of the project brief; • Accurate assessment of costs; and • Operator has the ability to influence design and operation thus improving operation and maintenance
Procurement	• Public client's satisfaction; • Tendering/bidding procedure; • Final negotiation framework; • Interface management; • Design quality; and • Finance/cost performance	• Stakeholder sign offs; • Clash detection; • Compliance checking; • Real-time/cost progress monitoring (e.g., BIM 360™ Field/Glue); and • Scanning to ensure quality (Quality Assurance: Integrity review)	• Improved design and cost modelling; • Improved logistics, scheduling, and safety planning; • Increased opportunity to consider off-site manufacture; • Improved clarification of specification and costs; and • Improved progress and monitoring.
Partnership	• Public client's satisfaction; • Creditors' satisfaction; • End-users' satisfaction; • Design and design process • TCQ performances; • Resource and material management; • Contract management; • Environmental impact; • Dispute resolution; • Operations management; • Facility maintenance and management; • Interface management; and • Handover management.	• Real-time/cost progress monitoring (e.g., BIM 360™ Field/Glue); • Energy management; • Continuous commissioning; • Maintenance tracking; • Post-occupancy evaluation; and • Space utilisation.	• Reduced costs and delays; • Improved quality (i.e. reduced rework) • Optimised and sustainable assets with improved maintenance; • Improved operational data; • Whole-of-life performance; • Reduced remedial work; • Reduced disruption from maintenance. • Smoother handover to asset owner/FM; and • Faster commissioning and handover.

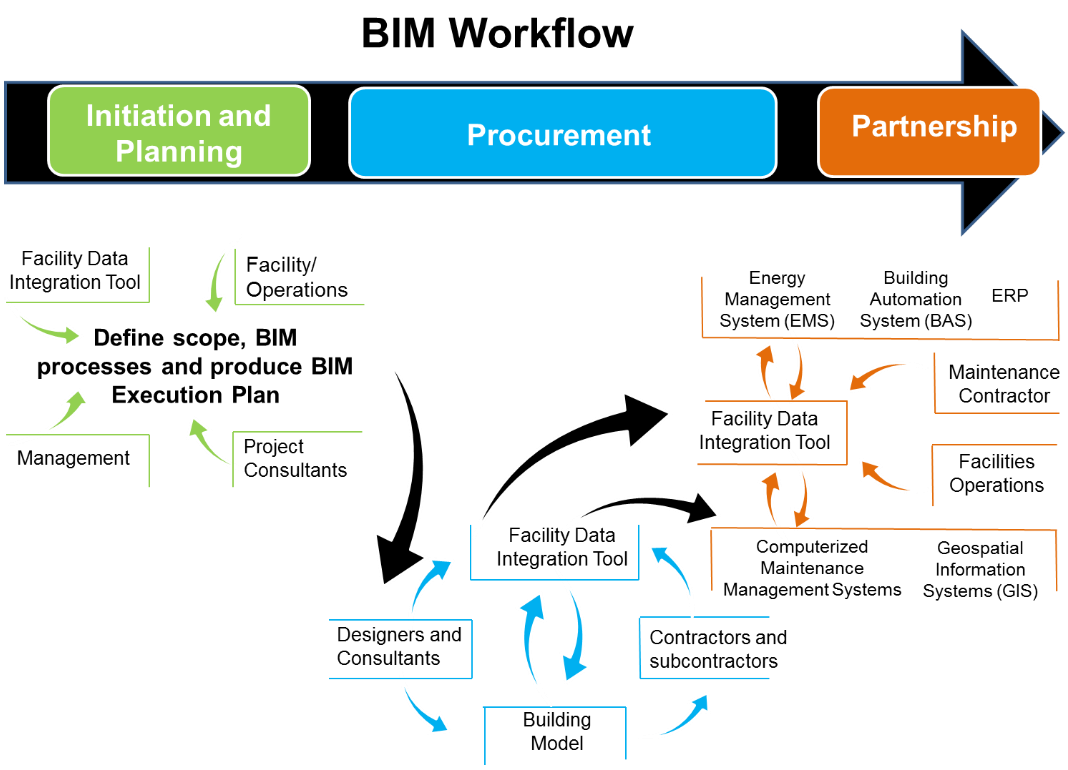
It is imperative that BIM workflows and processes are developed during the *Initiation and Planning* phase of an asset's life-cycle, as denoted in Figures 7.3 and 7.4; essentially, the development of a building information model for asset management should 'begin with the end in mind' (Love *et al.*, 2014a). This includes definition of the information needed to operate and maintain an asset as well as the agreed responsibilities for providing this information. In fact, to effectively future-proof the operation and maintenance of an asset and to ensure that the appropriate information is accommodated within the 'BIM Execution Plan', it is suggested that the following steps are required:

1. The SPV establishes the detailed requirements based upon the proposed Facility Management Programme. An independent Quality Assurance and Quality Control consultant is appointed to establish the data capture and review process of the design, engineering and construction team.
2. The design, engineering and construction consultants create a BIM or 'Construction Operations Building Information Exchange' (COBie) Execution Plan based upon the SPV's requirements.
3. Continuously collect and check the quality of the entered data and documents until the facility is handed over to the operator using appropriate software.
4. Final acceptance of the data handover as a COBie spreadsheet but preferably as a dataset that can be imported into a Computer Maintenance Management Systems (CMMS) and the system of Computer Aided Facility Management (CAFM).
5. Continuous improvement of the Facility Management Programme can be used to provide feedback for future project requirements.

In addressing the benefits of a BIM workflow, a service request is made and assigned to a technician, as noted in Figure 7.1. Typically, it may take several minutes (e.g., 10 minutes) to undertake the task; however, if the technician is not on-site, and he or she needs to travel to the site and find the room to evaluate its temperature, it could take an hour. With a BIM driven workflow in place, it is suggested, in this instance, that a substantial time saving of at least 5 hours can be made during the operation and maintenance phases for this specific task.

No	Baseline Current Process	Time Spent	Resources /Impact	Proposed BIM Model driven process	Time Spent	Resources /Impact
1	Creates a SR and assign to a technician.	10 min	Facility Manager tries to call the technician, not reaching him at first. The Technician calls back and receives the SR.	Create a service request (SR) in TMA CMMS and assign to a technician.	3 min	The SR is in the system linked to location information.
2	Since the technician is not on site, the technician must travel to the site in order to go to Room 130 and evaluate the room temperature.	1 hr	We assume that the technician is available immediately to go to the site. Usually they are busy with other work so they cannot	The Technician receives a notification (text message) and logs into the CMMS system on his computer to see the SR, and opens the EcoDomus FM application via an external link from the CMMS, which	5 min	The Technician can review the SR while still finishing another job. Preparation can start
	Total time spent on the SR:	5 hrs & 40 min		Total time spent on the SR:	30 min	
				Savings through BIM driven workflow:	5 hours	
	Impact on Operations		Potential impact on operations is high as it takes much longer, introduces human errors and on site presence is undesirable.			Minimized impact since all activities are done virtually, quickly.

Figure 7.3 Work order workflow comparison



Adapted from: Love *et al.* (2014b)

Figure 7.4 Workflow of Building Information Modelling

The COBie format is increasingly used as a mechanism for defining and gathering this information for handover. Through an application of COBie and considering handover information at the onset, facility data can be integrated more efficiently and effectively during the operation and maintenance phases. The inclusion of the facility manager (or operator) at this early stage is pivotal for ensuring that the appropriate information is identified and incorporated into the design. This is in stark contrast to other forms of project delivery, because SPVs can place the emphasis on maximising V*f*M prior to the commencement of the design process. The use of COBie can assist with capturing and recording important project data at the point of origin, including equipment lists, product data sheets, warranties, spare part lists and preventive maintenance schedules. This information is essential to support operations, maintenance and asset management once the constructed facility is in service. The asset manager, however, must take responsibility for determining the information required in a COBie file and how this will integrate with their existing systems. Again, this should be done at the project outset and communicated to all parties via a 'BIM Execution Plan' in the form of 'Employers Information Requirements'.

It has been suggested that the use of BIM can act as a catalyst to ensure that an asset's performance can be monitored and evaluated throughout its life-cycle. A BIM not only offers digital representation of the physical and functional characteristics of an asset, but also provides stakeholders with the ability to make decisions based on complete and integrated information, to ensure that their needs are considered and met. Essentially, in the case studies of the two social infrastructure PPP projects, the respondents of the interviews, all of whom have experience in the use of BIM, admitted that BIM has a promising future in the justification and performance evaluations of PPPs during the delivery of projects.

7.4.1 BIM in the Initiation and Planning of PPPs

There is a proclivity for CIs (i.e., KPIs) in this early phase to be focused on finance, taxation and the legal issues associated with the establishment of the PPP. The tools and techniques associated with the development of a building information model can be utilised to analyse and determine these issues. Typically, at this stage of a PPP, a building information model at *LOD 100* may be created to undertake reviews and compare the asset with built elemental costs and functional performance measurements of similar projects, through use of the *5D* component. This process is used to identify inefficiencies and to highlight opportunities that will benefit the asset's overall performance and enable modifications to be considered as the project progresses through design and construction. In particular, '*5D Cost Planning*' can be applied to examine the income and concessionaire elements of the PPP project. The various income-producing components can be dissected so that monitoring of costs versus income can occur to ensure that forecasted returns are consistent for various time periods. Depreciation entitlements also can be assessed to determine any taxation benefits adopting the *5D* technique for income-producing assets.

Figure 7.5 provides a visualisation of a residential public housing block (left) and a hospital (right). In the first instance, potential residents can 'visualise' how their prospective apartment will fit within the landscape and existing facilities. Similarly, stakeholders, such as the general public, are able to examine how their new facility may potentially function, specifically in terms of access and car parking. As a result of such the core indicators for public client, satisfaction can be more readily ensured. Depending on the type of asset to be delivered, a space inventory can be determined offering area measurements and schedules to establish accurate revenue forecasts. Software, such as dRofus, can be utilised for planning and administration of areas, rooms and departments/functions and, therefore, can facilitate the SPV to examine leasing options as part of financial CI.

Figure 7.5 Stakeholder visualisation of context

While information may be scant, during the *Initiation and Planning* phase, in regard to a facility's design, spatial requirements and functionality, an asset's information requirements during operation and maintenance should always be at the fore of the SPV. Undertaking 'whole-of-life costing' is therefore pivotal for ensuring that the CIs for macro-environmental analysis and desired output are met. However, building information models have not been extensively used to provide measurable estimation tools (e.g., CostX®), and with the data requirements for Life-Cycle Costing (LCC), such as escalation of future expenditure and/or Present Value (PV) costs, discount rates and study periods (Kehily *et al.*, 2012).

According to Kehily *et al.* (2012), without the incorporation of LCC into a building information model, or an external application that is interoperable, whole life-cycle costs cannot be generated. In addressing this issue, Kehily *et al.* (2012) developed a whole life-cycle costing template that could be used by an SPV to determine an economical design solution. While the proposed template (at its time of development) had merits, its effectiveness was hindered by the lack of a standard convention to capture and compare LCC data. In the UK, however, the New Rules of Measurement: Order of Cost Estimating and Cost Planning of Building Maintenance Works (NRM3) provide consistent rules and guidelines for the measurement of building maintenance and renewal works (published by the RICS, 2014). These rules will have a significant impact on how future buildings are handed over and maintained. Consequently, when NRM3 is aligned with the agenda for BIM it will enable whole life-cycle costing to be more effective, particularly for addressing issues relating to the CIs surrounding taxation. Being able to effectively undertake whole life-cycle costing will provide decision-makers within an SPV with the critical information necessary to ensure that 'future proofing' can commence at the project's onset. Undertaking LCC during this phase, using *5D* BIM, provides the option of refining the design of the asset and considering related costs (e.g., fuel, operation, maintenance, repair, replacement, residual values and finance charges). As the design progresses to *LOD 300* (detailed design) the asset's projected costs can be calculated more accurately, especially as stakeholders have the ability to visualise the context of their asset.

7.4.2 BIM in the Procurement of PPPs

The '*Procurement Phase*' of a PPP addresses the design and construction process. Due to the collaborative nature of PPPs, participants of the SPV are able to work in unison to design, engineer, construct and deliver an asset. Nevertheless, it should be acknowledged that there have been a number of PPP projects where disputes have arisen in Australia, for example, the *Southern Cross Railway Station* in Victoria, the *Airport Link* and *Clem 7* toll roads in Brisbane, the *Desalination Plant* in Eastern Victoria, and the *Reliance Rail* project in New South Wales (NSW). Traditionally, the design and construction process have been the major focus for implementing BIM (Song *et al.*, 2012; Brydea *et al.*, 2013; Davis and Harty, 2013; Chen and Luo, 2014). The advantages of implementing BIM during the *Procurement* phase have been widely espoused and include the following (Eadie *et al.*, 2013):

- improved visualisation;
- improved productivity due to easy retrieval of information;
- increased coordination of construction documents; and
- embedding and linking of vital information, such as vendors for specific materials, location of details and quantities for estimation and tendering.

Despite the widespread benefits attributable to the use of BIM, whether it reduces project costs and improves the schedule remains a subject of debate (Love *et al.*, 2011). What needs to be asked, however, is: “What are the costs of not using BIM?” For example, when end-users view 2D drawings, they often feel disconnected from the design and the project. On completion of the facility, end-users will take up residence but may be disillusioned with the space as it does not function in accordance with its intended purpose. When visualization is used during the design process, better end-user buy-in can be achieved as they understand what will be constructed. A state-of-the-art green design, for example, with quality construction and a high performance may enable the business to improve its life-cycle and output performance for the next 30 years. With this high-performing building, employee retention and business profits may increase by 5%. In another hypothetical building, it could be assumed that a site engineer finds errors, omissions and conflicts in documents on the $100 million project. Change orders arise and are funded through the project's cost contingency (i.e., 3%). However, if the contractor, design team and subcontractors use BIM to solve conflicts before construction, the cost of developing and using BIM should be more than covered by the saving of costs for rework that is no longer necessary. Thus, potential net savings of significance could be achieved.

An example of conflict extracted from BIM is presented in Figure 7.6.

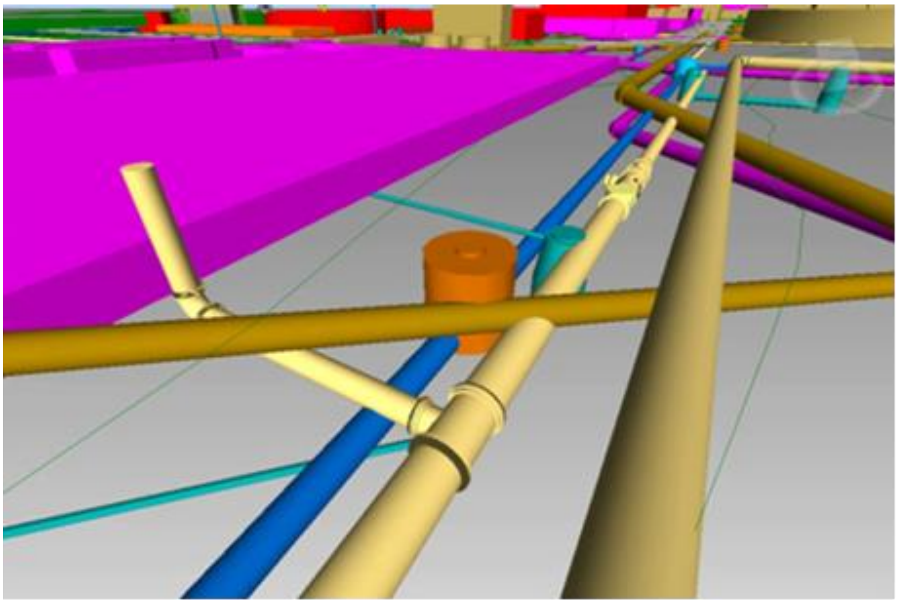


Figure 7.6 Clash detection

In terms of time performance, 'planned' versus as actually 'constructed' can be monitored in real-time. Linking the schedule to the building information model in software such as Autodesk Naviswork®, and using cloud-based technologies, such as BIM 360™ Field, allows progress on-site to be recorded in real-time, via a smart phone, PC tablet or iPad, and synchronised back to the model, which is instantly accessible to all key stakeholders in the project (Zhou *et al.*, 2015). Notably, a similar process can be used to monitor costs in real-time. Having access to a real-time schedule and cost information enhances both decision-making and the ability to meet pre-defined objectives, and provides shareholders with up-to-date information on the project's status, particularly if finance has been raised through the stock exchange.

The integrity of the building information model should be regularly checked to ensure design quality; what is being specified is going to be actually installed. In Figure 7.7, an integrity view for doors extracted from a building information model for a hospital project is presented. Here, it can be seen in the upper right corner that the fire rated door (denoted in red) has been installed into a low fire-rated partition. This was identified prior to construction and installation and thus saved the contractor, in this instance, a considerable amount of rework. Love *et al.* (2014c) observe that often 'As-Built' drawings prepared using conventional CAD systems do not reflect what has actually been installed and contain errors and omissions. Consequently, this can negatively impact an asset's integrity and contribute to safety hazards, particularly in the case of electrical and instrumentation systems.

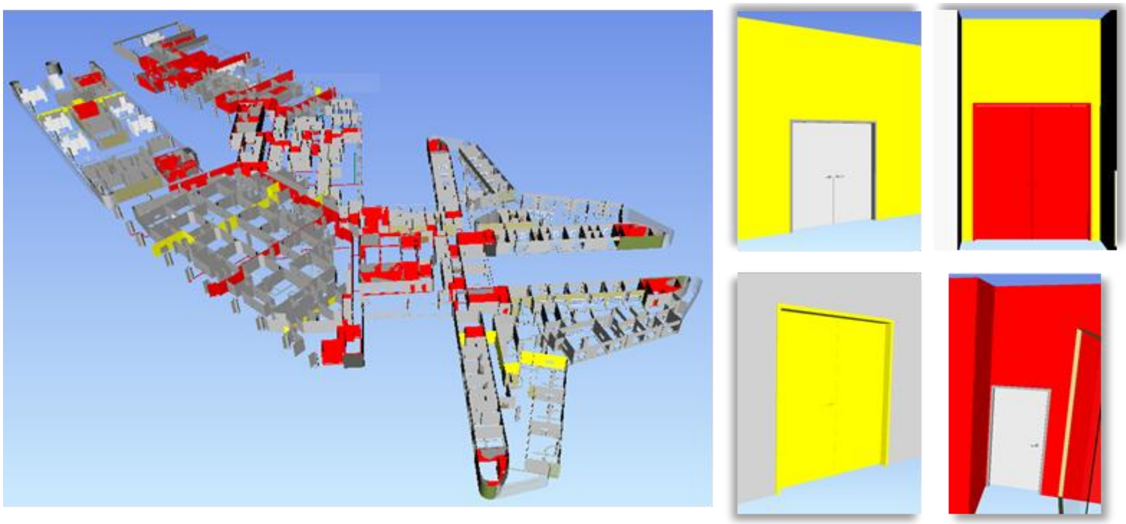


Figure 7.7 Model integrity reviews: Elements

On-site 3D scanners, using point cloud data, are able to be integrated with building information, for example, to ensure that construction is within defined tolerances and is accurately being undertaken (Figure 7.8). If structures are not regularly monitored during construction then there is a likelihood that quality, safety, cost and time can be compromised. Regularly undertaking 3D scans to verify the integrity of a structure can provide an asset owner with confidence that the project is progressing in accordance with pre-defined objectives.

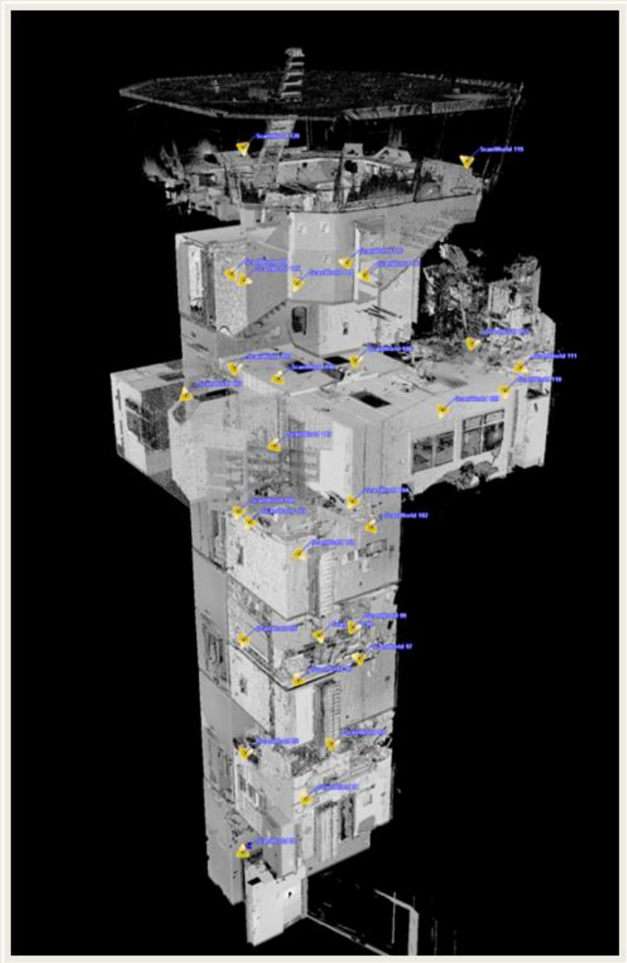


Figure 7.8 3D scanning (Point Cloud)

In addition to ensuring a building information model's integrity, building codes can be checked to guarantee that what has been specified and installed meets regulatory requirements (Malsane *et al.*, 2015). The process for compliance checking is presented in Figure 7.9, which is reliant on the use of a non-proprietary format for exchanging building data, which enables the SPV and design and construction teams to use any number of CAD-based packages. A major challenge is that each discipline has a different view of the real-world objects contained within a building information model and a different preference for a specific modelling platform. Thus, the task of creating an exchange format to suit the needs of all disciplines and independent of all software platforms has led to development of the Industry Foundation Class (IFC) – this is an open source interoperability standard. The use of the IFC has, amongst other things, enabled the creation of generic resources or libraries that can be shared across sectors to avoid duplication and to accelerate development. According to Malsane *et al.* (2015) the four core functionalities for rule-checking, which contribute for ensuring design quality, include:

1. Building model preparation – extracting and deriving model view data for checking;
2. Rule interpretation – translating human readable, written, rules; base into a computer implementable one;
3. Rule execution – applying rules to the building model; and
4. Report extraction - reporting results, ideally graphically (contravening objects highlighted in the model), and with reference to the source rules.

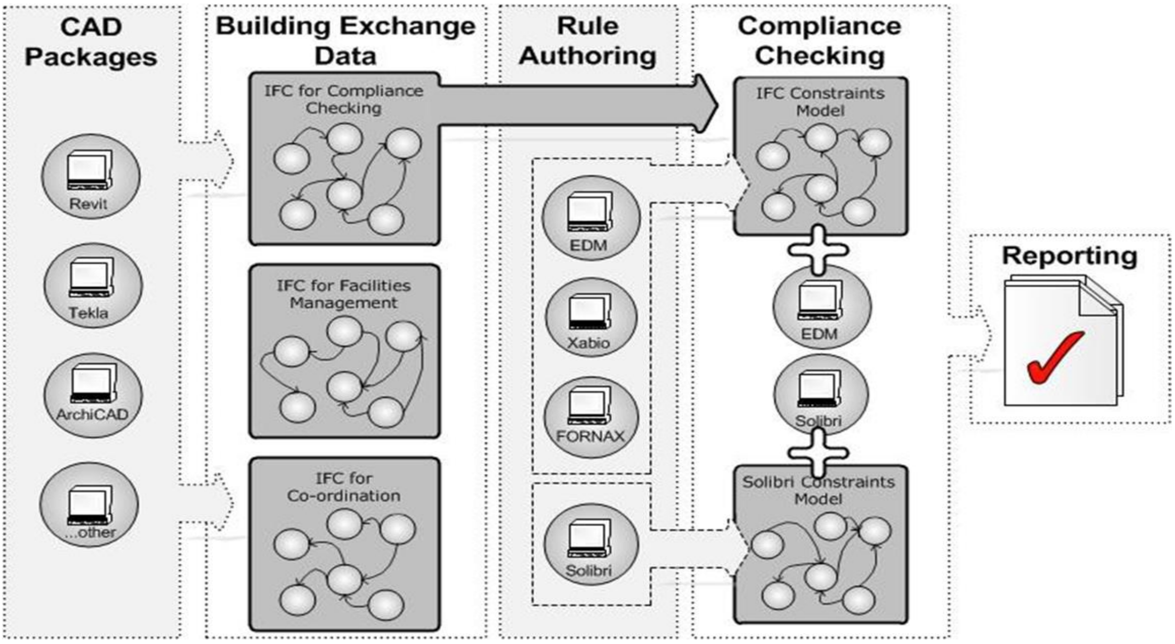


Figure 7.9 Process of automatic compliance checking

The strategy adopted in most compliance checking initiatives has been to convert proprietary BIM models, produced in software packages such as Autodesk®, Revit®, Tekla®, and Graphisoft ArchiCAD into an IFC format and then to develop bespoke compliance rules, which are executed via the model. Other standards, such as City Geography Mark-up Language and Green Building (XML), have been developed, but they do not have the required schema breadth that is offered by an IFC, which has been adopted by most of the major CAD vendors.

7.4.3 BIM in the Partnership of PPPs

The heart of a PPP project is the 'Partnership Phase', where the facility is constructed, managed and operated over a fixed time period, which can range from 20 to 30 years, depending on the conditions imposed in the contract for concessionaire. During construction, the building information model is changed and revised to produce the outputs needed to initiate this process. On validation, the 'As-Built' (*LOD 400* or *500*) building information model and the FM system are synchronised, so that essential information (e.g., cost data) can be transferred between the model and FM systems. This 'As-Built' cost information is then available for use throughout the life cycle of the project, enabling cost performance to be monitored after construction of the asset. Essentially, this is where the 'future proofing' undertaken during the previous two stages will begin to become manifest. So, if the SPV or alternative consortium is charged with operating and maintaining the asset, then it is clearly beneficial to consider whole life-cycle costs during the 'Initiation and Planning' phase.

Yet, since the emergence of BIM, there have been limited detailed practical examples of models developed to *LOD 500* and integrated with CMMS/CAFM (Love *et al.*, 2015). However, the foundations have been provided by the innovative and pioneering work that has been undertaken by institutions such as the University of Northumbria (Kassem *et al.*, 2015) and Pennsylvania State University (Computer Integrated Construction Research Programme – CICRP, 2012), and the proactive planning and preparation that has been undertaken by the UK government to prepare a BIM Soft Landings framework to ensure that value is achieved throughout the operational life-cycle of an asset. BIM Soft Landings essentially reflects the need for a smooth transition from design and construction to facility operations and management (i.e., specifically the integration with CMM/CAFAM), which goes beyond practical completion and the supply of As-Built drawings and manuals. The primary goal of BIM 'Soft Landings' is to optimise building performance and enable the integration with existing systems such as CMM/CAFM over a specified period of post-practical completion (refer to Figure 7.2). A detailed examination of the 'change management' required for an asset owner who is implementing BIM for facility management is described in Love *et al.* (2014b).

To enable this 'soft-landing' and assist with 'future proofing', elements can be barcoded and have Radio Frequency Identification (RFID) tags installed to facilitate the flow of information through the construction materials management process. This will enable dynamic material planning, ordering and monitoring and, in this instance, provide the platform to measure the performance of 'resources and materials' and 'operations management and maintenance'. For example, once the barcode or RFID tag is installed, then the activities that can be undertaken during the 'partnership phase' include (Wing, 2006):

- work management tracking of progress and response to reactive repair or complaint activities. Figure 7.10 illustrates how the building information model can display the element and a PC tablet can be used to extract information about service history and maintenance requirements from information contained within the barcode and RFID tags;
- invoice billing, tracking and approval sign-off; and
- asset management/maintenance tracking using plant and equipment identifiers, as noted in Figure 7.11.

Figure 7.10 Barcoding and RFID

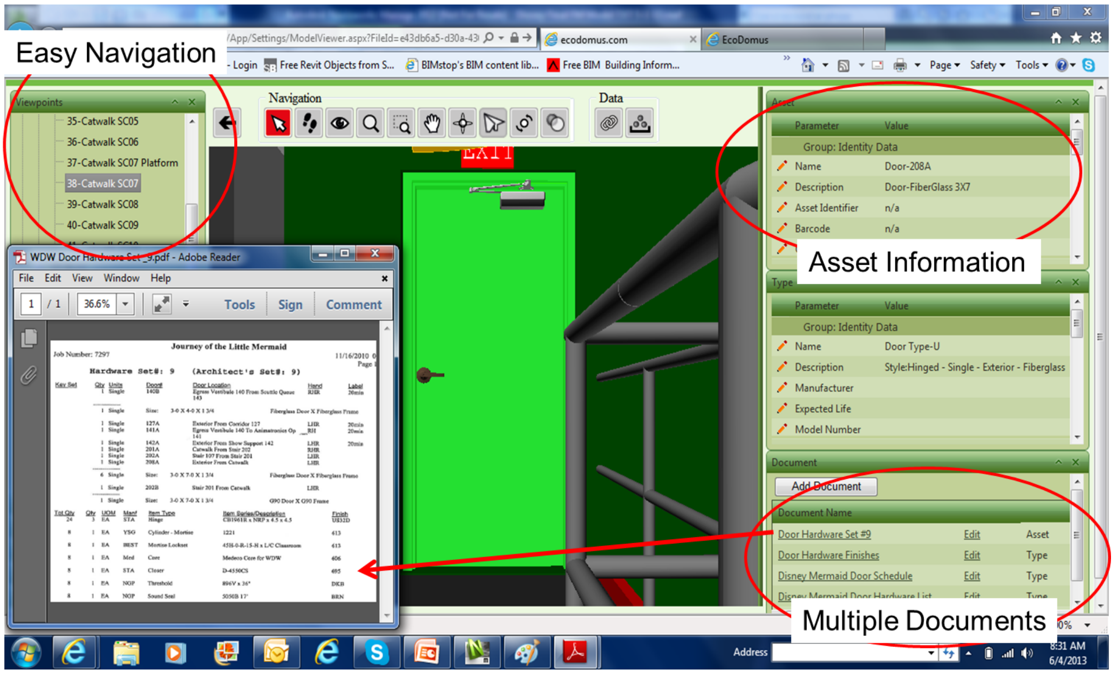


Figure 7.11 Asset management/maintenance tracking

The opportunities that are provided by a fully integrated building information model to manage the performance of a PPP during the ‘Partnership’ phase are bountiful. In particular, governments can have access to ‘real-time’ data about an asset's physical performance and ensure that maintenance is being undertaken. Nonetheless, public authorities/governments would need to stipulate this monitoring in their contracts with the consortia charged to deliver the project. Having knowledge of maintenance and operating costs first hand could alleviate some of the issues that have confronted the Private Finance Initiative (PFI) projects being undertaken in the UK. With the aforementioned in mind, developing a building information model that can be used for energy management and continuous commissioning would provide an asset owner with a considerable amount of data and information (Figure 7.12). The building information model that is constructed can be used to create a calibrated energy model (e.g., using software such as EnergyPlus and integrated into an EcoDomus database) that can provide a way of comparing an ideal, simulated building performance versus actual performance to identify areas of concern. In addition, building zones and rooms can be sorted based on their proximity to the simulated results. The graph in Figure 7.12 identifies the simulated values (orange) and actual data from sensors (blue).

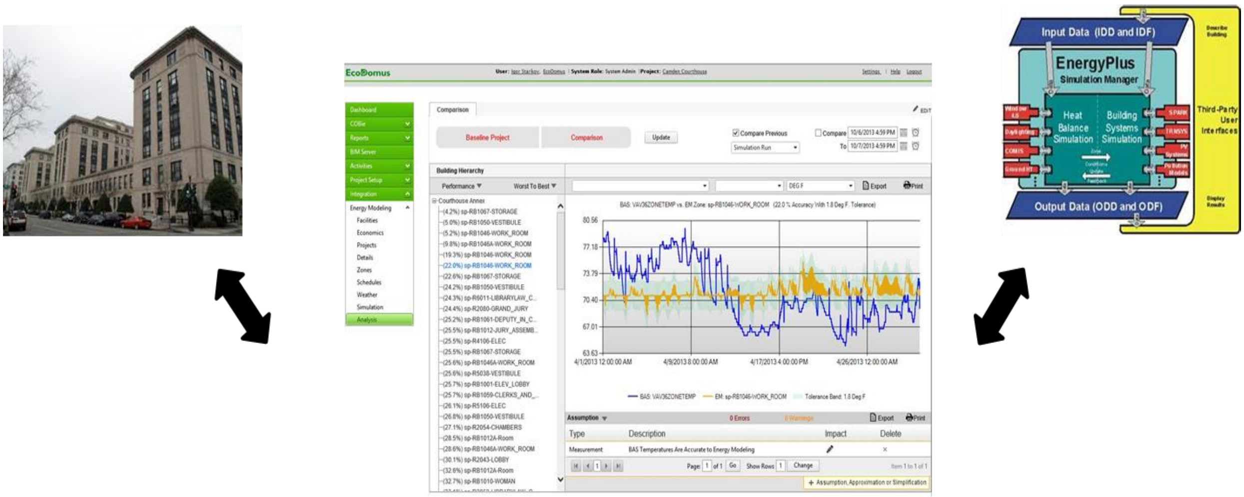


Figure 7.12 Energy management and continuous commissioning

7.5 Use of the Developed Life-Cycle Model

A life-cycle model of PPP performance measurement was finalised in the previous sections of this chapter. Table 7.2 clearly indicates the potential users of the CIs of this developed model.

Table 7.2 Potential users of the developed life-cycle model

Core Indicators	**Potential Users**
Phase 1 (Initiation and Planning)	
CI_{F1-2}	
CI_{F2-1}	
CI_{F3-1}, CI_{F3-3}, CI_{F3-4}, CI_{F3-6}, CI_{F3-8}, and CI_{F3-9}	Governments/Public authorities
CI_{F4-1} to CI_{F4-4}	
CI_{F5-1} to CI_{F5-3}	
Phase 2 (Procurement – Tendering/bidding and financial close)	
CI_{F1-3} and CI_{F1-4}	
CI_{F2-2}	
CI_{F3-10}, CI_{F3-11}, and CI_{F3-13}	Public authorities and private consortia
CI_{F4-5} to CI_{F4-7}	
CI_{F5-5} to CI_{F5-8}	
Phase 3 (Partnership – Design, construction, operation, maintenance and handover)	

CI_{F1-5} to CI_{F1-8} and CI_{F1-10} to CI_{F1-12} CI_{F2-3} CI_{F3-15} to CI_{F3-20} and CI_{F3-22} to CI_{F3-25} CI_{F4-9} to CI_{F4-18} CI_{F5-9} to CI_{F5-11}, and CI_{F5-13}	Public authorities and private entities

It is a fact that the *Initiation and Planning* of a PPP are conducted and completed by the public sectors/authorities concerned. According to this, the potential users of the CIs that were specifically designed for this project phase will be those governments. In the *Procurement* phase, private sector is involved and therefore the users of the CIs devised for this phase should include the private consortium. While the government can use the CIs to measure whether the tendering procedure or negotiation framework is competitive and efficient, the private consortium will be provided with valuable information to examine if the proposal submitted for bidding is innovative or if the coordination and communication between the member organisations are efficient. All of these issues are critical to the success of the future works of the PPP project (Chan *et al.*, 2005; Yuan *et al.*, 2009; Yong, 2010).

Similarly, in the *Partnership* phase, the private organisations serve as the project 'deliverers', while the public authorities act as the governors. This leads to the situation that the deliverables in this phase are produced by the private-sector entities but monitored by the governments. Therefore, the potential users of the CIs relating to the *Partnership* phase are the public clients and private concessionaire, meaning that such CIs are suitable for both the public and private sectors in a PPP project. For example, the government bodies and private consortia in PPPs share a common strategic goal, V*f*M. Hence, the CIs of the *Strategies* (e.g., CI_{F2-1} to CI_{F2-3}) are useful, not only for the governments but also for the concessionaire, and they can be used by both parties of a PPP project to indicate how well their strategies have been achieved. In addition, the CIs related to the *Stakeholders' Satisfaction* and *Contributions* (e.g., CI_{F1-5} to CI_{F1-8}, CI_{F1-10} to CI_{F1-12}, CI_{F5-9} to CI_{F5-11}, and CI_{F5-13}) are suitable for governments to evaluate the satisfaction and contribution levels of all involved private organisations, while the main private contractors can apply them to examine how well their sub-contractors are contributing to the project or to measure whether the public client and project financers are satisfied with the outputs and outcomes.

Furthermore, the CIs of the process (e.g., $CI_{F3\text{-}15}$ to $CI_{F3\text{-}20}$ and $CI_{F3\text{-}22}$ to $CI_{F3\text{-}25}$) and capability (e.g., $CI_{F4\text{-}9}$ to $CI_{F4\text{-}18}$) also possess 'dual natures/users'. The government can adopt them for the purpose of checking whether the implemented delivery process is effective and efficient in supporting the procurement of the project, or assessing whether the private consortium's capabilities are robust and reliable for the project's delivery. By contrast, the private concessionaire may introduce the process/capability-related CIs into its performance evaluation to: (1) measure whether its project delivery process is efficient in assisting to achieve the client's pre-defined policy goal (i.e., V*f*M); and (2) identify whether its sub-contractors' capabilities (i.e., finance infrastructure) are strong enough for further progress of the project within the contractual period.

7.6 Chapter Summary

This chapter presented a finalised life-cycle model of PPP performance measurement and explained how this model will benefit the performance of future PPP projects. In addition, it was suggested that information efficiency will be a potential hurdle for the successful implementation of the developed life-cycle performance measurement model into a 'real-world' PPP project. To deal with this problem, BIM was equipped with the developed model because of its usefulness and robustness in synergising the information required to design, build, operate and maintain an asset, and to model and simulate a variety of scenarios, both at the outset and as a project moves through its various stages of development. In relation to this, a symbiotic link that exists between PPP and BIM has been demonstrated through the lens of performance measurement. Together with the derived CIs, BIM is able to be adopted to ensure that an accurate assessment of value is being attained from the 'real-time' information rather than the static and historical data, which is inappropriate for determining efficiency gains and lacks transparency. Further, in this chapter, a 'user guideline' was devised for the life-cycle PPP performance measurement model, with the aim of indicating the potential users of the CIs of each project phase of a PPP. This guideline provides the key stakeholders of PPPs with valuable information about how to use the developed life-cycle model.

CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Chapter Introduction

The research presented in this thesis aims to originally contribute to the body of knowledge urgently required to comprehensively evaluate the performance of PPPs. With this primary aim, the triangulation approach was used to study the performance measurement/evaluation of PPPs within the Australian context; therefore, an in-depth literature review, 25 key-informant interviews, two detailed case studies of social infrastructure PPPs, a questionnaire survey and econometric techniques were used to explore and investigate how to comprehensively and effectively measure PPPs and to determine the indicators that need to be essentially addressed throughout the projects' life-cycles. This led to the development of a life-cycle performance measurement system (PMS) that was considered to be the most theoretically appropriate and practically effective basis for satisfying the primary research objectives. The major findings and outcomes that were derived and generalised from the previous chapters of this thesis, the recommendations stemming from this research, and the promising directions for future research are summarised and reported in this chapter.

8.2 Performance Measurement in PPPs

The background to, and necessity for, this research were examined in Chapter 1. As addressed and emphasised throughout this thesis, the major aim of this research was to develop a PMS on the basis of empirical evidence, and the system was specifically designed for completely evaluating and measuring the performance of PPPs and ensuring the projects' Value for Money (V*f*M) and long-term success. According to the primary aim, the relevant research objectives were proposed and the structure of this thesis was explicitly described in the first chapter. Additionally, the significance and contribution of this research was outlined in Chapter 1. Overall, this research is theoretically and practically significant because it bridges the current 'gap' of life-cycle performance measurement systems in the body of knowledge of PPPs and is able to provide the public and private sectors with an effective and efficient technique to comprehensively measure their PPP projects. Further, this is also the first research to be undertaken with the purpose of empirically deriving macroeconomic key performance indicators (KPIs) for PPPs, which can be used to assess whether the future macroeconomic environment will be suitable for procuring infrastructure assets by privately financed means.

After providing an overview of this research, a review of the normative literature was presented in Chapter 2, covering issues in regard to PPPs and PPP research, theories of performance measurement, performance evaluation of PPPs, and performance measurement of general construction projects. The review confirmed the importance and significance of a study of PPP performance measurement and provided assistance in identifying a promising direction for measuring the projects. It was first suggested that process management, whereby performance measurements are pivotal, has received limited attention in regard to PPPs. Secondly, it was noted that a process-based PMS is more appropriate for PPPs than a framework solely based on KPIs, but this type of measurement can completely overwhelm traditional *ex-ante* and *ex-post* evaluations, which are being widely used in PPP projects.

8.3 Data Collection

Based on the conclusions from the literature review, the philosophical basis of the methodology adopted for this research was demonstrated in Chapter 3. The research method depends on the concept of sequential triangulation, which emphasises the use of both qualitative and quantitative approaches in combination. Thus, a qualitative exploratory study, two detailed case studies, a questionnaire survey and econometric modelling were sequentially justified and implemented. With this research strategy, the interviews and survey were used for the collection of primary data, while the secondary data was taken from the public publications of three reliable institutions (i.e., the Australian Bureau of Statistics, the Reserve Bank of Australia, and the Australian Stock Exchange). In Chapter 3, the sample design and population of the survey, methods used for analysis of the survey data, and econometric techniques applied to the secondary data were also justified and described in detail. On the basis of the justifications, Confirmatory Factor Analysis (CFA) and the vector error correction (VEC) model were selected for quantitatively analysing the collected data.

8.4 Life-Cycle PMS of PPPs

According to the main research strategy designed in Chapter 3, an exploratory study was undertaken in the first phase of the research, relying on 25 interviews with experienced PPP practitioners who were familiar with the procurement and delivery of social infrastructure PPPs across Australia. All of these interviews were unstructured, allowing respondents to freely express their perspectives about any shortcomings and limitations of the current performance measurement systems of PPPs and how to resolve such problems. During the interviews, most respondents considered that the existing approaches that are being widely used to evaluate the performance of PPPs are conventional *ex-ante* and *ex-post* evaluations, which concentre on assessing the cost benefits of the proposed projects and examining whether the predetermined budget, schedule and quality requirements have been met. These traditional evaluations largely ignore some critical issues and cannot provide an insight into performance improvement, which is pivotal for achieving V*f*M and long-term project success.

For that matter, the respondents of the interviews proposed that a form of life-cycle/process-based performance measurement should be adopted to replace the existing evaluation approaches of PPPs. As a consequence of the findings derived from the exploratory qualitative study, a life-cycle PMS that integrates with a broader V*f*M assessment as well as a series of stakeholder-oriented performance measures was conceptually proposed, and this proposed system was essentially underpinned by the insertion of 'learning mechanisms' and building information modelling (BIM). As the measures of the proposed system were essentially stakeholder-oriented, the *Performance Prism* was applied to narrow down the stakeholder-oriented measures and derive five performance measurement perspectives and a sequence of core indicators (CIs). Thus, two hypotheses relating to the measurement perspectives and CIs were proposed for the subsequent studies. In summary, the outcomes of the exploratory study in this research not only determined the direction of the case studies (i.e., the selection of the case projects and design of the case study protocol), but also formed the base of the quantitative studies. In Chapter 5, the conceptual framework arising from, and supported by, the exploratory interviews was then examined by two detailed case studies (i.e., a public hospital and a prison) with the aims of testing its feasibility and applicability, and assessing whether the CIs that were derived from the normative literature are comprehensive enough. Interviews and documentary sources (e.g., Project Summary and Project Agreement) were used throughout the case studies. The analysis of the data obtained from the case projects suggested that the developed life-cycle PMS was feasible and applicable for overcoming the limitations of the performance evaluation measurements of the projects and was capable of substantially solving the relevant problems.

8.5 Core Indicators and Macroeconomic KPIs

Chapter 6 presented the quantitative studies that were based on the questionnaire survey and econometric modelling. A series of statistical techniques, including Cronbach's alpha, item-total statistics and CFA, were used to empirically test the survey data; therefore, both the descriptive and analytical statistics were reported in this chapter. By running the aforementioned statistical tests, a total of four inconsistent and seven insignificant CIs were eliminated from the dataset. The structural model constructed for CFA was validated by several Goodness-of-fit Indexes (GFIs), involving the *Chi-squared* statistic, the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA). The empirical results associated with these three GFIs indicated a good 'model fit', and this means that the constructed model is reliable for quantitatively analysing the data.

After running CFA, a set of macroeconomic KPIs was derived from the literature for PPPs according to the further suggestions from the respondents of the survey, with the purpose of assisting governments to assess the suitability of the macroeconomic environment where their proposed projects will be implemented. These KPIs (i.e., construction price level, domestic economic conditions, money market conditions, level of unemployment, profitability, capital market conditions, population growth and global economic climate) are the sub-indicators of the tested CI relating to 'macro-environmental assessment' and they were empirically validated by using the Granger causality test, variance decomposition and generalised impulse response function under a VEC-D model (i.e., a VEC model with a dummy variable). The empirical evidence indicated that all proposed macro-KPIs were significant to be used in analysing the macroeconomic environment and should be incorporated into a life-cycle performance measurement/evaluation of PPPs.

CFA and econometric study further quantitatively confirmed the propositions that were derived from the exploratory interviews and case studies and further examined. In other words, the life-cycle and stakeholder-oriented PMS developed in this research is a promising tool for the performance measurement of future PPP.

8.6 Future Proofing PPPs by Life-Cycle PMS

Life-cycle performance measurement, as assumed and emphasised throughout Chapters 1 to 4, can ensure that PPPs are delivered in accordance with a project's predetermined objectives, while also achieving V*f*M for the project's long-term success. This assumed perspective was empirically examined by the case studies and confirmed by the findings derived from the quantitative studies (Chapters 5 and 6). As a result of such findings, a life-cycle model of performance measurements for PPPs was finalised, as reported in Chapter 7. The use of the finalised model will provide the key project stakeholders of future PPPs with the following benefits and values: (1) enhancement of the veracity of the business cases due to a 'real' life-cycle V*f*M assessment; and (2) improvement in the effectiveness and efficiency of government parties' decision-making and private entities' ability to effectively control the deliverables to completely satisfy the key stakeholders' needs and expectations, due to the process-based CIs and 'learning mechanisms'.

It was suggested by the first-stage interviews and the case studies that information efficiency acts as the major impediment to the implementation of the developed life-cycle model with the 'real-world' PPP projects, and that limited techniques and tools are available for removing this hurdle. However, BIM has been acknowledged as an effective and efficient technology and method for accessing and presenting information related to the delivery of construction projects (e.g., design, build, operation and facility maintenance).Therefore, Chapter 7 also demonstrated how BIM will be able to support an implementation of the life-cycle model in PPPs. When aligned with the CIs of the life-cycle model, it was identified that BIM acts as a catalyst for 'future proofing' PPPs and enables the successful management of an asset all the way through the whole life of the project. In summary, BIM not only can provide digital representation of the physical and functional characteristics of an asset, but also can provide key decision-makers with the ability to make informed decisions across a project's life-cycle.

8.7 Recommendations from the Research

This research is both theoretically and practically significant and, therefore, reveals a series of practical implications. Hence, there are a number of valuable lessons to be learned for PPP practitioners from the research findings. These include:

- *Focusing more on measuring the outputs or deliverables of the pre-contract stages over the project's life-cycle* – The existing performance measurements of PPPs are still the construction-product-focused evaluations, which assess whether the predetermined schedule, budget and quality requirements have been met. However, the findings from both qualitative and quantitative studies indicated that the deliverables or outputs produced from the pre-contract stages of PPPs are critical to the achievement of V*f*M as well as long-term project success, yet they have been largely neglected. Accordingly, the governments should play a more active role in promoting phase-based and stakeholder-oriented performance measurement during the delivery of PPPs, and they had better negotiate, confirm and finalise the use of this type of measurement with the private consortia prior to the contract award.
- *Creating a robust and reliable database for the life-cycle VfM assessment* – It has been addressed over the course of this research that the governments involved with PPPs need to shift their current V*f*M assessment, which largely relies on cost issues, to a more comprehensive assessment that covers not only financial benefits but also non-financial positive impacts on local communities or regions. For example, the effect to be gained from a PPP hospital on the healthcare or level of medical attention for a local community/region, or the impact of a PPP school on the improvement of local educational quality are important non-financial issues. However, estimating the macro-effects of infrastructure assets is difficult and depends on

high-quality big data (Taris, 2000). In this regard, governments should create a reliable benchmark database concerning the operations of the facilities procured by the traditional approach, and this will be useful for comparing the outcomes of non-PPP assets with those of the proposed PPPs.

- *Introducing BIM into the procurement of PPPs from a project's initiation to facility maintenance* – As raised in previous chapters (i.e., Chapters 4 and 5), a major difficulty in implementing the life-cycle PMS into a 'real-world' PPP project is ensuring a high efficiency in accessing, managing and storing the data required for measuring its performance throughout the project's life-cycle. Also, it was suggested that BIM is robust in resolving this problem. Based on traditional wisdom, BIM is a technique that specifically provides physical representation of the asset's building. With this conventional perspective, the use of BIM was usually limited to the building stage only of completed projects. However, Love *et al.* (2013) state that BIM is not only a building technique, but also a technology-focused methodology suitable for both the life-cycle justification and evaluation of an asset. According to this point of view, the application of BIM should not be limited to the asset's building stage, but should be adapted to its whole life. As PPPs are highly complex construction projects, the project managers/directors in both the public and private sectors should attempt to make BIM penetrate the life-cycle of their projects, cascading down from initiation and planning to operation and facility maintenance/management.

8.8 Future Research

Prior to this research, the studies of PPPs had been limited to performance measurement of the projects. So, this research has fulfilled this significant knowledge 'gap' by the development of a life-cycle PMS. Although this developed PMS has significantly and substantially contributed to the normative literature, there are some opportunities for promising future research under the scheme of performance measurement of PPPs

In Chapter 4, some respondents of the first-stage interviews of this research proposed that a balanced abatement regime should be designed to support an implementation of the life-cycle PMS in PPPs, as it could stimulate the private-sector entities to strictly follow the concept of the developed PMS to measure their projects. As addressed in Chapter 1, the issue of the abatement regime would not be investigated in this thesis because the aim of this research was to explore how to comprehensively measure the performance of PPPs rather than to devise an effective regime to stimulate or monitor the use of the life-cycle measurement approach. However, this will be a topic valuable for future research owing to its usefulness in further enhancing the practicability of the process-based performance measurement.

Additionally, there are some interesting issues around the subject of life-cycle V*f*M assessment and these are also the significant topics for future research on PPPs. For example, the life-cycle V*f*M analysis that was addressed in this research is a concept related to financial and non-financial benefits. However, which non-financial benefits or factors should be involved in the life-cycle V*f*M assessment have not been detailed. In fact, this contributes to a lack of transparency in V*f*M evaluation and remains a problematic issue (Singh and Tiong, 2005; Sachs and Tiong, 2007). It is therefore a promising topic for future PPP research.

8.9 Chapter Summary

This chapter has summarised and reported the findings that were derived from the previous chapters of this research. Further, a series of recommendations have been drawn from the research findings and provided for the key stakeholders/practitioners, including: (1) paying more attention to the outputs or deliverables of the pre-contract stages; (2) creating a reliable database for the life-cycle V*f*M assessment; and (3) introducing BIM into PPPs, not only for a project’s construction, but also at the stage of its commercial investigation, planning and procurement (e.g., tendering). More importantly, this chapter also recommended several future research opportunities for the study of PPPs, such as a development of a balanced abatement regime in regard to life-cycle performance evaluation and an identification of non-financial factors in the V*f*M analysis.

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APPENDICES

Appendix A

Project of PPP Life-Cycle Performance Evaluation Exploratory-Study Protocol

Must do:

- ☞ Before the interview, make sure the *plain language statement* and *authorization from* the interviewee are sought. Also, ask their permission to digitally record the interview. Notify interviewee their interview will be transcribed and distributed to them for vetting/approval.
- ☞ Ask the interviewee to select a recently completed PPP project or one that they are currently involved with.
- ☞ State that we would like the interviewee to provide assistance in acquiring a deep understanding of problems associated with the performance evaluation of the case project and suggest what necessity and directions of a new approach for evaluating social infrastructure PPPs.
- ☞ Before the interviewee provides details about specific evaluation of PPPs, however, some background information about the project is first sought.

Research Project of PPP Life-Cycle Performance Evaluation

Ref: **Date:** **Start Time:**

Finish Time:

Interviewer:

Interviewee: **Gender:**

Organization: **Position:**

Organisation type:

Industry experience:

Before commencing the interview, obtain general overview of PPP performance evaluation from their experience and then ask to select a particular project

Background Information

1. Description of the project(s) (project type/purpose/alliance):
   ____
   ____
   ____
   ____

2. Project(s) value: $ ______________________________

3. Project(s) duration: ______________________________

4. Expected/actual completion period: ____________________

5. What are your perspectives on the overall performance of the PPP project you have selected?
   ____
   ____
   ____
   ____

Current Practice in Performance Evaluation in PPPs

6. How are/were the performances of the PPPs that you are/were involved with evaluated?
   ____
   ____
   ____
   ____

7. Regarding the selected project, what are the key measures the performance evaluation is/was focused on?
   ____
   ____
   ____
   ____

8. What do you consider to be the problems associated with the performance measurement of the PPP project(s) you were involved with?
   ____
   ____
   ____
   ____

9. Would you be able to describe how important of performance evaluation is to the success of a PPP project?

10. What have been done to improve these problems in the industry?

Improvement for Performance Evaluation of PPPs

11. According to your experience, is it necessary to develop a new performance evaluation for PPPs? Can you tell me why?

12. (If necessary) What do you consider to be areas where a PPP new performance measurement/evaluation can be improved?

13. What do you consider to be the main difficulties in implementing a new performance measurement in PPPs?

14. What are your general comments?

Appendix B

Curtin University

Project of PPP Life-Cycle Performance Evaluation Case-Study Protocol

Must do:

☞ Before the interview, make sure the *plain language statement* and *authorization from* the interviewee are sought. Also, ask their permission to digitally record the interview. Notify interviewee their interview will be transcribed and distributed to them for vetting/approval.

☞ State that we would like the interviewee to provide assistance in validating the feasibility, applicability and practicability of the developed PMS.

☞ Before the interviewee, provides details about specific performance evaluations of the PPP project used for case study, however, some background information about the project is first sought.

Research Project of PPP Life-Cycle Performance Evaluation

Ref: **Date:** **Start Time:**

Finish Time:

Interviewer:

Interviewee: **Gender:**

Organization: **Position:**

Organisation type:

Industry experience:

Before commencing the interview, obtain general overview of PPP performance evaluation from their experience and then ask to select a particular project

Background Information of the Selected Project

1. Description of this (selected) Public-Private Partnership (PPP) project (project structure/purpose/alliance):
   ____
   ____
   ____
   ____

2. Project value: $ ____

3. Project duration: ____

4. Expected actual completion period: ______________________________

5. Project current stage:
   ____
   ____
   ____
   ____

6. Delay or budget overruns (If so):
   ____
   ____
   ____
   ____

Current Performance Evaluation of the Selected PPP

7. Can you tell me how you evaluate the performance of the project? For example, what key performance indicators (KPIs) have been or will be used?
   ____
   ____
   ____
   ____

8. When such KPIs have been or will be applied for this project, in project design, finance, construction, operations, or maintenance?
   ____
   ____
   ____
   ____

9. Can you think of any specific problems in the current performance evaluation of the project?
   ____
   ____

10. Can you tell me how important of a comprehensive performance evaluation is to the success of this project?

Feasibility of Life-Cycle Performance Evaluation in PPPs

11. What is your perspective on the necessity in improving the performance evaluation of the project?

12. What is your perspective about the feasibility of a life-cycle PMS with the stakeholder-oriented KPIs in ameliorating the current performance evaluation system of the project?

13. If the life-cycle evaluation can be applied for this PPP project, would you be able to summarise any KPIs for each phase of this project, including design, finance, build, operations and maintenance?

14. According to your expertise and experience, what are the main difficulties in the application of a life-cycle evaluation for this case project?

15. Do you have any other general comments/suggestions on the development of a life-cycle evaluation model for this case project?

Appendix C

Appendix C: Coding of the data collected from the exploratory interviews

Existing PPP Evaluations	Responses of the Interviewees (Respondents)	Respondents' Codes
[a]Design and Construction: Time[1] Cost[2] Quality[3] [b]Asset Operations: Qualitative and Quantitative KPIs[4]	We used Gateway Review for the inception stages of our PPPs. But it is only a simple review for the business cases and tendering decision and I don't think it is a formal performance measurement mechanism. The only systematic performance measures we had in our PPP projects are the KPIs[4] for controlling the operations[b] of the private consortia. However, we also inspected the quality[3] of the asset built by the private sectors and checked progress[1] of the project to identify if everything is under the predetermined timeframe[1] during construction[a].	PC-01
	The performance measurement of our PPP projects is divided into two parts. The private contractors measured the projects by assessing if the pre-defined schedule[1], budget[2] and quality[3] criteria can be met. For us, the State Government, we used KPIs[4] to monitor the operational[b] performance of the facility. Indeed, the KPIs are not only the mechanisms for us, but also for the private consortia.	PC-02
	The approaches we used to evaluate the PPPs are straightforward; KPIs[4] for operations[b] and TCQ[1, 2, 3] for design and construction[a]. But this must be improved.	PC-03
	The performance evaluation of our social infrastructure PPP projects before the assets' operations is similar to that of the projects procured by using traditional methods. This kind of evaluation aims to measure whether the project was delivered on time[1] and on budget[2] and also evaluate if the procured asset can meet the predefined quality[3] specification.	PM-01
	Our PPPs are measured by time[1], cost[2] and quality[3] for the D&C[a], and the operational[b] performance is measured by KPIs[4].	PM-02
	We are responsible for the design, finance, construction and maintenance. The measures the project team used to evaluate the project's design and construction[a] performance are cost[2] and tim[1]e issues.	PM-03
	The performance measurements of our PPPs are primarily relied on assessing if the projects can meet our pre-defined budget[2]. This is the most important. Others are about checking if the timeframe[1] and client's quality[3] criteria are met.	A/DM-01

As a designer of PPPs, we don't have systematic performance measurement mechanism for the assets' designs. Our partner organisations, the builders, evaluate the projects by emphasising finance[2] and meeting schedule[1] and quality[3] requirement. For the operators, the KPIs[4] provided by the governments were used to assess the facilities' operation[b] performance.	A/DM-02
The concerns in measuring a PPP project before its operation stages are simple – examining if the project can be delivered behind the budget[2] and schedule[1] and meet the public sector's demand for quality[3].	A/DM-03
Performance evaluation in our PPPs was relied on construction outputs, like budgets[2], schedules[1], and physical quality[3]. For the projects under DBFM or DBFOM, maintaining the availability of the facility was also our job. So we had a full set of KPIs[4] stated in the contract to control the operational[b] outcomes.	A/DM-04
Financial[2] performance was the priority of the evaluation of our PPPs. Also, predetermined schedules[1] and client's quality[3] requirements (e.g., physical and service quality) were also pivotal in the projects' evaluations.	FA-01
We normally worked as financial advisor for the governments in PPPs. The performance measurements of PPPs contain two parts, TCQ[1, 2, 3] for D&C[a] and qualitative and quantitative KPIs[4] for operations[b].	FA-02
Northing special for our PPP evaluation. It is similar to the projects procured by traditional procurement. We measured PPs by examining if the projects are on budget[2], on time[1] and on quality[3]. The quality includes not only physical quality but also service quality.	FA-03
Finance[2] is the most critical issue in PPP performance evaluation. We also evaluated against time[1] and quality[3] performance. But this is only for projects' design and construction[a]. Look, for the operation[b] and FM, we just had operational KPIs[4] but nothing for maintenance.	FA-04
All our PPPs are evaluated by using cost[2] and time[1] measures, particularly during the stages of design and construction.	CA-01
The PPP projects I had been involved are measured by using the approach of traditional lump-sum projects. So time[1], cost[2] and quality[3] were the focuses. Our PPPs were normally under DBFOM, and so KPIs[4] agreed between the State Government and our group were introduced for operations[b].	LA-01
Our social infrastructure PPPs were evaluated under TCQ[1, 2, 3] and KPIs[4]. TCQ was for D&C[a] and KPIs were specific for operation[b]. This is all what we have to evaluate the projects.	LA-02

	Our social infrastructure PPPs are either under DBFOM or DBOM. According to the contracts, we had to keep well the availability of the projects. So more 100 KPIs in each project were agreed between the involved parties. These KPIs are operation-based. The Governments used them to monitor us and we used them to check if everything can satisfy the clients. In addition to operations, the projects were evaluated by time, cost and quality. This means we measured our PPPs by evaluating if the projects were on time and on budge.	LA-03
	We only have formal KPIs[4] for the operation of the asset. These KPIs cover something relating to the service quality. But, the asset designer and builder run evaluation by using other measures, like finance[2], schedule[1], or client's specification[3].	PA-01
	The performance evaluation conducted for social PPPs was divided into two parts. First, the measurements for design and construction are pretty straightforward focusing on time, cost and quality. Second, many social infrastructure PPPs are behind the operational model, and there are KPIs associated with the assets' operations, covering a series of issues.	PA-02
	The performance measurements at the project level normally rely on KPIs[4], and they are linked to the operations only within qualitative and quantitative contexts.	PA-03
	The KPIs[4], which are used to measure the performance outcome defined by the output specification, are primarily associated with the operation of our PPP that is under the operational model.	OM-01
	There were no formal performance measures in our PPPs, except the qualitative and quantitative KPIs[4] dictated by the government for the operation. But traditional time[1], cost[2] and quality[3] were used before operating the asset.	OM-02
	I think the evaluation of our PPPs can be divided into two parts. For D&C, our partner organisation measures the outputs by checking time[1], cost[2] and quality[3] performance. For us, as an asset operator, we used both qualitative and quantitative KPIs[4] to assess the operational performance.	AM-01
	In our projects, we have operational KPIs to maintain availability of the facility. We also examined the outputs of the D&C by checking financial reports and by assessing if the progress and quality were satisfactory.	AM-02

Appendix D

Appendix D: Dataset of the core indicators (CIs) of the conceptual performance measurement system

Constructs \ Phases	Initiation and Planning (P1)	Procurement (P2)	Partnership (P3) (Construction, Operation and Maintenance)
Stakeholder Satisfaction (F1)	CI_{F1-1}: Public client's satisfaction CI_{F1-2}: Skilled employees' satisfaction	CI_{F1-3}: Public client's satisfaction CI_{F1-4}: Skilled employees' satisfaction	CI_{F1-5}: Public client's satisfaction CI_{F1-6}: Skilled employees' satisfaction CI_{F1-7}: General concession contractor's satisfaction CI_{F1-8}: Subcontractors' satisfaction CI_{F1-9}: Building product suppliers' satisfaction CI_{F1-10}: Shareholders' satisfaction CI_{F1-11}: Creditors' satisfaction CI_{F1-12}: End-users' satisfaction
Strategies (F2)	$CI_{F2-1\ to\ 3}$: Value for Money (V*f*M) (optimum combination among life-cycle cost, physical and service quality of the asset, and the users' satisfaction)		
Processes (F3)	CI_{F3-1}: Comprehensiveness of macro-environmental analysis (political, economic, social and legal) CI_{F3-2}: Appropriateness of definition on service need and desired outputs CI_{F3-3}: Effectiveness and efficiency of risk management (e.g., identification, analysis and allocation) CI_{F3-4}: Comprehensiveness of feasibility/business-case study (financing, technical and engineering) CI_{F3-5}: Appropriateness of financing option CI_{F3-6}: Appropriateness of concessionaire selection criteria CI_{F3-7}: Appropriateness of concession period CI_{F3-8}: Appropriateness of legal, commercial, technical and engineering structure CI_{F3-9}: Effectiveness of interface management	CI_{F3-10}: Transparency and competitiveness of bidding process CI_{F3-11}: Comprehensiveness and efficiency of final approval and negotiation framework CI_{F3-12}: Effectiveness and efficiency of financial close CI_{F3-13}: Effectiveness of interface management	CI_{F3-14}: Compliance of legal and regulatory framework CI_{F3-15}: Proper design and efficient design process CI_{F3-16}: TCQ and material management CI_{F3-17}: Occupational health and safety CI_{F3-18}: Environmental impact of the project CI_{F3-19}: Effectiveness of contract management CI_{F3-20}: Effectiveness and efficiency of dispute solution CI_{F3-21}: Profit and profitability CI_{F3-22}: Effectiveness of operations management CI_{F3-23}: Effectiveness of facility management CI_{F3-24}: Effectiveness of interface management
Capabilities (F4)	CI_{F4-1}: Skilled employees/workforce CI_{F4-2}: Training and learning system CI_{F4-3}: Innovation for strategic planning and process design CI_{F4-4}: Innovation for project financing	CI_{F4-5}: Skilled employees/workforce of the public authority and private SPV CI_{F4-6}: Training and learning systems in the public and private sectors CI_{F4-7}: Innovation for procurement (bidding/tendering) CI_{F4-8}: Public sector's governance (for procurement)	CI_{F4-9}: Skilled employees/workforce in the private SPV CI_{F4-10}: Training and learning system of the private SPV CI_{F4-11}: Reliability of the finance infrastructure CI_{F4-12}: Public sector's governance CI_{F4-13}: Advanced technologies and equipment CI_{F4-14}: Innovation for technology CI_{F4-15}: Technology transfer and knowledge management
Stakeholder Contribution (F5)	CI_{F5-1}: Public client's performance in the establishment of investment environment CI_{F5-2}: Public client's performance in the establishment of a sound legal framework CI_{F5-3}: Skilled employees' performance/contribution	CI_{F5-4}: Public authority contribution to concessionaire selection CI_{F5-5}: Skilled employees' performance/contribution in tendering/bidding CI_{F5-6}: Private contractors' willingness to participation to the project CI_{F5-7}: Shareholders' willingness to participation to the project CI_{F5-8}: Creditors' willingness to participation to the project	CI_{F5-9}: Public client willingness to active involvement CI_{F5-10}: Skilled employees' performance/contribution in SPV CI_{F5-11}: Subcontractors' performance CI_{F5-12}: Suppliers' performance CI_{F5-13}: Users' willingness to the use of the procured asset

Appendix E

Appendix E: CIs dataset examined and expanded after the two case studies

Phases / Constructs	Initiation and Planning (P1)	Procurement (P2)	Partnership (P3) (Construction, Operation and Maintenance)
Stakeholder Satisfaction (F1)	CI_{F1-1}: Public client's satisfaction CI_{F1-2}: Skilled employees' satisfaction	CI_{F1-3}: Public client's satisfaction CI_{F1-4}: Skilled employees' satisfaction	CI_{F1-5}: Public client's satisfaction CI_{F1-6}: Skilled employees' satisfaction CI_{F1-7}: General concession contractor's satisfaction CI_{F1-8}: Subcontractors' satisfaction CI_{F1-9}: Building product suppliers' satisfaction CI_{F1-10}: Shareholders' satisfaction CI_{F1-11}: Creditors' satisfaction CI_{F1-12}: End-users' satisfaction
Strategies (F2)	$CI_{F2-1\ to\ 3}$: Value for Money (V*f*M) (optimum combination among life-cycle cost, physical and service quality of the asset, and the users' satisfaction)		
Processes (F3)	CI_{F3-1}: Comprehensiveness of macro-environmental analysis (political, economic, social and legal) CI_{F3-2}: Appropriateness of definition on service need and desired outputs CI_{F3-3}: Effectiveness and efficiency of risk management (e.g., identification, analysis and allocation) CI_{F3-4}: Comprehensiveness of feasibility/business-case study (financing, technical and engineering) CI_{F3-5}: Appropriateness of financing option CI_{F3-6}: Appropriateness of concessionaire selection criteria CI_{F3-7}: Appropriateness of concession period CI_{F3-8}: Appropriateness of legal, commercial, technical and engineering structure CI_{F3-9}: Effectiveness of interface management	CI_{F3-10}: Transparency and competitiveness of bidding process CI_{F3-11}: Efficiency of final approval and negotiation framework CI_{F3-12}: Effectiveness and efficiency of financial close CI_{F3-13}: Effectiveness of interface management	CI_{F3-14}: Compliance of legal and regulatory framework CI_{F3-15}: Proper design and efficient design process CI_{F3-16}: TCQ and material management CI_{F3-17}: Occupational health and safety CI_{F3-18}: Environmental impact of the project CI_{F3-19}: Effectiveness of contract management CI_{F3-20}: Effectiveness and efficiency of dispute solution CI_{F3-21}: Profit and profitability CI_{F3-22}: Effectiveness of operations management CI_{F3-23}: Effectiveness of facility maintenance and asset condition monitoring CI_{F3-24}: Effectiveness of interface management CI_{F3-25}: Effectiveness of asset residual value management
Capabilities (F4)	CI_{F4-1}: Skilled employees/workforce CI_{F4-2}: Training and learning system CI_{F4-3}: Innovation for strategic planning and process design CI_{F4-4}: Innovation for project financing	CI_{F4-5}: Skilled employees/workforce of the public authority and private SPV CI_{F4-6}: Training and learning systems in the public and private sectors CI_{F4-7}: Innovation for procurement (bidding/tendering) CI_{F4-8}: Public sector's governance (for procurement)	CI_{F4-9}: Skilled employees/workforce in the private SPV CI_{F4-10}: Training and learning system of the private SPV CI_{F4-11}: Reliability of the finance infrastructure for project delivery and future technical and technological upgrades for handover CI_{F4-12}: Public sector's governance CI_{F4-13}: Advanced technologies and equipment CI_{F4-14}: Innovation for technology CI_{F4-15}: Technology transfer and knowledge management CI_{F4-16}: Appropriateness of professional staff structure CI_{F4-17}: Capability in managing the information required for evaluation CI_{F4-18}: SPV's capability in the determination of cost-effective product to be installed into the asset
Stakeholder Contribution (F5)	CI_{F5-1}: Public client's performance in the establishment of investment environment CI_{F5-2}: Public client's performance in the establishment of a sound legal framework CI_{F5-3}: Skilled employees' performance/contribution	CI_{F5-4}: Public authority's contribution to concessionaire selection CI_{F5-5}: Skilled employees' performance/contribution in tendering/bidding CI_{F5-6}: Private contractors' willingness to participation to the project CI_{F5-7}: Shareholders' willingness to participation to the project CI_{F5-8}: Creditors' willingness to participation to the project	CI_{F5-9}: Public client willingness to active involvement CI_{F5-10}: Skilled employees' performance/contribution in SPV CI_{F5-11}: Subcontractors' performance CI_{F5-12}: Suppliers' performance CI_{F5-13}: Users' willingness to the use of the procured asset

Appendix F

Appendix F: Item-total statistics and Cronbach's alpha values of the observed items

Codes	Proposed Perspectives and CIs	Item-total Statistics	Cronbach's Alpha If Item Deleted
F1	Stakeholder satisfaction	0.52	0.96
F2	Strategy: Value for money (V*f*M)	0.50	0.96
F3	Project delivery process	0.56	0.96
F4	Capabilities of the involved organisations	0.55	0.96
F5	Stakeholder contributions	0.65	0.96
CI_{F1-1}	Public client's satisfaction during Initiation and Planning phase	0.06	0.96
CI_{F1-2}	Skilled employees' satisfaction	0.61	0.96
CI_{F1-3}	Public client's satisfaction in the Procurement phase	0.48	0.96
CI_{F1-4}	Skilled employees' satisfaction in the Procurement phase	0.62	0.96
CI_{F1-5}	Public client satisfaction towards SPV's design, construction, operation and facility maintenance (FM)	0.54	0.96
CI_{F1-6}	Skilled employees' satisfaction in the private-sector SPV	0.63	0.96
CI_{F1-7}	Concessionaire's satisfaction	0.53	0.96
CI_{F1-8}	Subcontractors' satisfaction	0.56	0.96
CI_{F1-9}	Building product suppliers' satisfaction	0.41	0.96
CI_{F1-10}	Shareholders' satisfaction	0.51	0.96
CI_{F1-11}	Creditors' satisfaction	0.64	0.96
CI_{F1-12}	End-users' satisfaction	0.64	0.96
CI_{F2-1}	Value for money assessment (V*f*M) of the proposed PPP	0.52	0.96
CI_{F2-2}	V*f*M of the PPP proposals submitted in the tendering/bidding stage	0.44	0.96
CI_{F2-3}	V*f*M achieved by the asset's design, construction, operation and FM	0.54	0.96

CI_{F3-1}	Comprehensiveness of macro-environmental assessment	0.57	0.96
CI_{F3-2}	Appropriateness of definition on service needs and desired outputs	0.28	0.96
CI_{F3-3}	Effectiveness of risk identification, analysis and allocation	0.42	0.96
CI_{F3-4}	Comprehensiveness of Feasibility/business-case study	0.47	0.96
CI_{F3-5}	Appropriateness of financing option	0.53	0.96
CI_{F3-6}	Appropriateness of concessionaire selection criteria	0.49	0.96
CI_{F3-7}	Appropriateness of concession period	0.52	0.96
CI_{F3-8}	Appropriateness of legal, commercial, technical and engineering structures	0.63	0.96
CI_{F3-9}	Effectiveness and efficiency of interface management	0.49	0.96
CI_{F3-10}	Transparency and competiveness of bidding process	0.64	0.96
CI_{F3-11}	Efficiency of approval and negotiation processes	0.51	0.96
CI_{F3-12}	Efficiency of financial close	0.52	0.96
CI_{F3-13}	Effectiveness of interface management during the Procurement phase	0.35	0.96
CI_{F3-14}	Compliance of legal and regulatory framework	0.24	0.86
CI_{F3-15}	Proper design and efficient design process	0.57	0.96
CI_{F3-16}	TCQ and material management	0.42	0.96
CI_{F3-17}	Occupational health and safety	0.45	0.96
CI_{F3-18}	Environmental impact of the project	0.47	0.96
CI_{F3-19}	Effectiveness of contract management	0.57	0.96
CI_{F3-20}	Effectiveness and efficiency dispute resolution	0.78	0.96
CI_{F3-21}	Project profitability	0.57	0.96
CI_{F3-22}	Effectiveness of operations management	0.65	0.96
CI_{F3-23}	Effectiveness of facility maintenance and management	0.58	0.96
CI_{F3-24}	Interface management during the Partnership phase	0.68	0.96

$CI_{F3\text{-}25}$	Effectiveness of asset residual value management	0.71	0.96
$CI_{F4\text{-}1}$	Skilled workforce associated with the public sector	0.58	0.96
$CI_{F4\text{-}2}$	Training/learning system in the public sector	0.52	0.96
$CI_{F4\text{-}3}$	Innovation for strategic planning and process design	0.72	0.96
$CI_{F4\text{-}4}$	Innovation for project financing	0.70	0.96
$CI_{F4\text{-}5}$	Skilled workforce associated with the public authority and SPV	0.59	0.96
$CI_{F4\text{-}6}$	Training/learning systems in the public and private sectors	0.55	0.96
$CI_{F4\text{-}7}$	Bidding innovation of the private-sector SPV	0.59	0.96
$CI_{F4\text{-}8}$	Public sector’s governance for tendering/biding	0.49	0.96
$CI_{F4\text{-}9}$	Skilled workforce in the private-sector SPV	0.70	0.96
$CI_{F4\text{-}10}$	Training and learning system of the private-sector SPV	0.73	0.96
$CI_{F4\text{-}11}$	Reliability of the finance infrastructure	0.62	0.96
$CI_{F4\text{-}12}$	Public sector’s governance for the on-going project	0.68	0.96
$CI_{F4\text{-}13}$	Advanced technologies and equipment for construction and FM	0.68	0.96
$CI_{F4\text{-}14}$	SPV’s innovation relating to design, construction, operation and FM	0.61	0.96
$CI_{F4\text{-}15}$	SPV’s abilities in technology transfer and knowledge management	0.69	0.96
$CI_{F4\text{-}16}$	Appropriateness of the structure of professional staff team	0.68	0.96
$CI_{F4\text{-}17}$	Capability in managing the information required for evaluation	0.66	0.96
$CI_{F4\text{-}18}$	SPV’s capability in the determination of cost-effective of products to be installed into the asset	0.63	0.96
$CI_{F5\text{-}1}$	Government’s support in establishing a favourable investment environment	0.62	0.96
$CI_{F5\text{-}2}$	Government’s support in establishing a sound legal framework	0.69	0.96
$CI_{F5\text{-}3}$	Contributions of the skilled employees with the public authorities	0.68	0.96
$CI_{F5\text{-}4}$	Public authority’s contribution to concessionaire selection	0.15	0.96
$CI_{F5\text{-}5}$	Contributions of skilled employees in public and private sectors to tendering or bidding	0.72	0.96

$CI_{F5\text{-}6}$	Private entities' willingness to the participation to the project	0.55	0.96
$CI_{F5\text{-}7}$	Shareholders' willingness to the participation to the project	0.64	0.96
$CI_{F5\text{-}8}$	Creditors' willingness to the participation to the project	0.66	0.96
$CI_{F5\text{-}9}$	Public client's willingness to active involvement	0.80	0.96
$CI_{F5\text{-}10}$	Contribution of the SPV's skilled employees	0.71	0.96
$CI_{F5\text{-}11}$	Subcontractors' performance	0.64	0.96
$CI_{F5\text{-}12}$	Suppliers' performance	0.48	0.96
$CI_{F5\text{-}13}$	End-users' willingness to the use of the procured facility	0.47	0.96
Cronbach's alpha: 0.96			
Number of the items: 76			

Appendix G

Appendix G: Estimates of the initially-hypothesised model

Measurement Perspectives and CIs	Loading Estimates	*P*-values
Five Performance Measurement Perspectives		
P1 (F1)	0.78	0.00
P2 (F2)	0.82	0.00
P3 (F3)	0.77	0.00
P4 (F4)	0.75	0.00
P5 (F5)	0.76	0.00
Phase 1 (Initiation and Planning – Business case, EOI, and pre-tendering preparation)		
P102 (CI_{F1-2})	0.68	0.00
P201 (CI_{F2-1})	0.76	0.00
P301 (CI_{F3-1})	0.66	0.00
P303 (CI_{F3-3})	0.69	0.00
P304 (CI_{F3-4})	0.54	0.00
P305 (CI_{F3-5})	0.40	0.13
P306 (CI_{F3-6})	0.51	0.00
P307 (CI_{F3-7})	0.16	0.40
P308 (CI_{F3-8})	0.57	0.01
P309 (CI_{F3-9})	0.54	0.00
P401 (CI_{F4-1})	0.71	0.00
P402 (CI_{F4-2})	0.59	0.00
P403 (CI_{F4-3})	0.78	0.00
P404 (CI_{F4-4})	0.69	0.00
P501 (CI_{F5-1})	0.68	0.00
P502 (CI_{F5-2})	0.73	0.00
P503 (CI_{F5-3})	0.81	0.00
Phase 2 (Procurement – Tendering/Bidding, final negotiation, and financial close)		
P103 (CI_{F1-3})	0.54	0.05
P104 (CI_{F1-4})	0.75	0.00
P202 (CI_{F2-2})	0.76	0.03
P310 (CI_{F3-10})	0.70	0.00
P311 (CI_{F3-11})	0.58	0.01
P312 (CI_{F3-12})	0.34	0.17

P313 (CI_{F3-13})	0.52	0.05
P405 (CI_{F4-5})	0.67	0.00
P406 (CI_{F4-6})	0.65	0.01
P407 (CI_{F4-7})	0.67	0.01
P408 (CI_{F4-8})	0.41	0.26
P505 (CI_{F5-4})	0.77	0.00
P506 (CI_{F5-5})	0.56	0.01
P507 (CI_{F5-6})	0.63	0.01
P508 (CI_{F5-7})	0.64	0.01

Phase 3 (Partnership – Design, Construction, Operation and Maintenance)

P105 (CI_{F1-5})	0.65	0.00
P106 (CI_{F1-6})	0.57	0.02
P107 (CI_{F1-7})	0.64	0.00
P108 (CI_{F1-8})	0.61	0.00
P109 (CI_{F1-9})	0.25	0.11
P110 (CI_{F1-10})	0.61	0.00
P111 (CI_{F1-11})	0.69	0.00
P112 (CI_{F1-12})	0.68	0.00
P203 (CI_{F2-3})	0.74	0.00
P315 (CI_{F3-15})	0.60	0.00
P316 (CI_{F3-16})	0.54	0.00
P317 (CI_{F3-17})	0.50	0.00
P318 (CI_{F3-18})	0.53	0.00
P319 (CI_{F3-19})	0.65	0.00
P320 (CI_{F3-20})	0.82	0.00
P321 (CI_{F3-21})	0.41	0.03
P322 (CI_{F3-22})	0.74	0.00
P323 (CI_{F3-23})	0.66	0.00
P324 (CI_{F3-24})	0.68	0.00
P325 (CI_{F3-25})	0.72	0.00
P409 (CI_{F4-9})	0.75	0.00
P410 (CI_{F4-10})	0.71	0.00
P411 (CI_{F4-11})	0.62	0.01
P412 (CI_{F4-12})	0.51	0.05
P413 (CI_{F4-13})	0.78	0.00
P414 (CI_{F4-14})	0.83	0.00
P415 (CI_{F4-15})	0.81	0.00
P416 (CI_{F4-16})	0.69	0.02
P417 (CI_{F4-17})	0.70	0.00
P418 (CI_{F4-18})	0.67	0.01

P509 (CI_{F5-9})	0.74	0.00
P510 (CI_{F5-10})	0.84	0.00
P511 (CI_{F5-11})	0.64	0.01
P512 (CI_{F5-12})	0.33	0.06
P513 (CI_{F5-13})	0.91	0.00

Appendix H

Appendix H: Estimates of the optimally-revised model

Measurement Perspectives and CIs	**Loading Estimates**	***P*-values**
Five Performance Measurement Perspectives		
P1 (F1)	0.80	0.00
P2 (F2)	0.81	0.00
P3 (F3)	0.79	0.00
P4 (F4)	0.74	0.00
P5 (F5)	0.76	0.00
Phase 1 (Initiation and Planning)		
P102 (CI_{F1-2})	0.69	0.00
P201 (CI_{F2-1})	0.76	0.00
P301 (CI_{F3-1})	0.65	0.00
P303 (CI_{F3-3})	0.66	0.00
P304 (CI_{F3-4})	0.55	0.00
P306 (CI_{F3-6})	0.50	0.00
P308 (CI_{F3-8})	0.55	0.01
P309 (CI_{F3-9})	0.53	0.00
P401 (CI_{F4-1})	0.72	0.00
P402 (CI_{F4-2})	0.60	0.00
P403 (CI_{F4-3})	0.79	0.00
P404 (CI_{F4-4})	0.68	0.00
P501 (CI_{F5-1})	0.66	0.00
P502 (CI_{F5-2})	0.71	0.00
P503 (CI_{F5-3})	0.83	0.00
Phase 2 (Procurement – Tendering/bidding)		
P103 (CI_{F1-3})	0.54	0.05
P104 (CI_{F1-4})	0.75	0.00
P202 (CI_{F2-2})	0.77	0.03
P310 (CI_{F3-10})	0.71	0.00
P311 (CI_{F3-11})	0.56	0.01
P313 (CI_{F3-13})	0.51	0.05
P405 (CI_{F4-5})	0.65	0.01
P406 (CI_{F4-6})	0.63	0.01

P407 (CI_{F4-7})	0.69	0.01
P505 (CI_{F5-4})	0.79	0.00
P506 (CI_{F5-5})	0.56	0.05
P507 (CI_{F5-6})	0.60	0.01
P508 (CI_{F5-7})	0.63	0.01
Phase 3 (Partnership – Design, Construction, Operation and Maintenance)		
P105 (CI_{F1-5})	0.66	0.00
P106 (CI_{F1-6})	0.63	0.00
P107 (CI_{F1-7})	0.62	0.00
P108 (CI_{F1-8})	0.56	0.00
P110 (CI_{F1-10})	0.59	0.00
P111 (CI_{F1-11})	0.66	0.00
P112 (CI_{F1-12})	0.68	0.00
P203 (CI_{F2-3})	0.75	0.00
P315 (CI_{F3-15})	0.61	0.00
P316 (CI_{F3-16})	0.55	0.00
P317 (CI_{F3-17})	0.53	0.00
P318 (CI_{F3-18})	0.55	0.00
P319 (CI_{F3-19})	0.68	0.00
P320 (CI_{F3-20})	0.84	0.00
P322 (CI_{F3-22})	0.75	0.00
P323 (CI_{F3-23})	0.66	0.01
P324 (CI_{F3-24})	0.68	0.01
P325 (CI_{F3-25})	0.70	0.00
P409 (CI_{F4-9})	0.74	0.00
P410 (CI_{F4-10})	0.70	0.00
P411 (CI_{F4-11})	0.61	0.01
P412 (CI_{F4-12})	0.52	0.02
P413 (CI_{F4-13})	0.79	0.00
P414 (CI_{F4-14})	0.83	0.00
P415 (CI_{F4-15})	0.82	0.00
P416 (CI_{F4-16})	0.70	0.00
P417 (CI_{F4-17})	0.69	0.00
P418 (CI_{F4-18})	0.68	0.00
P509 (CI_{F5-9})	0.74	0.00
P510 (CI_{F5-10})	0.84	0.00
P511 (CI_{F5-11})	0.62	0.01
P513 (CI_{F5-13})	0.90	0.00

Appendix I

Appendix I: CIs of the life-cycle model of performance measurement of PPPs

Phases / Constructs	**Initiation and Planning (P1)**	**Procurement (P2)**	**Partnership (P3) (Construction, Operation and Maintenance)**
Stakeholder Satisfaction (F1)	CI_{F1-2}: Skilled employees' satisfaction	CI_{F1-3}: Public client's satisfaction CI_{F1-4}: Skilled employees' satisfaction	CI_{F1-5}: Public client's satisfaction CI_{F1-6}: Skilled employees' satisfaction CI_{F1-7}: General concession contractor's satisfaction CI_{F1-8}: Subcontractors' satisfaction CI_{F1-10}: Shareholders' satisfaction CI_{F1-11}: Creditors' satisfaction CI_{F1-12}: End-users' satisfaction
Strategies (F2)	CI_{F2-1} to CI_{F2-3}: Value for Money (V*f*M) (optimum combination among life-cycle cost, physical and service quality of the asset, and the users' satisfaction)		
Processes (F3)	CI_{F3-1}: Comprehensiveness of macro-environmental analysis (political, economic, social and legal) • $MKPI_1$: Construction price level • $MKPI_2$: Domestic economic conditions • $MKPI_3$: Money market conditions • $MKPI_4$: Level of unemployment • $MKPI_5$: Profitability • $MKPI_6$: Capital market conditions • $MKPI_7$: Population growth • $MKPI_8$: Global economic climate CI_{F3-3}: Effectiveness and efficiency of risk management (e.g., identification, analysis and allocation) CI_{F3-4}: Comprehensiveness of feasibility/business-case study (financing, technical and engineering) CI_{F3-6}: Appropriateness of concessionaire selection criteria CI_{F3-8}: Appropriateness of legal, commercial, technical and engineering structure CI_{F3-9}: Effectiveness of interface management	CI_{F3-10}: Transparency and competitiveness of bidding process CI_{F3-11}: Comprehensiveness and efficiency of final approval and negotiation framework CI_{F3-13}: Effectiveness of interface management	CI_{F3-15}: Proper design and efficient design process CI_{F3-16}: TCQ and material management CI_{F3-17}: Occupational health and safety CI_{F3-18}: Environmental impact of the project CI_{F3-19}: Effectiveness of contract management CI_{F3-20}: Effectiveness and efficiency of dispute solution CI_{F3-22}: Effectiveness of operations management CI_{F3-23}: Effectiveness of facility maintenance and asset condition monitoring CI_{F3-24}: Effectiveness of interface management CI_{F3-25}: Effectiveness of asset residual value management
Capabilities (F4)	CI_{F4-1}: Skilled employees/workforce CI_{F4-2}: Training and learning system CI_{F4-3}: Innovation for strategic planning and process design CI_{F4-4}: Innovation for project financing	CI_{F4-5}: Skilled employees/workforce of the public authority and private SPV CI_{F4-6}: Training and learning systems in the public and private sectors CI_{F4-7}: Innovation for procurement (bidding/tendering)	CI_{F4-9}: Skilled employees/workforce in the private SPV CI_{F4-10}: Training and learning system of the private SPV CI_{F4-11}: Reliability of the finance infrastructure for project delivery and future technical and technological upgrades for handover CI_{F4-12}: Public sector's governance CI_{F4-13}: Advanced technologies and equipment CI_{F4-14}: Innovation for technology CI_{F4-15}: Technology transfer and knowledge management CI_{F4-16}: Appropriateness of professional staff structure CI_{F4-17}: Capability in management of information required for evaluation CI_{F4-18}: SPV's capability in determination of cost-effective product to be installed into the asset
Stakeholder Contribution (F5)	CI_{F5-1}: Public client's performance in the establishment of investment environment CI_{F5-2}: Public client's performance in the establishment of a sound legal framework CI_{F5-3}: Skilled employees' performance/contribution	CI_{F5-4}: Public client contribution to concessionaire selection CI_{F5-5}: Skilled employees' performance/contribution in tendering/bidding CI_{F5-6}: Private contractors' willingness to participation to the project CI_{F5-7}: Shareholders' willingness to participation to the project CI_{F5-8}: Creditors' willingness to participation to the project	CI_{F5-9}: Public client willingness to active involvement CI_{F5-10}: Skilled employees' performance/contribution in SPV CI_{F5-11}: Subcontractors' performance CI_{F5-13}: Users' willingness to the use of the procured asset

Appendix J and K

Appendix J: Questionnaire for the survey of the life-cycle core indicators of PPPs

(Please refer to the following pages for the complete questionnaire)

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Core Performance Indicators of Social Infrastructure PPPs

Aim and Scope of this Survey

This survey aims to validate and obtain information about the derived life-cycle core (performance) indicators (CIs) of social infrastructure Public-Private Partnerships (PPPs). Essentially, effective and comprehensive performance measurement is one of the challenges facing by both the public and private sectors in delivering infrastructure projects by using PPPs, as many of the unsuccessful delivery of PPPs were resulting from an ineffective and incomplete performance evaluations, which has been reported in the literature. Therefore, it is critical for the key project stakeholders of PPPs to develop the CIs associated with the project's life-cycle to ensure Value for Money (V*f*M). The social infrastructures defined here are long-term physical assets that accommodate public social services, e.g., public housings, hospitals, water treatment plants, prisons, car parks, and schools. In this survey, a sequence of innovative CIs have been developed for this survey. The majority of them have received limited attention and been rarely used in the procured PPPs.

To Compete the Survey

For the purposes of the survey, the whole delivery process (life-cycle) of a PPP project is divided into three phases: (1) Initiation & Planning (e.g., ex-ante evaluation, feasibility/business-case study, output definition, and risk allocation); (2) Procurement (e.g., tendering/bidding, final negotiation, contract award, and financial close); and (3) Partnership (e.g., design, construction, operation, and facility maintenance). Accordingly, the CIs to be validated by the survey respondents are used to measure the performances of the entities relating to each particular project phase. For example, the works of the 'Initiation & Planning' are undertaken by the public authority, and therefore the CIs proposed for this phase are designed for evaluating the performances of the projects' public authorities. Analogically, the CIs related to the 'Partnership' phase are devised for the private organisations (e.g., main concessionaires and sub-contractors).

It is important that each question is read carefully and all questions are answered. The survey should take about 15 to 20 MINUTES to complete.

Participants Approached

The survey has been distributed purposively to selected PPP practitioners. You are assured that the information obtained from this survey will be kept strictly CONFIDENTIAL and will be only used for research purposes. Data will not be made available to any third party or used in any published material, except as a component in aggregated statistics.

Report Offered

Upon request, those who participate in the study will receive a free copy of a report summarising the results of this survey. The name and address will be separated from the questionnaire.

Section 1: Background Information

The following questions are designed to provide a background summary of the respondents of this survey. No one other than the Curtin University researcher will have access to the information you provide here. Please check one option for each question.

1. In which State/Country are you situated in?

○ NSW ○ VIC ○ QLD ○ WA ○ SA ○ ACT ○ TAS ○ NT

Others (please specify)

[ ]

2. How long have you been associated with the research/works of PPPs?

○ ≤ 5 years ○ 6 to 10 years ○ 11 to 15 years ○ ≥ 15 years

3. How many social infrastructure PPP projects have you been involved with?

○ ≤ 2 ○ 3 ○ 4 ○ ≥ 5

4. What is your current job title?

[ ]

5. How long is/are the concession period(s) of the social infrastructure PPP project(s) that you have been involved with?

○ ≤ 5 years ○ 6 to 10 years ○ 11 to 15 years ○ 16 to 20 years ○ ≥ 25 years

Others (please specify)

[ ]

6. What is the value of the PPP project(s) you have been involved with (AUD $)?

○ ≤ 50 million

○ 51 to 100 million

○ 101 to 200 million

○ 201 to 300 million

○ ≥ 300 million

Other (please specify)

[ ]

7. Please select your main role in the infrastructure PPP project(s) that you have been involved with?

- [ ] Project Initiation & Planning (i.e., pre-project stages)
- [ ] Project Design
- [ ] Project Tendering/Bidding
- [ ] Project Finance
- [ ] Project Consultations (e.g., finance, business case, and procurement)
- [ ] Project Contract Management
- [ ] PPP Research
- [ ] Project Building/Construction
- [ ] Project Engineering Management
- [ ] Project Evaluations
- [ ] Project Opereations
- [ ] Facility Maintenance/Management
- [ ] Asset Management

Others (please specify)

Section 2: Performance Measurement Perspectives for Social Infrastructure PPPs

This section is designed to identify what performance measurement perspectives should be used to derive relevant performance measures (i.e., CIs) to measure a social infrastructure PPP project.

8. To What extent should the measurement perspectives below to measure the performance of a social infrastructure PPP project

	Not at all	Little extent	Moderate extent	Large extent	Very large extent
Key Project Stakeholder Satisfaction (e.g., public client, concessionaire, subcontractors, shareholders, creditors, and end-users)	○	○	○	○	○
Project Strategy (i.e., Value for Money - VfM)	○	○	○	○	○
Project Delivery Process (e.g., initiation, planning, procurement, design, construction, operations, and facility maintenance/management)	○	○	○	○	○
Capabilities of Involved Organisations/Partities (e.g., PPP delivery experience, workforce, finance reliability, training and learning system, and technology transfer ability)	○	○	○	○	○
Key Project Stakeholder Contributions (e.g., public client, subconstractors, and end-users)	○	○	○	○	○

Section 3: Performance Indicators of the Initiation & Planning Phase of PPPs

This section is designed to identify the importance of the CIs used for measuring the performance of PPP Initiation & Planning phase (i.e., ex-ante evaluation, feasibility/business-case study, output definition and risk allocation).

9. To what extent should the following factors be used to measure the performance of the Initiation & Planning phase?

	Not at all	Little extent	Moderate extent	Large extent	Very large extent
Public client's satisfaction during Initiation & Planning phase	○	○	○	○	○
Satisfactions of skilled employees (who are in public authority and external advisor teams) (i.e., occupational health, safety, and workplace environment)	○	○	○	○	○
Value for Money (VfM) assessment	○	○	○	○	○
Comprehensiveness of macro-environment assessment (political, economic, legal & environment)	○	○	○	○	○
Appropriateness of the definition on service needs & desired outputs	○	○	○	○	○
Effectiveness and Efficiency of risk identification, analysis, and allocation	○	○	○	○	○
Comprehensiveness of feasibility/business-case study (e.g., financing, technical & engineering)	○	○	○	○	○
Appropriate finance option	○	○	○	○	○
Appropriateness of concessionaire selection criteria	○	○	○	○	○
Appropriateness of concession period	○	○	○	○	○

	Not at all	Little extent	Moderate extent	Large extent	Very large extent
Appropriateness of legal, commerical, technical & engineering structures	◯	◯	◯	◯	◯
Effectiveness of interface management (i.e., communication and coordination between different organisations & project phases)	◯	◯	◯	◯	◯
Skilled workforce	◯	◯	◯	◯	◯
Effective training and learning system	◯	◯	◯	◯	◯
Innovation for strategic planning and process design	◯	◯	◯	◯	◯
Innovation for project financing	◯	◯	◯	◯	◯
(Public sector's) Support in establishing a favourable investment environment	◯	◯	◯	◯	◯
(Public sector's) Support in establishing a sound legal framework	◯	◯	◯	◯	◯
Skilled employees contribution to the project's initiation and planning (who are in public authority and external advisor teams) (e.g., project director's or advisors' creative ideas for the project's planning and management)	◯	◯	◯	◯	◯

Section 4: Performance Indicators of the Procurement Phase of PPPs

This section is designed to identify the importance of the CIs used for measuring the performance of PPP Procurement phase (i.e., tendering/bidding, final negotiation, contract award and financial close).

10. To what extent should the following factors be used to measure the performance of the Procurement phase?

	Not at all	Little extent	Moderate extent	Large extent	Very large extent
Public client's satisfaction	○	○	○	○	○
Skilled employees' satisfaction	○	○	○	○	○
Value for money relating to bidding	○	○	○	○	○
Transparency and competitiveness of bidding process	○	○	○	○	○
Efficiency of approval and negotiation processes	○	○	○	○	○
Effectiveness and efficiency of financial close	○	○	○	○	○
Effectiveness of interface management (i.e., communication & coordination between different organisations and project phases)	○	○	○	○	○
Skilled workforce	○	○	○	○	○
Effective training and learning system (for updating employees' skills)	○	○	○	○	○
Innovation for tendering/bidding	○	○	○	○	○
(Public client's) Governance for the process of bidding/tendering	○	○	○	○	○
Public authority's contribution to concessionaire selection	○	○	○	○	○

	Not at all	Little extent	Moderate extent	Large extent	Very large extent
Skilled employees' contributions (i.e., project manager's or advisors' innovative ideas for bidding/tendering)					
Private entities' willingness to the participation to the project					
Shareholders' willingness to the participation to the project					
Creditors' willingness to the participation to the project					

Section 5: Performance Indicators of the Partnership Phase of PPPs

This section is designed to identify the importance of the CIs used for measuring the performance of the PPP Partnership phase (i.e., design, construction, operations and maintenance).

11. To what extent should the following factors be used to measure the performance of the Partnership phase?

	Not at all	Little extent	Moderate extent	Large extent	Very large extent
Public client's satisfaction	◯	◯	◯	◯	◯
Satisfactions of skilled employees (who are in integrated organisations) (i.e., main concessionaire, subcontractors, operators,and facility management group)	◯	◯	◯	◯	◯
Concessionaire's satisfaction	◯	◯	◯	◯	◯
Subcontractors' satisfaction	◯	◯	◯	◯	◯
Building product suppliers' satisfaction	◯	◯	◯	◯	◯
Shareholders' satisfaction	◯	◯	◯	◯	◯
Creditors' satisfaction	◯	◯	◯	◯	◯
End-users' satisfaction	◯	◯	◯	◯	◯
Value for money throughout the concession period	◯	◯	◯	◯	◯
Complicance of legal and regulatory framework	◯	◯	◯	◯	◯
Proper design and efficient design process (e.g., innovation and sustainability)	◯	◯	◯	◯	◯
(Construction) Time, cost, quality and material management	◯	◯	◯	◯	◯
Occputional health and safety	◯	◯	◯	◯	◯

	Not at all	Little extent	Moderate extent	Large extent	Very large extent
Environmental impact of the project	○	○	○	○	○
Effectiveness of contract management	○	○	○	○	○
Effectiveness and efficiency of dispute solution	○	○	○	○	○
Asset's profit and profitability	○	○	○	○	○
Effectiveness of operations management	○	○	○	○	○
Effectiveness of facility maintenance and asset condition monitoring	○	○	○	○	○
Effectiveness of asset residual value management	○	○	○	○	○
Effectiveness of interface management (i.e., communication & coordination between involved organisations and project phases)	○	○	○	○	○
Skilled workforce	○	○	○	○	○
Effective training and learning system (for updating employees' skills)	○	○	○	○	○
Reliability of finance infrastructure for project delivery and future technical technological upgrades for handover	○	○	○	○	○
Governance for the on-going project	○	○	○	○	○
Advanced technologies and equipments for construction and facility management	○	○	○	○	○
Innovation for technologies and management	○	○	○	○	○
Abilities in technology transfer and knowledge management	○	○	○	○	○

	Not at all	Little extent	Moderate extent	Large extent	Very large extent
Appropriateness of professional staff structure	○	○	○	○	○
Capability in managing the information required for project performance evaluation	○	○	○	○	○
SPV's capability in the determination of cost-effective building product to be installed into the asset	○	○	○	○	○
Public client's willingness to active involvement (supports)	○	○	○	○	○
Contributions of skilled employees (who are in integrated organisations) (i.e., project team's innovation for design, construction, operations, and facility management)	○	○	○	○	○
Subcontractors' performance	○	○	○	○	○
Suppliers' performance	○	○	○	○	○
End-users' willingness to the use of the asset	○	○	○	○	○

Section 6: General Comments

12. This section provides you with an opportunity to generally comment on the survey as well as the issues that were raised. Please also provide details of any issues that you feel they are critical but were not addressed throughout the survey.

END OF THE SURVEY

THANK YOU VERY MUCH FOR YOUR TIME AND ASSISTANCE IN COMPLETING THE SURVEY!

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