BIM Based Value for Money Assessment in Public-Private Partnership

Guoqian Ren, Haijiang Li

BIM based Value for Money Assessment in Public-Private Partnership

Guoqian Ren and Haijiang Li

Cardiff School of Engineering, Cardiff University. The Parade, Cardiff, CF24 3AA, Wales UK

BRE Centre for Sustainable Construction, Cardiff University, Wales UK

{RenG,lih}@cardiff.ac.uk

Abstract. New urbanization approaches aligned with public- private partnership (PPP) which arose in the early 1990s, have become acceptable and even better solutions to outstanding urban municipal constructions. However, PPPs are still problematic regarding value for money (VFM) process which is the main driving force to deliver public services. The current VFM structure requires an integrated platform to manage multi-performance and collaborative relationship in project life-cycles. Building information modelling (BIM), a popular approach to the procurement in AEC sectors, provides the potential to ensure VFM while also working in tandem with the semantic approach to holistically measure the life cycle performance. This paper suggests that BIM applied to the PPP life cycle could support decision-making regarding VFM and thus meet service targets.

Keywords: Public-private partnership; Value for money; Building information modelling; Collaborative networks;

1 Introduction

PPPs (Public – Private Partnerships) have been developed to offer public services designed to relieve the pressures of local debt. The aim of PPP management is to identify clear goals, shared by both the public and private sectors, so that substantial capital gains can be achieved. However, despite the growing status of PPPs, there still exist a number of concerns with reference to infrastructure investment in developing regions regardless of financial uncertainties or poor quality performance[1]. It stress the importance of Value for money (VFM) processes as VFM does not yet receive sufficient attention within project practice. Most of the financial assessments and decisions made by PPPs are formulated without considering the amount of time needed to implement the necessary engineering works [2]. This can result in gross inaccuracies in collaborative networks, with reference to the life cycle of the project, leading to financial crises.

In most of the cases of PPP project, a subsidiary company called special purpose vehicle (SPV) is established at the early stage of the project to serve as counterparty which isolate the project financial risk meanwhile in charge of life cycle management. This new project management model have shown that they deliver a more sustainable procurement process in comparison to traditional approaches. That said, a holistic

approach to project performance provides better VFM with reference to sustainability, something which is necessary to decide whether or not PPP model is appropriate [3]. The information acquired for VFM, currently collected via multi-resources, is mostly second-hand data, any decisions having already been made [4]. The project data often failed to be integrated into management system. This poor quality data makes it very difficult for the public to assess whether the cost is commensurate with the benefits and risks to the public sector [5].

Regarding procurement workflow, BIM (Building Information Modelling) has the potential to be applied to the entire PPP process as opposed to current mainly ad hoc approaches [6]. However, BIM has not yet been used extensively to deliver measurable estimates on work but it does provide the possibility of "future proofing" on PPPs performance based assets. It is suggested here that BIM could be subsumed into PPP frameworks, ensuring that value for money has been provided and to even go a step further and measure and monitor project sustainability.

2 Value for Money Assessment

The definition of value for money (VFM) given by the UK government and the World Bank group is the optimum combination of whole-of-life costs and quality [7] . "Value" in this context represent the performance of project service to meet the user's requirement. It is not just the choice based on the lowest cost bid yet the public agencies must meet the project target on life cycle costs and service quality. In addition, the "value" emphasize more the overall assessment results rather than costs itself. In different project type and background, the weighing system in evaluation criteria could be relatively different yet in most of the cases, the life cycle cost represents by net present value (NPV) take the great proportion of the assessment outcome. Its criteria include business incentives at the procurement stage which could become the initial reference in terms of a good performance benchmark [8]. Even though VFM is a relatively hypothetical construct at present, lacking in clear substance and user guidance toolkits and measurement lists are available to guide PPP users to make comparisons of the actual outcomes to alternative procurement options. Calculations model of VFM quantitative assessment in many countries uses an indicative present value for both PPP options and PSC (Public Sector Comparator) and make comparison. Specifically, PSC is a comprehensive account of procurement strategies across the life cycle of the project by using traditional procurement model. The UK government took the lead in standardizing the content of PSC as a decision making process to define where, when and how to use privately-financed infrastructure solutions [9]. The National Audit Office (NAO), provides a rolling method to compute both PSC and PPP values keeping costings up to date. The key components indicative of the current values in PSC basically covers the raw PSC value (Basic resources costs), the value of risk transfer, retained risk values and the value of Competitive tax adjustment. [10]

As showed in the figure 1, VFM is not only focused on the whole life costs of assets at early stage quantitative assessment, but also requires the project to achieve a high level of qualitative performance across every aspect of the project [7].These two assessments work independently of each other providing different but interrelated

information. VFM in the project decision phase offers a decision making platform for the use and focus on the discipline of collaborative relationship to achieve common goals between shared parties.

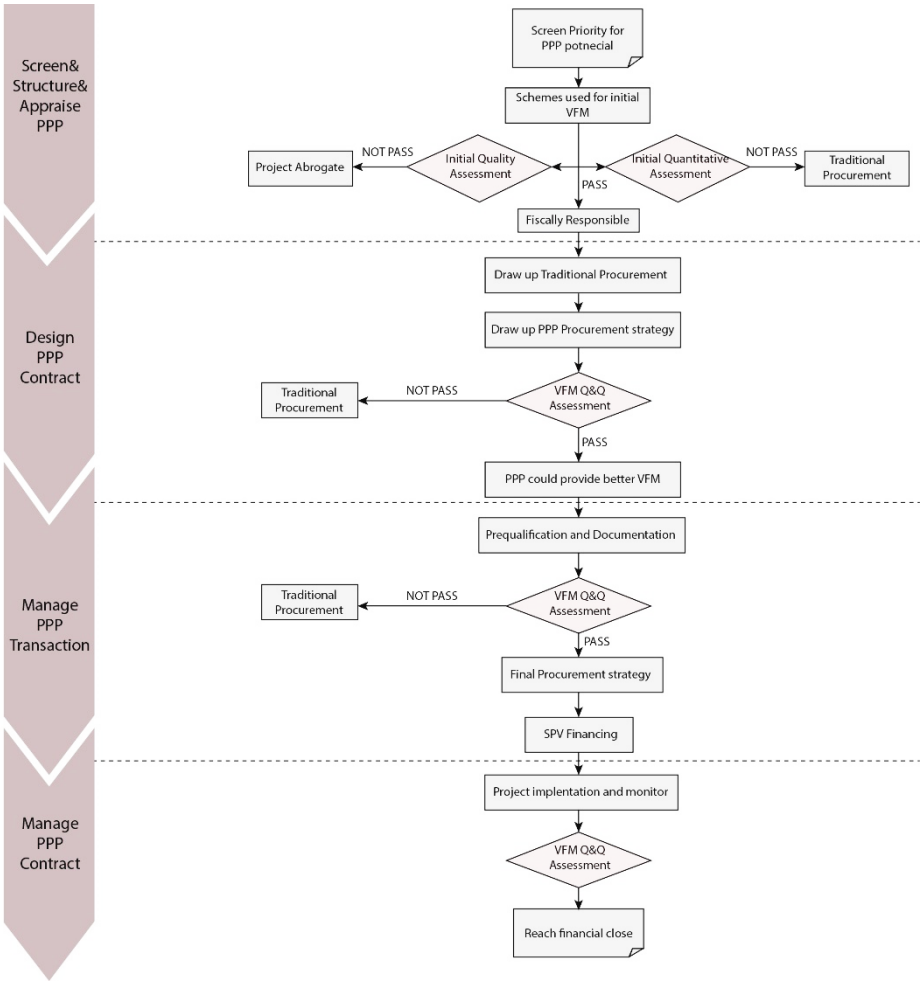

Fig .1. VFM process through the project life-cycle

Value for money analysis could be defined as a life cycle assessment for the whole project [11]. Regional variations regarding the use of VFM mean that there is a lack of consistency for both qualitative and quantitative assessments. In China, the only qualitative process required involves completing a very simple form while the quantitative process either does not occur or is postponed due to feasibility issue. [12] The spread of PPPs in infrastructure construction raises issues at various stages including a lack of risk management leading to implementation failure in construction

and operations. From the project management point of view, well-organized data management in the initial stages does not yet exist. VFM financial assessment issues can be summarised as follows:

· The current qualitative assessment lacks an information system to support information queries to measure the success and adoption of the projects.

· The project data related to quantitative financial accounting are historical and may therefore generate unreliable results. Information acquired from multiple sources and resources may not be clearly sourced or noted, this raising exchange issues for calculating present values which required more integrated enterprise data management.

3 Building Information Modelling

PPP parties are facing barriers because they cannot guarantee that VFM is provided. In consequence, this paper proposes that indicators of VFM should be identified and communicated using Building Information Modelling. The collaborative structure in BIM could also help PPP parties carry out integrated information management in order to support both qualitative and quantitative assessment.

Building information modelling (BIM), introduced in the early 1990's, is considered the foundation for project information development in construction engineering projects [13]. "Building Information Management" is the accepted way to describe the application of BIM as it is a digital process designed to guide project construction and operations. In the project-based industry, the collaborative relationships (Fig 2) between different contract sectors and organizations are required to be more integrated to reshape the traditional ways of procurement activities. [14] BIM actually could also offer the opportunity for clients to be involved in procurement management. Nowadays, BIM technologies serve to build low-cost, integrated working systems in infrastructure projects [15]. The digital models have the potentiality to function as an aid to inspection, but are more applicable to management at the municipal level [16].

As showed in the figure 2, Building Information Modelling (BIM) has potential to influence the entire process of PPP in the procurement workflow, rather than just part of the project. In the UK, BIM level 2 is generating a comprehensive network, accessible for all parties involved in construction management, it also potentially offers a better quality operational framework for PPPs. The benefits of collaborative network in BIM stress the information delivery and data extraction. Project information attached with digital model could be passed to various project stakeholders in standardized data format. Questions concerned about project quality and objective details could be queried in an easy pattern. Moreover, the semantic extension of BIM makes it even better function on project domain management such as construction risk assessment [17] and low carbon designs.[18] The link data approach functioning between building information modelling and different semantic knowledge bases is becoming increasingly practical in construction industry. [19] The advantages of BIM aligned with semantic approaches in PPP could benefit the procurement decision to achieve better value for money.

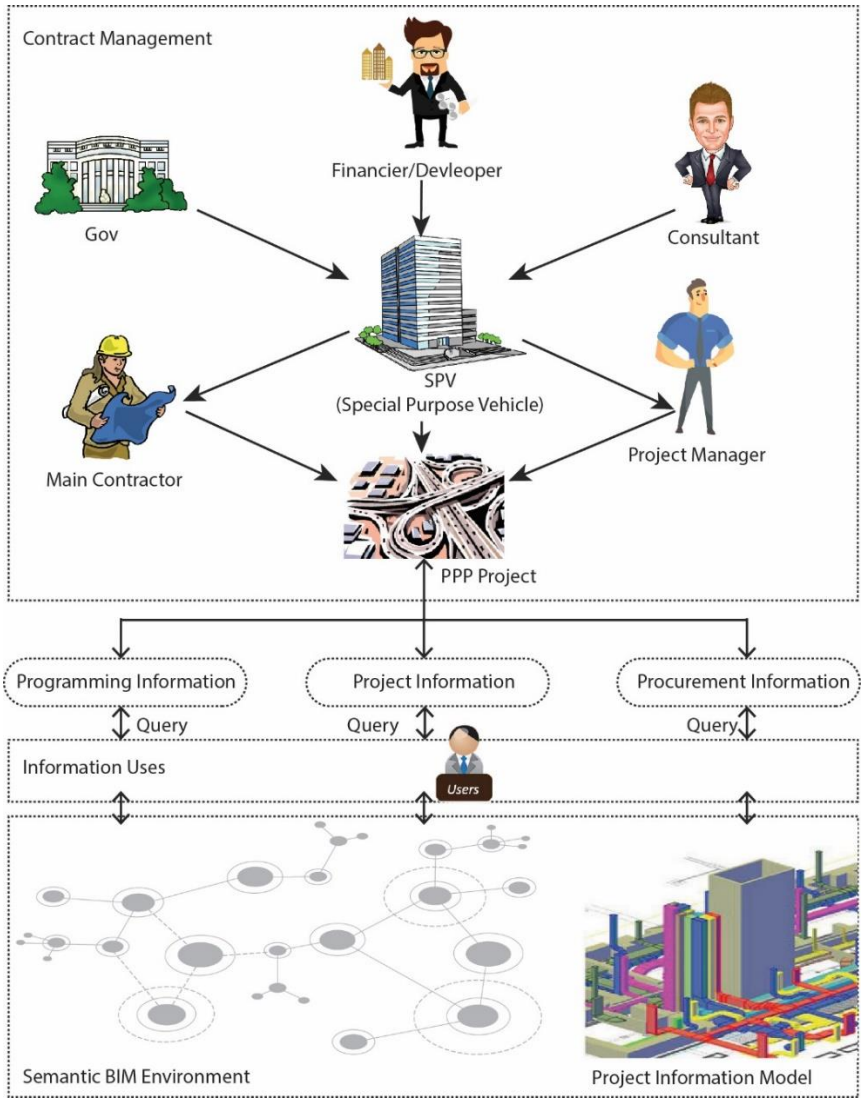

Fig. 2. BIM supported collaborative networks in Public – private partnerships

4. BIM based VFM in PPP

The development of BIM to date suggests that it has the potential to work with PPP models by challenging electronic procurement [20]. BIM, as seen from an engineering point of view, can be described as providing benefits for management frameworks, tools, standards and assessment methods through the whole project lifecycle in

comparison to PPP which is more about standardised and sustainable targets. Through the concept review on both PPP and BIM and their implementation focus, this paper has identified scope for a partnership between these two project management concepts. As a lifecycle project management concept, PPP focuses mainly on procurement benefits; but to achieve these, the PPP approach needs a life-cycle information exchange and management platform, and it is here that BIM can play an important role. The article stresses that the VFM process throughout the entire PPP workflow is actually the BIM application object since it determine whether the provided value is sufficient yet are still under development and require more information supports in both qualitative and quantitative assessment processes. Thus, it is necessary to build a VFM strategy that can provide more valuable deliverables by considering lifecycle performance. In this way, it is suggested that BIM could be one of best application system in PPP as it allows sharing of life cycle measurements and ongoing editing of information using a digital plan. The lack of supporting data and an unstable framework concerning VFM processes could be improved by integrated with BIM which presupposes the need for an all-inclusive information that contains lifecycle functionalities to deal with change.

In most PPP cases, key performance targets are written into the contract meaning that some of the indicators of these could be used life cycle evaluation. The impact on public services caused by major infrastructure projects should be strictly supervised by government who need to consider project operation status, project adaptability and its impact on society and the environment [21]. The following table 1 illustrates how BIM could help to improve the VFM process in both quality and quantitative aspects by listing all the related function, tool and carries though lifecycle performance checks and possible semantic extension for PPP.

Table 1 PPP life-cycle performance and corresponding BIM function

PPP Stages	**Life-cycle indicators**	**BIM functions**	**BIMTools/carrier**	**Description**
Screen	Methodology of Project selection Detailed Project plan/programming	Information formatting Site information; Surveys Formatting	*dPOW; OIR* *3D scan*	Initialize the need to develop the project brief information used to specific the feasibility
Structure & Appraise	**VFM qualitative assessment** Whole project lifecycle integration Operation flexibility Risk management Contract and assets Duration Incentives and Monitoring Market interest Efficient Procurement	Cost analysis Compliance checking Semantic BIM approach Project management Information exchange Model Simulation; Project management	*Solibri; CostX®; Revit* *Solibri* *Semantic platform AIR; Cobie* *Navisworks; Projectwise* *InfraWorks 360* *BIM 360™; Viewpoint*	The application of BIM used to improve the the performance of quality aspects
	VFM Quantitative assessment(PSC) FM costs, Construction costs, Operation costs, Transportation costs, Human resource costs, User fee, Risk costs	Cost analysis; Semantic BIM approach	*Semantic platform; 5D BIM related tools*	The Semantic BIM approach help to reasoning the logic of project risk and support the outputs of related indicators of quantitative assessment
	Feasibility of task	Cost analysis; Scheduling	*BIM 360™; Viewpoint*	Format the project schedule updated with the

				project data
Design & Manage	Tender process and competition	Information exchange; Visualization	*EIR; Bentley; Revit*	Deliver the requirement of stakeholders in
	Requirements of stakeholders/Goals	Information formatting; Information exchange	*OIR; EIR;*	Deliver the requirement of stakeholders
	Clear project brief/Contract documents	Information formatting; Information exchange	*OIR; EIR; BIM Execution Plan*	Deliver and translate the objectives of contract digitally
	Transparent procurement process/verify/monitoring	Project management	*BIM 360™; Viewpoint*	Provide progress monitoring and management
	Change in contract/private sector change	Project management	*EIR; BIM 360™; Viewpoint*	Highly efficient deal with progress change
Implementation	Site availability	Surveys Formatting; Space analysis	*IES; Green Building studio*	Information used to input into later design and construction
	Completion/Time Delay	Construction Scheduling	*Navisworks; ProjectWise; Tekla*	Format the scheduling and reduce the costs and delays
	Design deficiency/buildability	Clash detection; Compliance checking	*Navisworks; Solibri; Xsteel*	Improve design quality and benefits construction
	High-quality workmanship	Scheduling; Quantities take off	*3D scan; QTO; Vico*	Improve construction quality
	Site construction safety	Compliance checking; Clash detection	*3D scan; Naviswork; BIM 360™; Solibri*	Improve safety planning by interactive as-build information
	Technical innovation in design to construction	Information exchange	*EIR; AIR; BIM 360™*	Deliver/format the information from design to construction
	Material/Labour/Equipment	Project management	*AIR;BIM 360™;Revit*	Asset Information in Common data environment for F&M
	Construction Cost overrun	Cost analysis; Construction Scheduling	*Solibri; CostX®; Navisworks*	Accurate measurement of cost in construction
	operation cash flow	Maintenance	*ArchiBUS*	Deliver the information from Construction to Operation
	Operation performance	Energy management	*AIR; Energy Plus*	Cost of Energy or electric use in operation stage
	Residual assets	Project management	*AIR;BIM 360™*	Asset Information in Common data environment

This article referenced the PPP process stages based on the World Bank Group and simultaneously referenced construction project flow by using RIBA info exchange.[22] The indicators in PPP life cycle is referenced from different literature sources. [23]–[30] As discussed below, BIM with its extensive support potential, could theoretically maximize the benefits of VFM process and go step further on project life cycle.

The initial stage of project screening, usually involving investment planning, should be formally approved. Unsolicited proposals and initial projected end results of the project in this phase, could benefit from a digital plan of work (dPOW) related platform such as National Building Specification (NBS), which uses plain language questions (PLQs) to capture the clients' initial needs and gradually generates Organization

Information Requirements (OIR). It is also one vital documentation process in previous UK BIM level 2 standard. [31] The information in this phase will then pass to an initial assets management inquiry that considers the clients' need. A Special Purpose Vehicle (SPV), or a related client based organization, could take the responsibility to update information for further asset management and information about prospective employees relevant to project performance. Other factors related to project planning are the physical scale of the project and a review of the constraints of potential sites. Space and site analysis attached to BIM software, has the advantage of providing visual data which is of value in early decision making. Even it is the early stage, VFM assessment has the potential to start building a support information/reference library for PSC projects. Domain and cost related knowledge bases can be structured using the Semantic approach while data could be supported by using BIM related tools.

Second phases which is defined as "structure PPP" and "appraise PPP" in World Bank PPP guidance, involve the collation of core information that helps determine the substance of the project including Risk Identification and Allocation, project feasibility, VFM and viability. Risk management is directly connected with VFM assessment and can be represented using domain-involved indicators to define project risks. A "Semantic BIM" approach is proposed at this stage as interaction of the ontological structure and Industry Foundation Class (IFC) data in the risk management field provide a model which lists the risk events relevant to the PPP. Information can be collated into a semantic environment as "knowledge blocks", represented by a domain-based taxonomy. Because this stage is leading towards the final procurement stage, the quality of data should allow VFM assessment. Figure 2 and Table 1 show how information exchanged within the BIM environment could help to extract the relevant data which could be used in initial design or existing models for Net Present Value (NPV) measurement. 5D representation, regardless of the presence of a digital model, should contain a certain level of detailed information regarding assets during this stage. The use of costing tools aligned with BIM could provide a good measure to structure the cost measurement in general. At this point, quantitative assessment will not depend on non-transparent historical data as the information contained in BIM has its real-time properties [6].

"Manage PPP" refers to the final procurement strategy and business agreement. VFM findings, specifically quantitative output, should be incorporated by the final contract award. Employment information requirements (EIR), includes reference to when contractors need to handover to different sectors. Project goals and assets information could be delivered by using Construction Operations Building Information Exchange (Cobie). The Cobie-UK-2012 is a good application with reference to non-graphical information exchange as it initializes key project information in a standardised format. Information delivery and sharing are often seen in a common data environment (CDE), defined as a single source of information and as the extranet source of information used to import, manage and disseminate all material [22]. The BIM and its CDE are commonly used in most of the cases in DB or BOT procurement model yet only in separated stages. Now it could be used in VFM process as it stress the importance of life cycle costs measurement and performance monitor.

The PPP project implementation stage (Construction and Operation) is likely to be the point at which the benefits of BIM functions at previous points become fully evident. The costs of construction currently account for a large proportion of the NPV of

quantitative results in VFM. Theoretically, the cost results should meet the previous value in quantitative assessment, while BIM now has potential to deal with change in real time. There are plenty of resources amenable to BIM application in project design and construction. In most cases, contractors should take the responsibility for integrating processes from ‘‘as-built’’, while BIM could maximise the profits of this. An application in the earlier design stage could be regarded as 3D parametric design, which differs from traditional design approaches; it offers software tools allowing the design team to visualise the architecture, structure, MEP and supported facilities plan. Similarly, 4D and 5D BIM used at the pre-construction stage could eventually output a federated model for construction specifications. Any insufficiency occurring at earlier design stages could be visualised within the bounds of known parameters, in software, to minimise any need for later reworking. The other vital process in the “PPP operation stage” is asset management. Before BIM appears in Facility management, The Radio Frequency Identification (RFID) that discriminates the Quick response (QR) Code on devices, or structural component to track the information needed by operators, can now connect to the assets information model (AIM) which is the result of CDE. More detailed information about operational attributes could also be provided. The tracking system in the BIM environment makes the “future proofing” of VFM easier by enhancing assets maintenance efficiency. The summary of BIM functionality for PPP construction and operation covers the following aspects:

Model Checking: automatic checking comprises two aspects: object-oriented checking and rule-based regulation checking. Software functions e.g. clash detection, could help the project team to solve conflicts before construction starts. This is important specifically for large scale projects or complicated structures as traditional 2D or 3D approaches cannot minimize design fault to a suitable level at pre-construction stages. Performance during the construction stage also needs to satisfy industry standards or sustainability benchmark systems. These automatic checks should be carried out before creation of the combined model. Information extracted, IFC data, could take the form of plain language information in authoritative standards such as LEED and BREEAM, using a rule engine attached to the digital model. The results also could confirm if part of the digital model could help to carry out VFM quality assessment as well.

Model analysis: the availability and diversity of automatic BIM analyses are becoming more adaptable and practical. Current data focus mainly on cost and workload. The cost appraisal during the Planning and construction stage is a vital component of the WLCC as it frequently deals with multiple changes and directly influences the management of assets in the operation stage. Real-time data imported into the analysis system, is used to create CDE output. Theoretically, costings should meet the previous value designated in VFM assessment while CDE now has the potential to deal with change.

Model comparison: the used of point cloud 3D scanning technologies within construction is still limited, but complex quality assessment tasks in VFM like the structural renovation of existing infrastructures which are regarded as “stock assets” in PPP projects, could benefit from these. The process of generating a model from pointed clouds to mesh geometries is also available within the BIM environment, meaning that the 3D scan has access to a combination of data for further assets management [32].

Model Simulation: simulation, a basic software function, provides the potential visualize the build. At the pre-construction stage, BIM modelling and emergency-based software can create an appropriate emergency plan designed to cope with a range of emergencies. [33] Since the majority of PPP projects are urban infrastructures, and VFM in this filed required more comprehensive assessment. The simulation attached with VFM outputs in BIM based project construction is more meaningful to compare with different strategies.

The advantages of the application of BIM based VFM in PPP are as follows:

· The information extracted from BIM is a vital part of the information initialization providing high-quality data, guaranteeing accuracy and high levels of synchronization in VFM qualitative assessment.

· Benefits are created as BIM encompasses the PPP lifecycle project flow and information extraction in VFM quantitative assessment.

5 Conclusion

BIM's comprehensive ability to manage information could facilitate the VFM process by supporting both qualitative and quantitative assessment. Through a literature review on both PPP application and BIM, this paper has identified a potential partnership between these two project management concepts. PPP, as a life-cycle project management concept, mainly focusses on procurement benefits. However, to achieve this, it requires a life-cycle information exchange and collaborative network hence the need for BIM. Regarding PPP as a whole, it can be concluded that VFM processes could determine whether the value provided is effective by using the PPP procurement model as it is a long-term assessment designed to guarantee profits at program, project and procurement level. However, VFM practice is still under development and requires application at a general level and to the whole procurement process to achieve both qualitative and quantitative assessment. Based on this, this paper proposes to create a BIM-based decision-making framework which benefits VFM assessment alone PPP project life cycle. Future work should cover the comprehensive semantic development of this knowledge base, along with automatic means of VFM measurement.

5 References

[1] X. Zhang and S. Chen, "A systematic framework for infrastructure development through public private partnerships," *IATSS Res.*, vol. 36, no. 2, pp. 88–97, 2013.

[2] ACCA, *Taking Stock of PPP and PFI around the World*. 2012.

[3] L. Du, W. Tang, C. Liu, S. Wang, T. Wang, W. Shen, M. Huang, and Y. Zhou, "Enhancing engineer-procure-construct project performance by partnering in international markets: Perspective from Chinese construction companies," *Int. J. Proj. Manag.*, vol. 34, no. 1, pp. 30–43, 2016.

[4] E. Farquharson, J. Encinas, E. R. Yescombe, and C. Torres de Mästle, *How to Engage with the Private Sector in Public-Private Partnerships in Emerging Markets*. 2011.

[5] J. Shaoul, *Financial Black Holes: Accounting for Privately Financed Roads in the UK.*, vol. 20, no. 1. 2011.
[6] P. E. D. Love, J. Liu, J. Matthews, C. P. Sing, and J. Smith, "Future proofing PPPs: Life-cycle performance measurement and Building Information Modelling," *Autom. Constr.*, vol. 56, pp. 26–35, 2015.
[7] HM Treasury, "Value for Money Assessment Guidance," p. 49, 2006.
[8] J. Cowper and M. Samuels, "Performance benchmarking in the public sector: the United Kingdom experience," *Benchmarking, Eval. Strateg. Manag. Public Sect.*, no. November 1995, pp. 11–32, 1997.
[9] R. Bain, "Public sector comparators for UK PFI roads: Inside the black box," *Transportation (Amst).*, vol. 37, no. 3, pp. 447–471, 2010.
[10] National Audit Office, "Review of the VFM assessment process for PFI," no. October, 2013.
[11] Office of Transportation Public Private Partnerships, "PPTA Value for Money Guidance," no. April, pp. 1–60, 2011.
[12] M. of F. of the P. R. of China, "政府和社会资本合作项目物有所值评价指引（试行）," pp. 1–8, 2014.
[13] G. A. van Nederveen and F. P. Tolman, "Modelling multiple views on buildings," *Autom. Constr.*, vol. 1, no. 3, pp. 215–224, Dec. 1992.
[14] D. Cao, H. Li, G. Wang, X. Luo, X. Yang, and D. Tan, "Dynamics of Project-Based Collaborative Networks for BIM Implementation : Analysis Based on Stochastic Actor-Oriented Models," pp. 1–12, 2015.
[15] A. Bradley, H. Li, R. Lark, and S. Dunn, "BIM for infrastructure: An overall review and constructor perspective," *Autom. Constr.*, vol. 71, pp. 139–152, 2016.
[16] T. Hartmann, H. Van Meerveld, N. Vossebeld, and A. Adriaanse, "Aligning building information model tools and construction management methods," *Autom. Constr.*, vol. 22, pp. 605–613, 2012.
[17] L. Y. Ding, B. T. Zhong, S. Wu, and H. B. Luo, "cost ontolgoy," *Saf. Sci.*, vol. 87, pp. 202–213, 2016.
[18] S. Hou, H. Li, and Y. Rezgui, "Ontology-based approach for structural design considering low embodied energy and carbon," *Energy Build.*, vol. 102, no. 2015, pp. 75–90, 2015.
[19] F. H. Abanda, J. H. M. Tah, and R. Keivani, "Trends in built environment Semantic Web applications: Where are we today?," *Expert Syst. Appl.*, vol. 40, no. 14, pp. 5563–5577, 2013.
[20] A. Grilo and R. Jardim-Goncalves, "Challenging electronic procurement in the AEC sector: A BIM-based integrated perspective," *Autom. Constr.*, vol. 20, no. 2, pp. 107–114, 2011.
[21] F. Guo, Y. Chang-Richards, S. Wilkinson, and T. C. Li, "Effects of project governance structures on the management of risks in major infrastructure projects: A comparative analysis," *Int. J. Proj. Manag.*, vol. 32, no. 5, pp. 815–826, 2014.
[22] RIBA, "Guide Information Exchanges," 2015.
[23] J. Chou and D. Pramudawardhani, "Cross-country comparisons of key drivers , critical success factors and risk allocation for public-private partnership projects," *Int. J. Proj. Manag.*, vol. 33, no. 5, pp. 1136–1150, 2015.
[24] B. Hwang, X. Zhao, and M. J. S. Gay, "Public private partnership projects in Singapore: Factors, critical risks and preferred risk allocation from the perspective of contractors," *Int. J. Proj. Manag.*, vol. 31, no. 3, pp. 424–433, 2013.
[25] T. Liu, Y. Wang, and S. Wilkinson, "Identifying critical factors affecting the effectiveness and efficiency of tendering processes in Public-Private Partnerships (PPPs): A comparative analysis of Australia and China," *Int. J. Proj. Manag.*, vol. 34, no. 4, pp. 701–716, 2016.

[26] S. Thomas Ng, Z. Tang, and E. Palaneeswaran, “Factors contributing to the success of equipment-intensive subcontractors in construction,” *Int. J. Proj. Manag.*, vol. 27, no. 7, pp. 736–744, 2009.

[27] L. Tang and Q. Shen, “Factors affecting effectiveness and efficiency of analyzing stakeholders’ needs at the briefing stage of public private partnership projects,” *Int. J. Proj. Manag.*, vol. 31, no. 4, pp. 513–521, 2013.

[28] S. Toor and S. O. Ogunlana, “Critical COMs of success in large-scale construction projects : Evidence from Thailand construction industry,” *Int. J. Proj. Manag.*, vol. 26, pp. 420–430, 2008.

[29] A. Wibowo and S. Mohamed, “Risk criticality and allocation in privatised water supply projects in Indonesia,” *Int. J. Proj. Manag.*, vol. 28, no. 5, pp. 504–513, 2010.

[30] Y. Xu, A. P. C. Chan, and J. F. Y. Yeung, “Developing a Fuzzy Risk Allocation Model for PPP Projects in China,” *J. Constr. Eng. Manag.*, vol. 136, no. 8, pp. 894–903, 2010.

[31] British Standard Institution (BSI), “PAS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling,” *Br. Stand. Inst.*, no. 1, pp. 1–44, 2014.

[32] F. Bosché, M. Ahmed, Y. Turkan, C. T. Haas, and R. Haas, “The value of integrating Scan-to-BIM and Scan-vs-BIM techniques for construction monitoring using laser scanning and BIM: The case of cylindrical MEP components,” *Autom. Constr.*, vol. 49, pp. 201–213, 2015.

[33] B. Wang, H. Li, Y. Rezgui, A. Bradley, and H. N. Ong, “BIM based virtual environment for fire emergency evacuation,” *Sci. World J.*, vol. 2014, no. October, 2014.