

# Northumbria Research Link

Citation: Zhao, Jianfeng, Liu, Henry, Sing, Michael C. P., Jin, Xiaohua and Humphrey, Richard (2019) VfM assessment of transport PPPs: Implications for future improvement. In: Proceedings of the 43rd Australasian Universities Building Education Association (AUBEA) Conference. Central Queensland University, North Rockhampton, Australia, pp. 170-180. ISBN 9781921047510

Published by: Central Queensland University

URL: [https://figshare.com/articles/book/43rd\\_AUBEA\\_Aust...<https://figshare.com/articles/book/43rd\\_AUBEA\\_Australasian\\_Universities\\_Building\\_Education\\_Association\\_Conference\\_Proceedings\\_6-8\\_November\\_2019\\_RACV\\_Noosa\\_Resort\\_Noosa\\_QLD\\_Australia/13455515/1>](https://figshare.com/articles/book/43rd_AUBEA_Aust...<https://figshare.com/articles/book/43rd_AUBEA_Australasian_Universities_Building_Education_Association_Conference_Proceedings_6-8_November_2019_RACV_Noosa_Resort_Noosa_QLD_Australia/13455515/1>)

This version was downloaded from Northumbria Research Link:  
<http://nrl.northumbria.ac.uk/id/eprint/41010/>

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: <http://nrl.northumbria.ac.uk/policies.html>

This document may differ from the final, published version of the research and has been made available online in accordance with publisher policies. To read and/or cite from the published version of the research, please visit the publisher's website (a subscription may be required.)

# VFM ASSESSMENT OF TRANSPORT PPPs: IMPLICATIONS FOR FUTURE IMPROVEMENT

Jianfeng Zhao<sup>1</sup>, Henry J. Liu<sup>1</sup>, Michael C.P. Sing<sup>2</sup>, Xiaohua Jin<sup>3</sup>, Richard Humphrey<sup>1</sup>

<sup>1</sup>Department of Architecture and Built Environment, Northumbria University, Newcastle upon Tyne, United Kingdom

<sup>2</sup>School of Architecture and Built Environment, The University of Newcastle, Callaghan, Australia

<sup>3</sup>School of Computing, Engineering and Mathematics, Western Sydney University, Kingswood, Australia

---

## Abstract

Public-Private Partnerships (PPPs) have been adopted to deliver transport infrastructure assets worldwide, attributing to governments' increasingly limited fiscal budget. However, the key issue about whether PPPs can provide taxpayers with better value for money (VfM) is still under controversy. As an integral component of infrastructure procurement process, VfM assessment acts as an essential stage of governments' ex-ante evaluation for the use of PPPs. Despite this, relevant empirical research, especially within the context of transport infrastructure, has received limited attention. Against this backdrop, a total of 3 case studies of the Australian transport PPP projects has been undertaken and the SWOT analysis was conducted to examine the current practice in VfM assessment. The empirical evidence indicates that the approach being used by the Australian state governments for assessing VfM fails in addressing a critical perspective in terms of the improved service quality to be generated by private-sector entities. Based on this finding, a novel VfM-oriented decision-making model that is underpinned by the Dynamic Discrete Choice Model (DDCM) has been proposed. This paper contributes to the body of knowledge of PPPs VfM assessment and is significant for improving industry practice in decision making of procurement selection for transport assets.

## Keywords

PPPs, Transport PPPs, VfM assessment, decision making, SWOT analysis, case study

## Introduction

PPPs have been widely used to procure transport infrastructure due to the governments' limited budget (Reeves 2015; Penyalver, Turro & Williamson 2019). For example, \$20 billion has been invested into PPPs since 2014 in New South Wales (NSW), Australia and more than 100 transport projects have been procured through the use of PPPs from 1980 to 2017 in Australia (NSW Treasury 2017; Department of Infrastructure and Regional Development 2017). Fundamentally, PPPs are considered as being a procurement method that can potentially generate such benefits as increased efficiency, competitive public services and risk sharing (McQuaid & Scherrer 2010; Appuhami, Perera & Perera 2011). However, they have been subjected to controversy, owing to a number of issues such as cost overruns, lengthy tendering and negotiation, inappropriate risk transfer and conflicting interests among stakeholders (Song et al. 2019). Therefore, VfM has been a critical criterion for governments to make a decision about whether or not PPPs can be adopted.

In this regard, the national guidelines of VfM assessment used for justifying the use of PPPs have been published in many developed countries such as Australia and the United Kingdom (UK) (HM Treasury 2006; Department of Infrastructure and Regional Development 2008). VfM in these documents is defined as "the optimum combination of whole-of-life costs and quality (fit for purpose) of the good or service to meet users' requirement". It is required that the Net Present Value (NPV) of a Public Sector Comparator (PSC) and that of a PPP option should be compared and whichever is lower is deemed

favourable (Henjewe, Sun & Fewings 2012). Nonetheless, this approach is criticised as being vulnerable to manipulation, asymmetric comparison and incomplete evaluation (Murphy 2008; DeCorla-Souza & Farajian 2017; Opara 2018). Several studies have been conducted to identify the disadvantages of the PSC (Ng, Wong & Wong 2012; Decorla-Souza et al. 2017; Penyalver et al. 2019). But extant literature lacks empirical research to investigate how to improve current practice in VfM assessment of PPPs. Against this backdrop, this study aims to propose a novel VfM-oriented decision-making model by undertaking a case study of three Australian transport PPP projects and then a SWOT analysis for their VfM assessments.

## **Research on VfM assessment**

VfM is a critical concept in the literature of infrastructure procurement. Yuan et al. (2009) identified a total of 15 process factors useful for measuring if PPPs are value for money. Moreover, Robinson and Scott (2009) contended that VfM is largely determined by the effectiveness of the asset's operational performance monitoring system. In addressing this, Liu et al. (2018) proposed a life-cycle performance prism to evaluate PPPs with the aim of ensuring value for money.

Essentially, VfM has been viewed as a terminology concerning life-cycle cost savings within the context of PPPs (e.g. Grimsey & Lewis 2005; Shaoul 2005; Morallos & Amekudzi 2008; Siemiatycki & Farooqi 2012 and Opara 2018). Consequently, VfM assessment is essential for the decision making of infrastructure projects to identify an appropriate procurement method.

## **Case study: Current practice in VfM assessment in Australia**

Case study has been applied in this paper as it is acknowledged as being an approach suitable for all stages of a research program, such as the generation of new knowledge (Flyvbjerg 2006). In order to propose a new model, a total of 3 transport projects based in NSW have been selected to conduct the case study, including the Cross City Tunnel (CCT), Lane Cove Tunnel (LCT) and North West Rail Link (NWRL).

### **Case background**

The Cross City Tunnel (CCT) project incorporates a 2.1km twin-tunnel toll road, which links Darling Harbour of Sydney CBD to Rushcutters Bay, NSW. It is under a 33-year DBFOM (design-build-finance-operate-maintain) contract that is up to a value of AU\$680 million, running from December 2002 to December 2035. The CCT project is being operated by a private entity (Transurban) and engaged with a series of public-sector parties such as Minister for Roads, Treasury and NSW Roads and Marine Services (RMS) (project client). Similarly, the Lane Cove Tunnel (LCT) is a project based in NSW and is under the DBFOM contract (i.e. contract value AU\$1.1 billion) valid from December 2003 to January 2037. The LCT is a 3.6km-long motorway in twin tunnels connecting Epping Road Bridge crossing to Gore Hill Freeway, Artarmon. This project is also being operated by Transurban with a partnership of such public-sector organisations as NSW Minister for Roads, Rail Corporation and RMS (project client). In addition to CCT and LCT, another NSW-based project being studied in this paper is the Sydney North West Rail Link (NWRL), where the relevant contract is associated with a total value of AU\$3.7 billion and a term from September 2014 and April 2034. The NWRL is approximately 15.5 kilometres, which connects Cudgegong Road, Rouse Hill and Chatswood, and it incorporates a total of eight new stations. This project encompasses three major contracts, including a: (1) D&C (design and construct) contract of the tunnel and station civil works package that has been awarded to the Thiess, John Holland and Dragados Joint Venture; (2) D&C contract of the surface and viaduct civil works package to be delivered by Impregilo Salini Joint Venture; and (3) PPP contract between the Transport for NSW (public authority) and NRT Pty Ltd for the operations, trains and systems package.

## Current VfM assessment practice

During the decision-making stage of procurement selection, the three PPP projects introduced above had undergone a VfM assessment that was performed by the NSW state government. As stated in the ‘Summaries of Contract Change’ of the CCT projects, the NSW RMS’s VfM assessment was primarily relying on (NSW Government, 2008, p.4):

... a ‘comparative value’ assessment against a PSC – a hypothetical, risk-adjusted estimate of the net present cost of delivering the project, to the same level and standard of service, using the most efficient likely form of delivery able to be financed by the public sector ...

Essentially, the ‘Updated Summary of Contracts’ of the LCT has a statement that is same as above, indicating that the project’s VfM assessment in terms of the decision making of selection of procurement method relating to PPPs is a cost-focused comparison depending on the PSC. A detailed statement (shown as below) about the VfM assessment can be identified in the footnote of the LCT contract summary (NSW Government, 2010, p.8).

.. For a ‘public sector comparator’ based on the most efficient likely form of delivery of the Lane Cove Tunnel project able to be financed by the public sector, the estimated net present value of the normalised risk-adjusted financial cost of the project to the RMS, using 10 September 2003 interest rates, was \$193.2 million. In contrast, the delivery of the project by the private sector, in accordance with the rights, obligations and risk allocations described in this report, was expected to result in a significant net financial benefit to the RMS, with the financial costs of the project to the RMS being outweighed by a substantive transfer of risks to the private sector.

In the NWRL project, which is a more recent project passing the financial close in September 2014, the relevant VfM assessment also relied on the PSC. The official ‘Contract Summary’ of the NWRL has statements presented as follows (Transport NSW, 2014, pp.12-13).

... the 'Public Sector Comparator' (PSC) provides a hypothetical estimate of the risk adjusted cost of the project if it (i.e. NWRL) were to be designed, built and operated by the State. To develop the estimate, the PSC was based on a reference project developed by the State, consistent with the Specified Performance Requirements ...

... the present value of the OTS PPP was evaluated using a discount rate that included a systematic risk premium of 1.40%, in accordance with NSW Treasury policies on the assessment of complying proposals ...

To provide more detailed information, Table 2 summarises the PSC-based VfM assessment of the NWRL project. It can be noted that the NSW state government’s decision making for applying PPPs to the NWRL project was based on ‘financial benefit’.

Table 1: PSC-based VfM Assessment of the NWRL project

<i>Cost Category</i>	<i>PSC (NPC \$m)</i>	<i>PPP (NPC \$m)</i>	<i>Cost Savings (NPC \$m)</i>	<i>Cost Savings (%)</i>
<i>D&amp;C cost</i>	2,911.9	2,893.7	(-18.2)	(0.5%)
<i>O&amp;M cost</i>	1,178.1	872.7	(-305.4)	(8.1%)
<i>Total costs</i>	4090.0	3,766.4	(-323.6)	(8.6%)
<i>Transferred risk</i>	488.8	<i>Include above</i>	-	-
<i>Total NPC</i>	4,578.8	3,766.4	(-812.4)	(21.6%)

(Source: Transport for NSW, 2014)

## SWOT analysis

It can be identified from the case study above that the method being applied for VfM assessment of the three NSW-based transport PPP projects were primarily focused on cost savings to be yielded from an involvement of private-sector entities. Essentially, this kind of assessment is dominating in 17 out of 22 countries according to a survey that was conducted by Leigland (2018). To further interpret current VfM assessment practice, the SWOT analysis for the PSC is conducted for the purpose of identifying implications for future improvements.

### Strengths

S<sub>1</sub> – Benefits measuring: Governments embarking on PPPs need to demonstrate their potential benefits as they represent the interest of the public (Broadbent & Laughlin 2004). The qualitative aspect of the PSC has addressed service quality, regional development, time saving and environmental and intergenerational impacts, and taken into account tariff level, cost effectiveness, financial attractiveness, public support and transparent procurement process (Ng et al. 2012; Almarri & Boussabaine 2017; Penyalver et al. 2019). By contrast, the quantitative side of the PSC has alleviated the tight wallet of public sectors (Cheung, Chan & Kajewski 2009). For example, an average saving of 15% for roads and 2-4% for schools and hospitals respectively has been revealed (Opara 2018).

S<sub>2</sub> – Choices making: The primary objective of the PSC is to facilitate the decision making of governments in terms of what is an appropriate procurement method (Gopalkrishna & Karnam 2015). In this regard, it draws a comparison between the NPV of PPP life-cycle cost or shadow bidding price (SBP) and that of a PSC, and whichever is lower is postulated to be the ‘winner’ (Zwalf, Hodge & Alam 2017; Kweun, Wheeler & Gifford 2018). Therefore, the PSC has been widely adopted worldwide.

S<sub>3</sub> – Less complex and more specialised: Compared with massive information and hypotheses required in cost-benefit analysis, a simple spreadsheet is sufficient to instigate explicit result of PSC (OECD 2008). Furthermore, the PSC is a binomial targeting at the selection between PPPs and conventional public sector procurement (PSP), making it more specialized and pinpoint (Dewulf, Blanken & Bult-Spiering 2012; Leigland 2018). Occasionally, in a procurement market where competition is weak and/or dynamic assessment is needed (SBP and actual bidding price) (Mols 2010), the PSC can still function well and the statistics used for indicating whether the proposed projects are VfM are easy to compile and to be understood by key stakeholders (OECD 2008; Ren et al. 2019).

## Weaknesses

W<sub>1</sub> – Asymmetric comparison: First, the PSC is a hypothetical scenario where governments are in charge of financing, building and asset operations (Connolly, Martin & Wall 2008). It is thus meaningless in comparing the hypothetical with an actual bidding of PPP (Gopalkrishna & Karnam 2015). Second, although it's a comparison between the PSC and SBP where pricing is an estimate value before actual bidding, there is disparity in the use of different discount rate (Zwalf et al. 2017). For example, governments may prefer a social discount rate in the PSC, while private-sector consortia request the weighted average cost of capital (Decorla-Souza et al. 2016; Zwalf et al. 2017). Third, project is assumed to be risk-free in conventional PSP while risks can be transferred to private sectors in PPPs. In fact, the risks and corresponding costs in conventional PSP are underwritten by taxpayers and those in PPPs are offset through private sector's reasonable profit or governments' compensation over time (Murphy 2008). Put it simply, it is unclear who pays the cost. Therefore, Murphy (2008) concluded that comparison benchmark is false and should be substituted by the net benefit rather than cost.

W<sub>2</sub> – Contentious discount rate: Central to the calculation of the PSC is the selection of a reasonable discount rate (Zwalf et al. 2017), which is however criticised as being 'contentious' (Quiggin 2004; Peng et al 2014). For instance, in the UK, the discount rate of the PSC was initially assigned to 7% and then was decreased to 6% and 3.5% eventually (Hodgson & Corrigan, 2005). This change incurs the underestimate of PPPs and overstate of the PSC, which are beneficial to private sector but generate risk to government (Opara et al. 2017).

W<sub>3</sub> – Subjective assumptions and inaccurate estimate: An assumption in the PSC is that PPPs can provide better services than the PSP, utilising same or less resources (cost and time). However, many PPPs have experienced time and budget overruns, poor performance and even contract termination (Vining & Boardman 2014). For example, Blanc-Brude, Goldsmith and Vålilä (2009) proved that PPPs are more expensive than conventional PSP by 24% in European road projects. Moreover, another core aspect in the PSC is risk transfer (Ball & King 2006). But, risk transfer can be unsuccessful, as relevant risk quantification and analysis are inaccurate (Aldrete, Bujanda & Valdez 2012). Cases have been reported that disproportioned risk transferred to private sector has led to the decrease of ridership and poor service quality in transport projects (Siemiatycki and Friedman, 2012; Mouraviev and Kakabadse, 2014). Moreover, a series of other issues have been identified, including the lack of (1) sustainability; (2) social benefits; and (3) transaction costs (Patil & Laishram 2016; DeCorla-Souza & Farajian 2017; Opara & Rouse 2019), causing the invalidity of the PSC.

## Opportunities

O<sub>1</sub> – Prosperous market: The demand for building new infrastructure and rehabilitating aging assets is increasing (Sing, Love & Liu 2019). More than £600 billion has been spent to different infrastructure sectors in the UK since 2018, involving transport, hospitals and schools (HM Treasury 2018). In the era of new public management, expectations from the public are relating to high-quality services, improved government accountability and performance (Opara & Rouse 2019). With this, government's concern has been changed to seeking an economic, effective and efficient procurement approach (McKevitt & Davis 2016). Thus, it is anticipated that the PSC will be ameliorated and harnessed for decision making.

O<sub>2</sub> – Scientific and technique stimulus: Due to the irreplaceable position, significant efforts have been made to improve VfM assessment in infrastructure procurement (Tsamboulas, Verma & Moraiti 2013; Jasiukevicius & Vasiliauskaite 2018). These cover the establishment of a qualitative assessment framework, discount rate selection, data exchange and risk pricing (Ng et al. 2012; Zwalf et al. 2017; Makovšek & Moszoro 2018; Ren et al. 2019). Although debate about VfM assessment has not been diminished, such aforementioned actions will further stimulate the development of other techniques, such as the simulation of all benefits of transport projects, to supplement the PSC.

## Threats

T<sub>1</sub> – Ideological bias and manipulation: An critical principle of choosing an appropriate procurement method is that no predetermined preference should exist (Eadie, Millar & Toner 2013). Essentially, PPPs are more preferred than conventional PSP under certain ideological bias (Loxley 2012). For example, guarantees and subsidies are promised to attract private sectors in order to enable PPPs to be the ‘only game in town’ (Reeves 2011; Bayliss & Van Waeyenberge 2018). The PSC under this situation is forced to be more expensive than PPPs, and this can easily be realised by manipulating calculation in the spreadsheet (Hodgson & Corrigan 2005; Wall & Connolly 2009; Whiteside 2019). The bias and manipulation may be the corollary of the constrained budget and desire to keep investment off balance sheet, and they tarnish VfM assessment and result in the sacrifice of social welfare (Vining & Boardman 2014; Opara et al. 2017).

T<sub>2</sub> – Opaque information: There is a concern that information about how VfM is assessed by the governments is unavailable to the public in some regions/countries, e.g., Alberta, Canada, Ireland and Belgium (Reeves 2015; Opara et al. 2017; Willems et al 2017). The aftermath of opaque information is binary. First, infrastructure investment will fall short of scrutiny and the above discussed manipulation will become a ‘new normal’ (Reeves 2015). Second, there is a risk that project or corporate bankruptcy and chaos may happen (Whiteside 2019). A solution proffered by Opara (2018) is disclosing the components of the PSC before the contract is signed.

## A novel VfM-oriented decision-making model

According to the analysis results, it is obvious that the current VfM assessment within the context of transport infrastructure procurement focuses primarily on cost comparison and does not address the relationship between two critical aspects that are related to key stakeholders’ expectations (e.g. client and asset end-users), i.e., improved service quality and enhanced asset usage (after introducing private sector into the asset procurement), which have been identified as critical in transport (Department for Transport, 2017; Liu et al., 2018). As a result, there is a need for developing a new method to supplement extant VfM assessment for the decision making of PPP option.

VfM in terms of government’s selection for an appropriate procurement method for transport infrastructure is referred to as a concept with regard to maximizing values to taxpayers by: (1) saving costs from public money and/or (2) enhancing asset service to better satisfy the public’s transport demand (i.e. an improved functionality) throughout the project’s dynamic life-cycle (Macário, Ribeiro & Costa 2015). This definition enables an ideal environment to apply the Dynamic Discrete Choice Model (DDCM), which is developed from the Random Utility Maximization (RUM) theory and is helpful for an ‘economic agent’ to efficiently make a proper choice that is capable of maximizing the value to satisfy relevant key stakeholders over change of time (McFadden 1977).

Mathematically, DDCM can be represented as Equation (1) below:

$$V(x_{n0}) = \max_{\{d_{nt}\}_{t=1}^T} E \left( \sum_{t=1}^T \sum_{i=1}^J \beta^{t-t} (d_{nt} = i) U_{nit}(x_{nt}, \varepsilon_{nit}) \right) \quad \text{Equation 1}$$

where  $x_{nt}$  represents state variables,  $x_{n0}$  is the agent’s initial condition;  $d_{nt}$  is  $n'$  decision from among  $J$  discrete alternatives;  $U_{nit}$  stands for the flow utility; and  $T$  denotes the time horizon. As this is a choice between PPPs and conventional PSP, a binomial logit decision-making model derived from Equation (1) can be developed to modelling the choice of the use of PPPs in terms of the private sector’s contribution to asset usage through an improved service quality.

$$u_{ijt} = \text{Logit} \left( \frac{P_{ijt}}{1 - P_{ijt}} \right) = \alpha + \alpha_1^{x_{ijt}^o} x_{ijt}^o + \zeta_{ijt} \quad \text{Equation 2}$$

where  $u_{ijt}$  denotes the utility government  $i$  can gain from the decision  $j$  ( $j=1$ , PPPs are favoured;  $j=0$ , traditional procurement method may be better) at time  $t$ ;  $P$  stands for probability;  $\alpha$  is a constant;  $\alpha_1^{x_{ijt}^o}$  is the coefficient that indicates functionality  $x_{ijt}^o$ 's impact on  $u_{ijt}$ ; and  $\zeta_{ijt}$  is a random vector depending on  $i, j, t$ , indicating the impacts of unobservable dynamic issues on the economic agent's decision making.

To further develop Equation (2),  $x_{ijt}^o$  can be expanded by introducing an 'impact factor' ( $x_o$ ) and an initial traffic volume ( $VOL_{kqm}$ ) (i.e. Traffic volume has been widely used in practice as a proximity variable to forecast asset usage (i.e. transport demand) (Department for Transport, 2017) to estimate the relationship between private-sector-provided service and asset usage (traffic volume).  $x_o$  is simulated through a process of adapting the Bayesian Networks (BN) (which is demonstrated below) with an input variable of service quality ( $x_s$ ). In other words,  $x_{ijt}^o$  in Equation (2) is a variable comprising: (1) service quality ( $x_s$ ); (2) transport demand represented by traffic volume ( $VOL_{kqm}$ ); and (3) an impact factor ( $x_o$ ) mathematically representing the causal relationship between  $x_s$  and  $VOL_{kqm}$ . The service quality ( $x_s$ ) can be viewed as end-user satisfaction, which has been acknowledged as being an important key performance indicator of the service provided by transport systems (Mouwen 2015; Yuan, Ji, Guo & Skibniewski 2018).

The BN-based modelling in this study is developed with an assumption proposed by (Sun, Zhang & Yu 2006), who assumed that factors determining the observed volume are independent of each other. Therefore, let (s, o) be a partition of the node indices of the BN, so that it converts to disjointed subsets, and then let ( $x_s, x_o$ ) be a partition of the corresponding variables. Accordingly, the marginal probability of  $x_s$  can be written as:

$$p(x_s) = \sum_{x_o} p(x_s, x_o) \quad \text{Equation 3}$$

Consequently, the conditional probability  $p(x_o|x_s)$  derived from BN can be reformulated as:

$$p(x_o | x_s) = \frac{p(x_o, x_s)}{p(x_s)} = \frac{p(x_o, x_s)}{\sum_{x_o} p(x_s, x_o)} \quad \text{Equation 4}$$

With a reference to the Gaussian mixture model (Sun et al. 2006) and a lemma proved in Rao (1973), Equation (4) can be further represented as below.

$$p(x_o | x_s) = \sum_{l=1}^M \beta_l G(x_o; \mu_{l|o|s}, \sum_{l|o|s}) \quad \text{Equation 5}$$

where  $G(x_o; \mu_{l|o|s}, \sum_{l|o|s})$  is a multidimensional normal density function with mean  $\mu_{l|o|s}$  and covariance matrix  $\sum_{l|o|s}$ ;

$$\begin{aligned} \beta_l &= \frac{\alpha_l G(x_s; \mu_{l|s}, \sum_{l|ss})}{\sum_{j=1}^M \alpha_j G(x_s; \mu_{j|s}, \sum_{j|ss})} \\ \mu_{l|o|s} &= \mu_{l|o} - \sum_{l|os} \sum_{l|ss}^{-1} (\mu_{l|s} - x_s) \\ \sum_{l|o|s} &= \sum_{l|oo} - \sum_{l|os} \sum_{l|ss}^{-1} \sum_{l|so} \end{aligned} \quad \text{Equation 6}$$

And, an optimal forecasting of  $x_o$  after the calculation of minimum mean square error equals to:

$$\begin{aligned}
x_o &= E(x_o | x_s) = \int x_o p(x_o | x_s) dx_o \\
&= \sum_{l=1}^M \beta_l \int x_o G(x_o; \mu_{l|o|s}, \sum_{l|o|s}) dx_o = \sum_{l=1}^M \beta_l \mu_{l|o|s}
\end{aligned} \tag{Equation 7}$$

Finally,  $x_o$  is integrated into the annual average daily traffic AADT forecasting method (US Department of Transportation, 2018) to forecast  $x_{ijt}^o$ , being represented as:

$$x_{ijt}^o = \frac{1}{12} \sum_{m=1}^{12} \left[ \frac{1}{7} \sum_{q=1}^7 \left( \frac{1}{n_{qm}} \sum_{k=1}^{n_{qm}} VOL_{kqm} \right) \right] \left( 1 \pm \sum_{l=1}^M \beta_l \mu_{l|o|s} \right) \tag{Equation 8}$$

where  $VOL_{kqm}$  is the daily volume for  $k^{\text{th}}$  occurrence of the  $q^{\text{th}}$  day (1 to 7) of week within the  $m^{\text{th}}$  month (1 to 12);  $k$  is occurrences of day  $q$  in month  $m$  for which traffic data are available; and  $n_{qm}$  is number of occurrences of day  $q$  in month  $m$  for which traffic data is available.

To integrate the elements presented from Equations (3) to (8) into Equation (2), a decision-making model therefore can be finalized as Equation (9) below:

$$u_{ijt} = \text{Logit} \left( \frac{P_{ijt}}{1 - P_{ijt}} \right) = \alpha + \alpha_1^{x_{ijt}^o} \frac{1}{12} \sum_{m=1}^{12} \left[ \frac{1}{7} \sum_{q=1}^7 \left( \frac{1}{n_{qm}} \sum_{k=1}^{n_{qm}} VOL_{kqm} \right) \right] \left( 1 \pm \sum_{l=1}^M \beta_l \mu_{l|o|s} \right) + \zeta_{ijt} \tag{Equation 9}$$

The final decision of an ‘economic agent’ (i.e., a public authority embarking on PPPs) is based on the result to be generated from Equation (9). In alignment with the RUM theory, if there exit  $l$  and  $m$  ( $l$  and  $m \in j$ ), the phenomenon represented as Equation (10) will be enabled and then an alternative procurement method  $l$  is estimated to be more effective than the other option.

$$D_{ijt} = P(u_{ilt} > u_{imt}, \forall l \neq m) \tag{Equation 10}$$

## Conclusion

PPPs have been an integral strategy of governments’ procurement of transport infrastructure worldwide. VfM assessment, as a critical stage of the development process of PPPs, plays a decisive role in ensuring future success of the projects. However, relevant empirical research into this field is limited, particularly within the context of transport infrastructure. Thus, this paper has undertaken a total of three case studies of the Australian transport PPPs followed by a SWOT analysis for current practice in VfM assessment.

Empirical evidence has demonstrated that existing VfM assessment concentrates only on the comparison between the NPV of PSC and that of PPPs. The salient features of transportation, such as service quality and traffic volume, are neglected. The results of the SWOT analysis further indicate that the PSC is unable to provide a comprehensive evaluation ( $W_3$ ) and is subjected to asymmetric comparison ( $W_1$ ) and inaccurate discount rate ( $W_2$ ). In addition, the PSC can easily be manipulated to be preference of PPPs ( $T_1$ ) and the information about how VfM assessment is undertaken is not transparent to the public ( $T_2$ ). Therefore, it is imperative that new models should be developed to address them and to supplement the use of the PSC.

Based on the case study and SWOT, a new VfM-oriented decision-making model is proposed, encompassing the components of service quality, traffic demand and an impact factor that represents their causal relationship ( $O_2$ ). This model can be used to supplement current VfM assessment ( $S_1$ - $S_3$ ) and shed light on improvement of future practice in PPPs. Future research will be focused on testing the feasibility of the developed model.

## References

- Aldrete, R, Bujanda, A & Valdez, GA. 2012, *Valuing public-sector revenue risk exposure in transportation public-private partnerships*, Article, <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84988515235&doi=10.3141%2f2297-11&partnerID=40&md5=afa3b3033905adb91b14cdee4184432c>.
- Almarri, K & Boussabaine, H. 2017, 'The Influence of Critical Success Factors on Value for Money Viability Analysis in Public-Private Partnership Projects', *Project Management Journal*, vol. 48, pp. 93-106.
- Appuhami, R, Perera, S & Perera, H. 2011, 'Coercive policy diffusion in a developing country: The case of public-private partnerships in Sri Lanka', *Journal of Contemporary Asia*, vol. 41, no. 3, pp. 431-51.
- Ball, R & King, D. 2006, 'The private finance initiative in local government', *Economic Affairs*, vol. 26, no. 1, pp. 36-40.
- Bayliss, K & Van Waeyenberge, E. 2018, 'Unpacking the Public Private Partnership Revival', *Journal of Development Studies*, vol. 54, no. 4, pp. 577-93.
- Blanc-Brude, F, Goldsmith, H & Väilä, T. 2009, 'A comparison of construction contract prices for traditionally procured roads and public-private partnerships', *Review of Industrial Organization*, vol. 35, no. 1-2, pp. 19-40.
- Broadbent, J & Laughlin, R. 2004, 'Striving for Excellence in Public Service Delivery: Experiences from an Analysis of the Private Finance Initiative', *Public Policy and Administration*, vol. 19, no. 4, pp. 82-99.
- Cheung, E, Chan, APC & Kajewski, S. 2009, 'Enhancing value for money in public private partnership projects: Findings from a survey conducted in Hong Kong and Australia compared to findings from previous research in the UK', *Journal of Financial Management of Property and Construction*, vol. 14, no. 1, pp. 7-20.
- Connolly, C, Martin, G & Wall, A. 2008, 'Education, education, education: The third way and PFI', *Public Administration*, vol. 86, no. 4, pp. 951-68.
- DeCorla-Souza, P & Farajian, M. 2017, *Evaluation of a nontraditional approach to fund, finance, and manage metropolitan freeways*, Article, <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85033782866&doi=10.3141%2f2670-05&partnerID=40&md5=8aa955344f08867f86c1f9b3cab3062d>.
- Decorla-Souza, P, Lee, DB, Sullivan, M & Timothy, D. 2017, 'A Benefit-Cost Analysis Framework for Evaluation of Highway Public-Private Partnership Projects', in *Advances in Public-Private Partnerships - Proceedings of the 2nd International Conference on Public-Private Partnerships*, pp. 257-74.
- Decorla-Souza, P., Ham, M. & Timothy, D. 2016, Illustration of a framework for benefit-cost evaluation of highway concession proposals. *Transportation Research Record*, 2597, pp. 52-59.
- Department for Transport. 2017, 'Value for money framework', available at: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/630704/value-for-money-framework.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/630704/value-for-money-framework.pdf) (29 May 2019).
- Department of Infrastructure and Regional Development. 2008, 'National Public Private Partnership Guidelines- Volume 4: Public Sector Comparator Guidance', Available at: <https://www.infrastructure.gov.au/infrastructure/ngpd/files/Volume-4-PSC-Guidance-Dec-2008-FA.pdf> (Accessed: 12-2018).
- Department of Infrastructure and Regional Development. 2017, 'Infrastructure and Transport PPPs and Privatisation in Australia', Available at: [https://www.bitre.gov.au/publications/2017/files/is\\_093.pdf](https://www.bitre.gov.au/publications/2017/files/is_093.pdf) (Accessed: 12-2018).
- Dewulf, G, Blanken, A & Bult-Spiering, M. 2012, *Strategic Issues in Public-Private Partnerships: Second Edition*, Strategic Issues in Public-Private Partnerships: Second Edition.
- Eadie, R, Millar, P & Toner, L. 2013, 'Public private partnerships, reevaluating value for money', *International Journal of Procurement Management*, vol. 6, no. 2, pp. 152-69.
- Flyvbjerg, B. 2006, 'Five Misunderstandings About Case-Study Research', *Qualitative Inquiry*, vol. 12, no. 2, pp. 219-45.
- Gopalkrishna, N & Karnam, G. 2015, 'Performance Analysis of National Highways Public Private Partnerships in India', *Public Works Management and Policy*, vol. 20, no. 3, pp. 264-85.
- Grimsey, D & Lewis, MK. 2005, 'Are Public Private Partnerships value for money?', *Accounting Forum*, vol. 29, no. 4, pp. 345-78.
- Heckman J. 1981, *Statistical models for discrete panel data*. In *Structural analysis of Discrete Data with Econometric Applications*, Manski C, McFadden D (eds). MIT Press, USA.
- Henjewe, C, Sun, M & Fewings, P. 2012, 'Analysis of factors affecting value for money in UK PFI projects', *Journal of Financial Management of Property and Construction*, vol. 17, no. 1, pp. 9-28.
- HM Treasury. 2018, 'National infrastructure and construction pipeline 2018'. Available at: <https://www.gov.uk/government/publications/national-infrastructure-and-construction-pipeline-2018> (Accessed: 26-11-2018).
- Hodgson, M & Corrigan, K. 2005, 'To privatize or not?', *Canadian Consulting Engineer*, vol. 46, no. 1, pp. 26-33.

- Jasiukevicius, L & Vasiliauskaite, A 2018, 'The assessment of public-private partnership's possibilities to optimize investments in public infrastructure', *Engineering Economics*, vol. 29, no. 1, pp. 32-45.
- Kweun, JY, Wheeler, PK & Gifford, JL. 2018, 'Evaluating highway public-private partnerships: Evidence from U.S. value for money studies', *Transport Policy*, vol. 62, pp. 12-20.
- Leigland, J. 2018, 'Public-private partnerships in developing countries: The emerging evidence-based critique', *World Bank Research Observer*, vol. 33, no. 1, pp. 103-34.
- Liu, HJ, Love, PED, Smith, J, Sing, MCP & Matthews, J. 2018, 'Evaluation of public-private partnerships: A life-cycle Performance Prism for ensuring value for money', *Environment and Planning C: Politics and Space*, vol. 36, no. 6, pp. 1133-53.
- Loxley, J. 2012, 'Public-private partnerships after the global financial crisis: Ideology trumping economic reality', *Studies in Political Economy*, no. 89, pp. 7-38.
- Macário, R, Ribeiro, J & Costa, JD. 2015, 'Understanding pitfalls in the application of PPPs in transport infrastructure in Portugal', *Transport Policy*, vol. 41, pp. 90-9.
- Makovšek, D & Moszoro, M. 2018, 'Risk pricing inefficiency in public-private partnerships\*', *Transport Reviews*, vol. 38, no. 3, pp. 298-321.
- McFadden, D. 1977, *Modelling the Choice of Residential Location*, Cowles Foundation for Research in Economics, Yale University.
- McKevitt, D & Davis, P. 2016, 'Value for money: a broken piñata?', *Public Money and Management*, vol. 36, no. 4, pp. 257-64.
- McQuaid, RW & Scherrer, W. 2010, 'Changing reasons for public-private partnerships (PPPs)', *Public Money and Management*, vol. 30, no. 1, pp. 27-34.
- Mols, F. 2010, 'Harnessing market competition in PPP procurement: The importance of periodically taking a strategic view', *Australian Journal of Public Administration*, vol. 69, no. 2, pp. 229-44.
- Morallos, D & Amekudzi, A. 2008, 'The State of the Practice of Value for Money Analysis in Comparing Public Private Partnerships to Traditional Procurements', *Public Works Management & Policy*, vol. 13 pp. 114-25.
- Mouraviev, N & Kakabadse, NK. 2014, 'Risk allocation in a public-private partnership: A case study of construction and operation of kindergartens in Kazakhstan', *Journal of Risk Research*, vol. 17, no. 5, pp. 621-40.
- Mouwens, A. 2015, 'Drivers of customer satisfaction with public transport services', *Transportation Research Part A: Policy and Practice*, vol. 78, pp. 1-20.
- Murphy, TJ. 2008, 'The case for public-private partnerships in infrastructure', *Canadian Public Administration*, vol. 51, no. 1, pp. 99-126.
- NSW Government. 2008, 'Cross City Tunnel: Summary of contracts', available at: [http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/Cross\\_City\\_Tunnel\\_contracts\\_summary\\_2008\\_update\\_lowres.pdf](http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/Cross_City_Tunnel_contracts_summary_2008_update_lowres.pdf) (20 May 2019).
- NSW Government. 2010, 'Lane Cove Tunnel: Updated summary of contracts', Available at: [http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/Lane\\_Cove\\_Tunnel\\_contracts\\_summary\\_09August2010.pdf](http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/Lane_Cove_Tunnel_contracts_summary_09August2010.pdf) (20 May 2019).
- NSW Treasury. 2017, 'NSW PPP Guidelines 2017 Official Launch', <https://www.treasury.nsw.gov.au/sites/default/files/201707/NSW%20PPP%20Guidelines%202017%20Official%20Launch%20Presentation%20-24%20July%202017.pdf> (Accessed: 24-7-2017).
- Ng, ST, Wong, YMW & Wong, JMW. 2012, 'Factors influencing the success of PPP at feasibility stage - A tripartite comparison study in Hong Kong', *Habitat International*, vol. 36, no. 4, pp. 423-32.
- OECD. 2008, *Public-private partnerships: In pursuit of risk sharing and value for money*, vol. 9789264046733, Public-Private Partnerships: In Pursuit of Risk Sharing and Value for Money.
- Opara, M. 2018, 'Value for Money and Risk Relationships in Public-Private Partnerships: Evaluating Program-based Evidence', *Australian Accounting Review*, vol. 28, no. 3, pp. 391-404.
- Opara, M, Elloumi, F, Okafor, O & Warsame, H. 2017, 'Effects of the institutional environment on public-private partnership (P3) projects: Evidence from Canada', *Accounting Forum*, vol. 41, no. 2, pp. 77-95.
- Opara, M & Rouse, P. 2019, 'The perceived efficacy of public-private partnerships: A study from Canada', *Critical Perspectives on Accounting*, vol. 58, pp. 77-99.
- Patil, NA & Laishram, BS. 2016, 'Sustainability of Indian PPP procurement process: Development of strategies for enhancement', *Built Environment Project and Asset Management*, vol. 6, no. 5, pp. 491-507.
- Peng, W, Cui, Q.B., Lu, Y & Huang, L. 2014, 'Achieving value for money: An analytic review of studies on Public Private Partnerships', *The 2014 Construction Research Congress: Construction in a Global Network proceedings*, Georgia Institute of Technology, America, pp. 1189-1198.
- Penyalver, D, Turro, M & Williamson, JB. 2019, 'Measuring the value for money of transport infrastructure procurement; an intergenerational approach', *Transportation Research Part a-Policy and Practice*, vol. 119, pp. 238-54.

- Queiroz, C. 2007, *Public-private partnerships in highways in transition economies recent experience and future prospects*, Article, <https://www.scopus.com/inward/record.uri?eid=2-s2.0-38349118259&doi=10.3141%2f1996-05&partnerID=40&md5=2167ee4234d487b84eae261dd01a1158>.
- Quiggin, J. 2004, 'Risk, PPPs AND THE Public Sector Comparator', *Australian Accounting Review*, vol. 14, no. 33, pp. 51-61.
- Rao, C.R. 1973, *Linear statistical inference and its applications*. Wiley, USA.
- US Department of Transportation. 2018, 'Traffic data: Computation method', available at: [https://www.fhwa.dot.gov/policyinformation/pubs/pl18027\\_traffic\\_data\\_pocket\\_guide.pdf](https://www.fhwa.dot.gov/policyinformation/pubs/pl18027_traffic_data_pocket_guide.pdf) (20 May 2019).
- Reeves, E. 2011, 'The only game in town: Public private partnerships in the Irish water services sector', *Economic and Social Review*, vol. 42, no. 1, pp. 95-111.
- Reeves, E. 2015, 'A Review of the PPP Experience in Ireland: Lessons for Comparative Policy Analysis', *Journal of Comparative Policy Analysis: Research and Practice*, vol. 17, no. 5, pp. 467-80.
- Ren, GQ, Li, HJ, Ding, R, Zhang, JS, Boje, CL & Zhang, WS. 2019, 'Developing an information exchange scheme concerning value for money assessment in Public-Private Partnerships', *Journal of Building Engineering*, vol. 25.
- Robinson, HS & Scott, J. 2009, 'Service delivery and performance monitoring in PFI/PPP projects', *Construction Management and Economics*, vol. 27, no. 2, pp. 181-97.
- Shaoul, J. 2005, 'A critical financial analysis of the Private Finance Initiative: selecting a financing method or allocating economic wealth?', *Critical Perspectives on Accounting*, vol. 16, no. 4, pp. 441-71.
- Siemiatycki, M & Farooqi, N. 2012, 'Value for Money and Risk in Public-Private Partnerships', *Journal of the American Planning Association*, vol. 78, no. 3, pp. 286-99.
- Siemiatycki, M & Friedman, J. 2012, 'The Trade-Offs of Transferring Demand Risk on Urban Transit Public-Private Partnerships', *Public Works Management and Policy*, vol. 17, no. 3, pp. 283-302.
- Sing, MCP, Love, PED & Liu, HJ. 2019, 'Rehabilitation of existing building stock: A system dynamics model to support policy development', *Cities*, vol. 87, pp. 142-52.
- Song, J, Li, Y, Feng, Z & Wang, H. 2019, 'Cluster Analysis of the Intellectual Structure of PPP Research', *Journal of Management in Engineering*, vol. 35, no. 1.
- Sun, S, Zhang, C & Yu, G. 2006, 'A Bayesian Network Approach to Traffic Flow Forecasting', *IEEE Transactions on Intelligent Transportation Systems*, vol. 7, no. 1, pp. 124-32.
- Transport for NSW. 2014, 'Contract summary: Operations trains and systems, Public Private Partnership contract', available at: [http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/NWRL\\_OTS\\_PPP\\_Contract\\_Summary\\_Dec\\_2014.pdf](http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/NWRL_OTS_PPP_Contract_Summary_Dec_2014.pdf) (20 May 2019).
- Tsamboulas, D, Verma, A & Moraiti, P. 2013, 'Transport infrastructure provision and operations: Why should governments choose private-public partnership?', *Research in Transportation Economics*, vol. 38, no. 1, pp. 122-7.
- Vining, AR & Boardman, AE. 2014, 'Self-interest springs eternal: Political economy reasons why public-private partnerships do not work as well as expected', *CESifo DICE Report*, vol. 12, no. 3, pp. 17-23.
- Walder, JH & Amenta, TL. 2004, 'Financing new infrastructures: Public/private partnerships and private finance initiatives', in *Moving People, Goods, and Information in the 21st Century: The Cutting-Edge Infrastructures of Networked Cities*, vol. 9780203642962, pp. 88-110.
- Wall, A & Connolly, C. 2009, 'The private finance initiative: An evolving research agenda?', *Public Management Review*, vol. 11, no. 5, pp. 707-24.
- Whiteside, H. 2019, 'Public-private partnerships: market development through management reform', *Review of International Political Economy*.
- Willems, T, Verhoest, K, Voets, J, Coppens, T, Van Dooren, W & Van den Hurk, M. 2017, 'Ten Lessons from Ten Years PPP Experience in Belgium', *Australian Journal of Public Administration*, vol. 76, no. 3, pp. 316-29.
- Yuan, J, Ji, W, Guo, J & Skibniewski, MJ. 2018, 'Simulation-based dynamic adjustments of prices and subsidies for transportation PPP projects based on stakeholders' satisfaction', *Transportation*.
- Yuan, J, Zeng, AY, Skibniewski, MJ & Li, Q. 2009, 'Selection of performance objectives and key performance indicators in public-private partnership projects to achieve value for money', *Construction Management and Economics*, vol. 27, no. 3, pp. 253-70.
- Zwalf, S, Hodge, G & Alam, Q. 2017, 'Choose Your Own Adventure: Finding a Suitable Discount Rate for Evaluating Value for Money in Public-Private Partnership Proposals\*', *Australian Journal of Public Administration*, vol. 76, no. 3, pp. 301-15.