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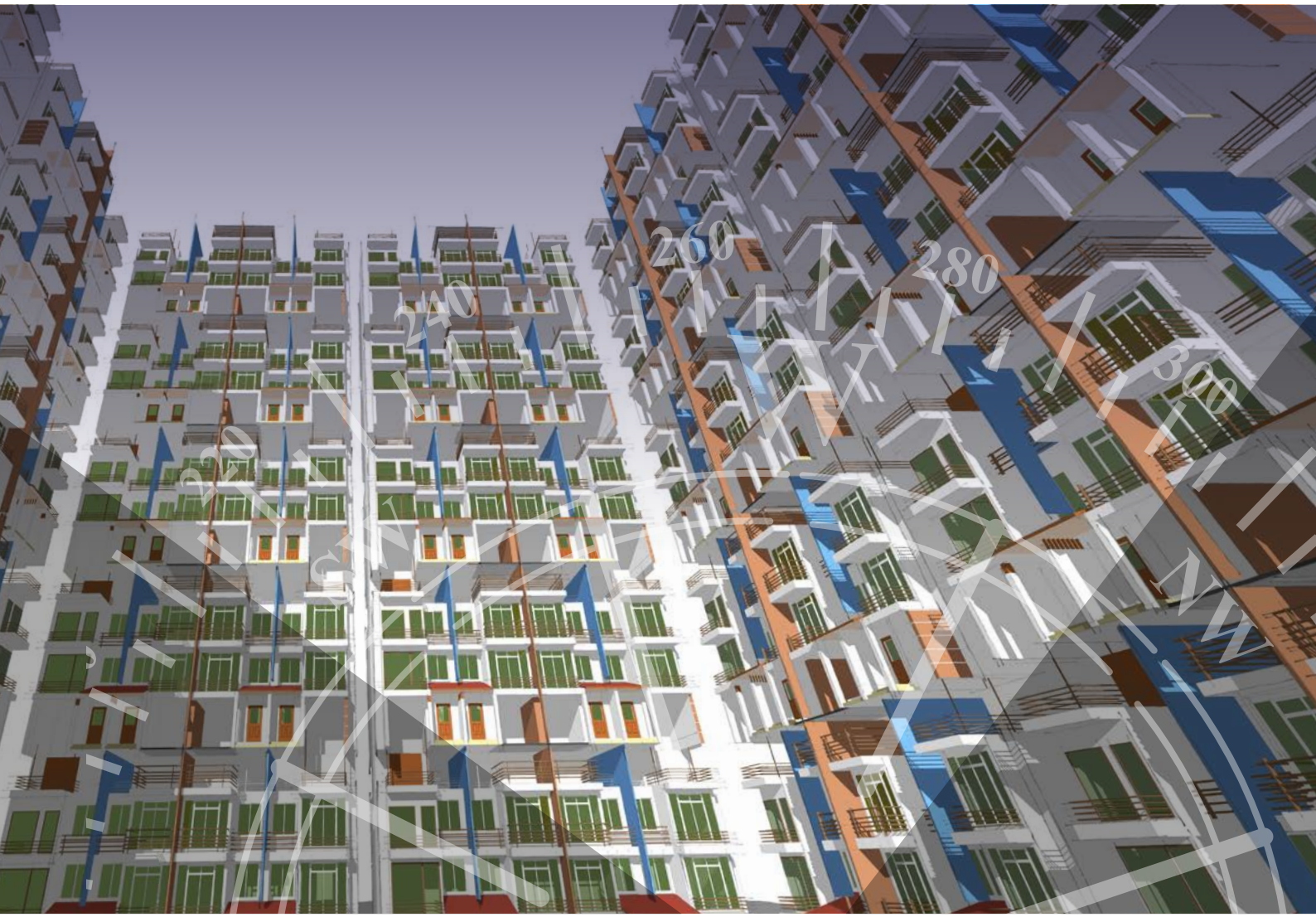
BIM Execution Framework for early-stage estimating in PPP projects



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BIM Execution Framework for early-stage estimating in PPP projects

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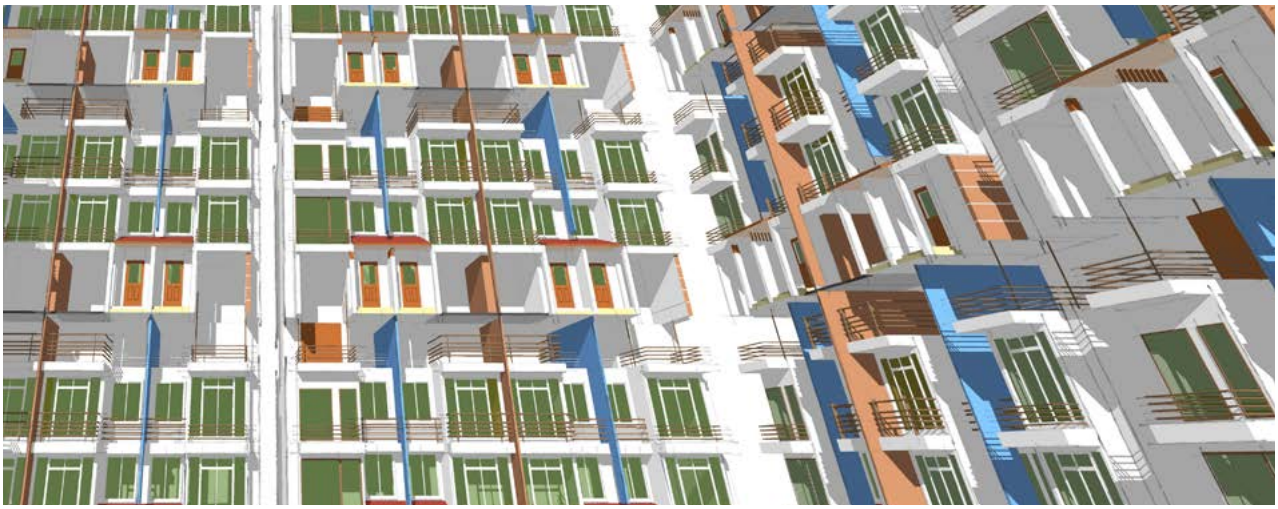
Abbreviations

AEC	Architecture Engineering and Construction
AFC	Anticipated Final Cost
AIQS	Australian Institute of Quantity Surveyors
BEFEP	BIM Execution Framework for Estimating in PPP projects
BEP	BIM Execution Plan
BIM	Building Information Modelling
BLT	Build-Lease-Transfer
BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
BOT	Build-Operate-Transfer
BQ	Bills of Quantity
BTO	Build-Transfer-Operate
CECA	China Engineering Cost Association
CIC	Computer Integrated Construction
CPPPC	Social Capital Cooperation Centre
DBFO	Design Build Finance Operate
DBOM	Design Build Operate Maintenance
DIT	Department of Infrastructure and Transport
ECOSOC	United Nations Economic and Social Council (French Abbreviation)
EOI	Expression of Interest
EPC	Engineering, procurement and construction
GC21	General Conditions of Contract 21
GDP	Gross Domestic Product
HM	Her Majesty's
IBC	Institute for BIM Canada
NATSPEC	National Building Specification
NDRC	National Development and Reform Commission
NRM	New Rules of Management
NZIQS	New Zealand Institute of Quantity Surveyors
OECD	Organisation of Economic Development and Co-operation
PFI	Private Finance Initiative
PPP	Public Private Partnerships
PSC	Public Sector Comparator
QS	Quantity Surveying
RFP	Request for Proposal
RICS	Royal Institution of Chartered Surveyors
ROT	Rehabilitate-Operate-Transfer
UK	United Kingdom
VfM	Value for Money

Executive summary



The use of Public Private Partnerships (PPP) as the vehicle to procure large-scale social and physical infrastructure projects is becoming increasingly deployed around the globe. This international study evaluated the use of PPP procurement in the UK, Australia and China as three of the most mature and rapidly developing users of the PPP procurement route. It focused on the ways of improving digitalisation in PPP procurement with the use of Building Information Modelling (BIM) and its impact on early-stage estimating. This research aimed at developing an execution framework for BIM-enabled early-stage estimating for PPP procured projects, learning from the situations in these three most advanced user countries. The expectation is that such a framework will also help the rapidly developing countries, who are increasingly reliant of PPP types of procurement.

The construction industry although contributing over US$10 trillion per annum and having 13% of global GDP is one of the least digitalised industries (McKinsey, 2017). The past decade saw the dawn of the 4th Industrial Revolution exacerbating the need for digitalisation of the construction industry, which is facing global challenges. BIM has been the answer of the construction industry to achieve this step change although the proliferation of the FinTech sector is an imminent addition in the decade to come. There are varying levels of adoption of BIM in the construction industry in the three countries examined, with the UK having the lead with the most mature levels of adoption and use, followed by China and Australia.

The research examined the practice of estimating in PPP projects in these three countries and concluded that there are growing similarities in the perception of advantages, challenges and recommendations that make for the greater adoption of BIM-enabled estimating for PPP projects.

The key advantages were efficient process of design and estimating through reductions in time, clash detection, ease of dealing with changes and analysing their impact, increased speed of decision-making, and visualisation, among others.

The challenges were the scarcity of skilled personnel who have knowledge and experience in using BIM and in particular for estimating, absence of a standard guideline for use of BIM for estimating purposes, software integrations issues, and lack of client appetite to develop BIM models (or spend for it), among others.

The recommendations that flow from these include: greater levels of industry-wide training of personnel, universities and tertiary education establishments focusing on more training, development of BIM-related estimating standards, and policy level government led support (as in the case of the UK mandating level 2 BIM for public sector projects over £16m). It is recommended that BIM adoption especially for estimating purposes should occur at the Project Development Phase to Request for Proposal (RFP) Phase where PPP consortia can implement BIM models in their bids that would include the first generation of BIM-enabled estimates for the project.

This report proposes an execution framework for BIM-enabled early-stage estimating in PPP projects with three primary components:

1. Process protocol model for BIM-enabled early-stage estimating in PPP projects (Section 6.2)
2. Drivers and barriers for BIM-enabled early-stage estimating that should be considered (Section 7.1)
3. Best practice guidelines for adopting BIM-enabled early-stage estimating in PPP projects (Section 7.2)

The process protocol model (Figure 5 on page 34) is the main component that provides step by step guidance on how to integrate BIM-enabled estimating at early stages of PPP projects. This model helps in developing a BIM Execution Plan (BEP) for the project. Project managers, cost managers and BIM managers involved in the project should use this proposed process protocol as the basis of a considered and systematic adoption of BIM for estimating purposes. In adopting the process protocol, one should consider the estimating practice of the country concerned. For example, in the UK, the New Rules of Management (NRM 1) developed by the Royal Institution of Chartered Surveyors (RICS, 2012a & b) should be considered, while in Australia, estimating guidelines produced by the Australian Institute of Quantity Surveyors (AIQS) can be considered. Similarly, in China, the China Engineering Cost Association (CECA) has detailed guidance on developing estimates using its index or quota-based systems that should be considered. The process protocol is designed in a generic manner enabling easy adoption to fit individual country-specific requirements. It is also accompanied by a table that defines and describes each of the terms in the protocol (Table 6.1) followed by guidance notes for implementation (Table 6.2).

Understanding the drivers and barriers for BIM-enabled estimating at early stages of PPP projects is vital for the successful implementation of the process protocol. Drivers are the factors that encourage and enhance the adoption of BIM for early-stage estimating.

The top three drivers for the UK were: **Government pressure towards better practices** was top, followed by **Easier communication and collaboration between all stakeholders**. Both **Cost savings and increased efficiency in monitoring with reduction of requests for information** and **Greater access to information, enabling earlier input into feasibility, planning, design, costs and environmental assessment** were the joint third most important driver.

In Australia, the top three Drivers were: **Desire for innovation to remain competitive** at the top spot indicating commercial pressures, followed by **Accurate construction sequencing and clash detection** and **Time savings in the preparation of cost estimates** respectively.

The situation in China especially at the top was similar to Australia with **Desire for innovation to remain competitive** being considered the top driver, followed by **Improving the capacity to provide whole life value to client** and **Facilitating increased pre-fabrication with information-rich BIM**. It is interesting to see the emphasis China puts on prefabrication here.

The top four drivers for all countries were: **Desire for innovation to remain competitive**, **Accurate construction sequencing and clash detection**, **Improving the capacity to provide whole life value to client**, and **Client/Competitive pressure** respectively. These had cross-board acceptance from all six international experts.

Barriers for the adoption of BIM-enabled estimating at early stages of PPP projects were defined as the inhibitors that discourage the use of BIM-enabled estimating. Understanding barriers that apply to each country is important so that adequate steps can be taken to eliminate such.

The top three barriers identified in the UK were: **Technological issues**, followed by **Inadequate relevant knowledge and expertise in using BIM** and **Poor information sharing and collaboration issues**.

The top three barriers in Australia were: **Inadequate relevant knowledge and expertise** at the top, followed by **Cultural resistance for using new technologies like BIM** and **Incompatibility between BIM data and standard practices**.

The barriers identified in China were very much similar to what was identified in the UK and Australia where the top three were: **Technological issues**, at the top followed by **Inadequate relevant knowledge and expertise in using BIM**, and **Implementing BIM is expensive/Cost overrun with BIM** respectively.

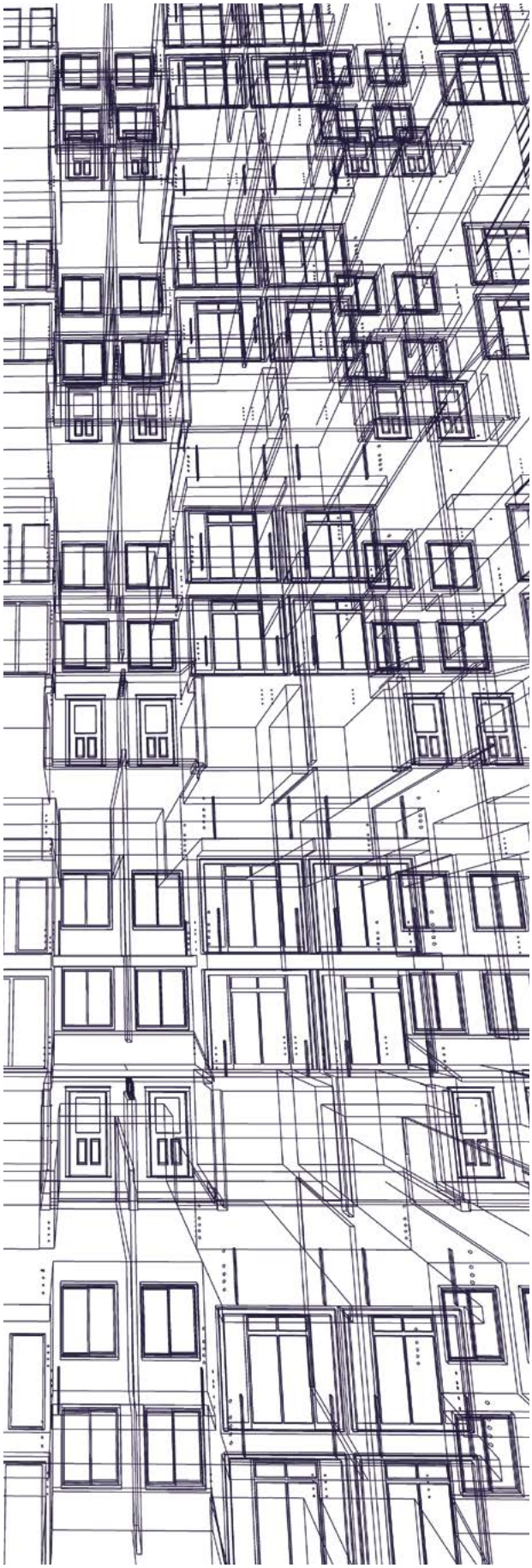
There were six barriers identified at the top for all countries. These were: **Inadequate relevant knowledge and expertise in using BIM**, which was clearly at the top. Though, both second and third ranked barriers did not have full consensus they were in overall terms: **Technological issues** and **Low quality of BIM data**. The fourth ranked barrier, **Incompatibility between BIM data and standard practices** did have full consensus of all experts. Two barriers were jointly ranked fifth by all experts: **Cultural resistance for using new technologies like BIM** and **Liability issues including professional licensing, design liability and vulnerability to changes of BIM by unauthorised parties**.

The third key component of the framework is the best practice guide for BIM-enabled estimating (Table 7.11) at the early stages of a PPP procured project. The guide identifies seventeen aspects that BIM managers, project managers and cost managers should consider in implementing the process protocol proposed. These are categorised into Process, Practice and Policy, covering the three main areas of concerns for implementing BIM-enabled estimating. The Process category contains the measures that practitioners need to carefully consider when they are in the process of using the BIM for early-stage estimating. The second category, Practice consists of practice that ensures the overall management of the use of BIM in early-stage estimating in PPP projects. This informs practitioners of the measures to take into consideration when drafting PPP contracts and a BIM Execution Plan. The third category, Policy provides measures on how governments and external stakeholders could help to facilitate the use of BIM in early-stage estimating in PPP projects.

The report strongly advocates the adoption of the following recommendations to help in the digitalisation processes of the construction industry. Construction procurement is the area that is least digitalised and that inhibits the integration of digitalisation in the vastly complex and fragmented construction industry.

The main recommendations are:

1. Adopt the BIM Execution Framework proposed in this report and integrate it with the cost management processes of each respective country.
2. Start to implement the use of BIM during the Project Development Phase to Request for Proposals (RFP) phase of PPP projects.
3. Encourage or mandate the use of BIM and BIM-enabled estimates for consortia bids in PPP projects.
4. Develop country-specific standards for BIM-enabled estimating based on the process protocol proposed.
5. Use the guidelines provided through drivers and barriers for BIM-enabled estimating in developing BIM Execution Plans for projects.
6. Use the best practice guide as a document providing guidance and a checklist in writing BIM Execution Plans for PPP projects.
7. Take steps in educating the workforce on BIM-enabled estimating with necessary training and academic programmes.
8. Encourage public authorities and construction clients to mandate BIM for projects considering the long-term benefits that it generates for PPP projects.
9. Governments to take action to mandate use of BIM in PPP-type of public sector projects considering the successes of the lead taken by the UK government in this respect.
10. Explore the impact and possibilities of complementary digitalisation technologies such as blockchain, Internet of Things and big data analytics in achieving greater levels of digitalisation in estimating and overall construction procurement.



1.0 Introduction

Satisfying clients' requirements has been the focal point of landmark reports since the publications of Sir Michael Latham's report (Latham, 1994) and Sir John Egan's report (Egan, 1998). For instance, over the years, the construction industry has been criticised for its poor performance by both government and institutional reports across the globe. The recent report published by McKinsey (2017) on the global construction industry shows global construction productivity improving at the low rate of 1% compared to manufacturing at 3.6%. The situation is worse in the case of digitalisation where the construction industry is lacking behind all other industries except agriculture. This is corroborated by Ashworth and Perera (2015) and Elmualim and Gilder (2014) that fragmentation exists in the division of obligation between the professions, professionals and contractors. These are the basis of the ill-disposed culture between contractors, subcontractors, suppliers and their clients. The main goal within the construction industry is to deliver a well-designed, quality product to meet clients' requirements, on time and within budget. Be that as it may, a large proportion of construction projects fail to achieve client satisfaction. For example, according to Egan's report, in the UK around 30% of construction projects, usually buildings, fail to meet clients' requirements in terms of quality (Cunningham, 2013). It is against this backdrop that many researchers advocate Building Information Modelling (BIM) as the panacea and a genuinely necessary change in the construction industry. BIM has certainly created a clamour in the construction industry to shift the way that design and construction documents are produced and communicated. In joining developed countries like the US and those in Scandinavia where high-level adoption of BIM is found, the UK government mandated the use of BIM by September 2016, for all those involved in larger-scale public sector projects.

BIM has received much attention in the management of infrastructure projects delivery with the possibility to change the traditional construction practices. For instance, a number of earlier researchers have alluded to the benefits of BIM, such as reduction in design errors, reduction in project time and cost, better production quality, lifecycle data management, and an integrated project delivery approach that encourages collaboration among different stakeholders to the project over its lifecycle (Ashworth and Perera, 2018). Public Private Partnerships (PPPs) are exceptionally complex contractual arrangements evolved to manage different risks associated with projects by assigning the responsibilities to various project stakeholders. Increasingly, governments around the world consider PPP as an option of choice for large-scale physical and social infrastructure projects.

BIM, which is the platform for an integrated project delivery approach, can add value to PPP projects by providing an established medium for collaboration and information sharing among the stakeholders (Laishram, 2013). McArthur and Sun (2015) affirmed that PPPs are now becoming an increasingly popular procurement method and are highly challenging as they require the collaboration of the designers, constructors and operators from the earliest stage of the project, with each having a particular perspective. Therefore, balancing the conflicting needs and identifying where they align are critical steps in project planning (McArthur and Sun, 2015). Hence, using BIM in PPP projects can provide substantial benefits to the project team by facilitating the information flow between stakeholders, minimising duplication of efforts and allowing the team to make informed decisions to optimise the project over its lifecycle.

Relevant previous works, especially by Laishram (2011) explored the hurdles in the implementation of BIM to manage the construction projects procured through PPPs. Ganah and John (2013) examined the suitability of BIM for enhancing value for money (VfM) in PPP projects. McArthur and Sun (2015) reviewed the best practices for using BIM in PPP projects among others. Despite these previous studies, there is a dearth of efforts at exploring the application of BIM to early-stage cost estimating for PPP projects. Thus, research on the integration of BIM into early-stage cost estimating for PPP projects is a timely need. It is on this premise that this research becomes imperative with a view to developing the best practice framework for BIM-enabled early stage cost estimating for PPP projects in order to enhance value for money in PPP projects.

This research aims to achieve the following:

- Review methods of estimating practised in early-stage estimating for PPP projects
- Explore application of BIM to early-stage estimating
- Analyse best practice in estimating and use of BIM for estimating
- Evaluate drivers and barriers for BIM-enabled early-stage estimating in PPP projects
- Develop an execution framework for BIM-enabled early-stage estimating

The next section identifies the approach used to achieve these aims.

2.0 Methodology

The research methodology consists of a literature review, organisational case studies and Delphi-based expert forum. These qualitative methods enable the research to capture the state of BIM-enabled estimating in PPP projects at an in-depth and comprehensive level enabling a holistic view. The overview of the research method is provided in Figure 1.

The research data was gathered from three partner countries: UK, Australia, and China. Each country was represented by a project team that investigated the use of PPP, the early-stage estimating processes and the level of use of BIM in PPP projects for the three countries. Information gathered was collated and analysed subsequently to develop the framework.

The literature review was initially used to conceptualise the state of early-stage estimating in PPP projects and the use of BIM in general. The first stage of the review was to develop a greater understanding of the PPP process and stages involved and the role of estimators at different stages. This was followed by a review of BIM and the level of use in general. Subsequently, drivers and barriers for the adoption of BIM were investigated. This stage helped in conceptualising a process model for BIM-enabled estimating in PPP projects.

The case studies phase of the research involved primary data gathering through case study interviews identifying organisational practice of early-stage estimating and the level of use of BIM. It enabled the research to identify best practice, as well as identify weaknesses that require improvement leading to drivers and barriers. The conceptual process model established was further developed and reviewed in this phase.

The final phase of the research involved the formation of an Expert Forum consisting of six international experts in PPP and estimating. The forum included two experts from each country as indicated in Table 2.1. It enabled the research to capture the knowledge and experience of the experts in PPP and BIM. The expert forum was conducted in two stages where drivers and barriers for adoption of BIM for estimating in PPP projects were reviewed and refined. It further enabled the research to refine and validate the process model developed at the case studies phase and to finalise the framework. The final BIM Execution Framework consists of drivers and barriers for BIM adoption in early-stage estimating in PPP projects, a detailed model for executing BIM-enabled estimating and a set of best practice guidelines.

The next section of the report examines the estimating process in PPP projects and the issues related to use of BIM.

Figure 1 **Research method**

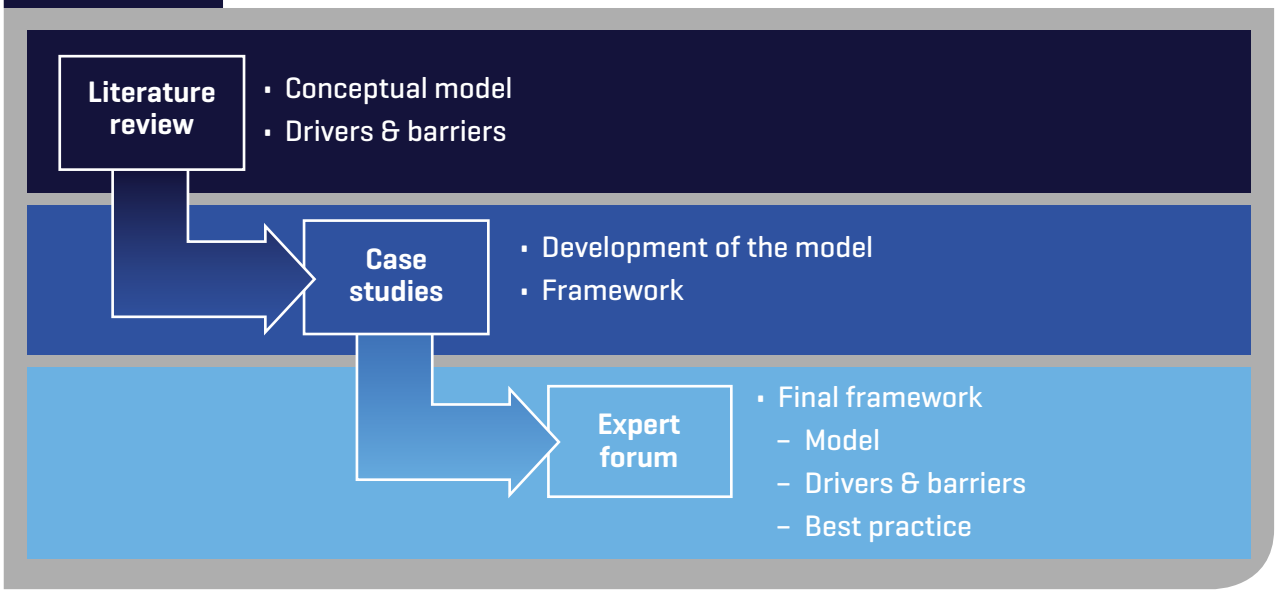
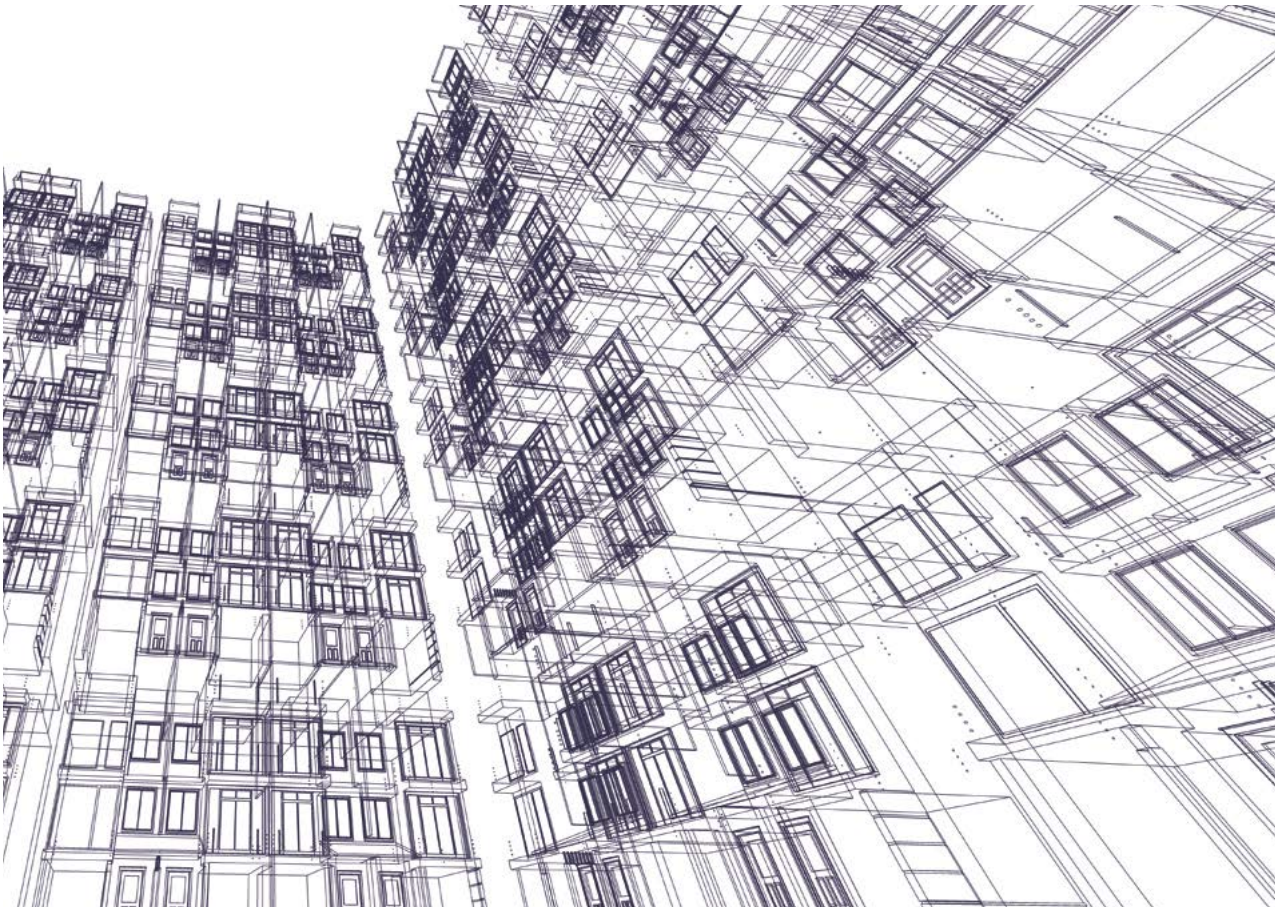


Table 2.1 **Expert information**

Country		Designation	Qualifications	Years of experience
UK	Expert 1	Associate Professor in BIM & Digital Technologies, Research Fellow	MSc in Information Technology in Property and Construction PhD (Computer-Aided-Learning in Building Pathology)	15 years in academia, construction industry research and advisory
	Expert 2	Construction Manager /Group CEO International, The Chairperson of a professional institution	PGCert APL, FCIOB, FCMI, FIoD, FHEA, EURBE	42 years in construction industry
Australia	Expert 1	Senior Cost Planner of a leading international property and infrastructure company involved in PPP procurement	B App Science in Building, OAM, FAIB	32 years in construction industry, and academia
	Expert 2	Co-founder of a quantity surveying technology software company and an advocate for BIM as chair of a 'Smart' building association	B App Science in Quantity Surveying	35 years in the construction and IT software industries
China	Expert 1	Vice General Manager of an engineering company, General Secretary of a municipal association, Deputy Dean, (PPP research Centre) of a university	PhD, MSc (Mgmt), BEng	12 years in construction industry specialising in PPP
	Expert 2	Consultant to the World Bank OECD and the ECOSOC of the United Nations; Advisor to the Ministry of Finance of China, the State Development and Reform Commission and many local governments in China on PPP	B.Eng., M.Eng., M.Fin. and PhD	20 years in construction industry, research and academia



3.0 Overview of the Public Private Partnership concept

It is widely recognised that infrastructure is an enabler for developing an economy, and that vast segments of existing infrastructure in the developed world are becoming deficient. The unfolding impacts of climate change and population increase are putting a strain on countries and their aging infrastructure (Petru, 2014). Countries across the globe need to construct new transit systems, roads and utilities or modernise their aging infrastructure to adapt to the changing climate, reduce carbon emissions and support growing populations. Thus, global infrastructure requirements could involve expenditure totalling US$50 trillion in the period up to 2030 (The City UK, 2014). While meeting this demand, public finances in many countries face major constraints that could result in private sector finance playing a key role in bridging the gap. Being aware of this, led the UK to revolutionise the delivery of public infrastructure using Private Finance Initiative/Public Private Partnership (PFI/PPP). Today, the UK is considered one of the most mature in PPPs, though recent years saw the decline of use after the introduction of the Private Finance Initiative 2. HM Treasury (2014) reported that as at 31 March 2014, there were 728 PFI projects, of which 671 were operational in the UK with a total capital value of £56.6 billion. Currently, the success of PPP procurement recorded in countries like the UK and Australia has been witnessed by the world. In Australia, since the late 1990s PPP procurement started growing rapidly as an alternative public procurement mechanism and has since been used for a wide range of projects such as infrastructure, utilities, health and correctional services (Siddiquee, 2011). It is evident that PPPs have made significant impacts worldwide in public infrastructure development and are now used in over 40 countries.

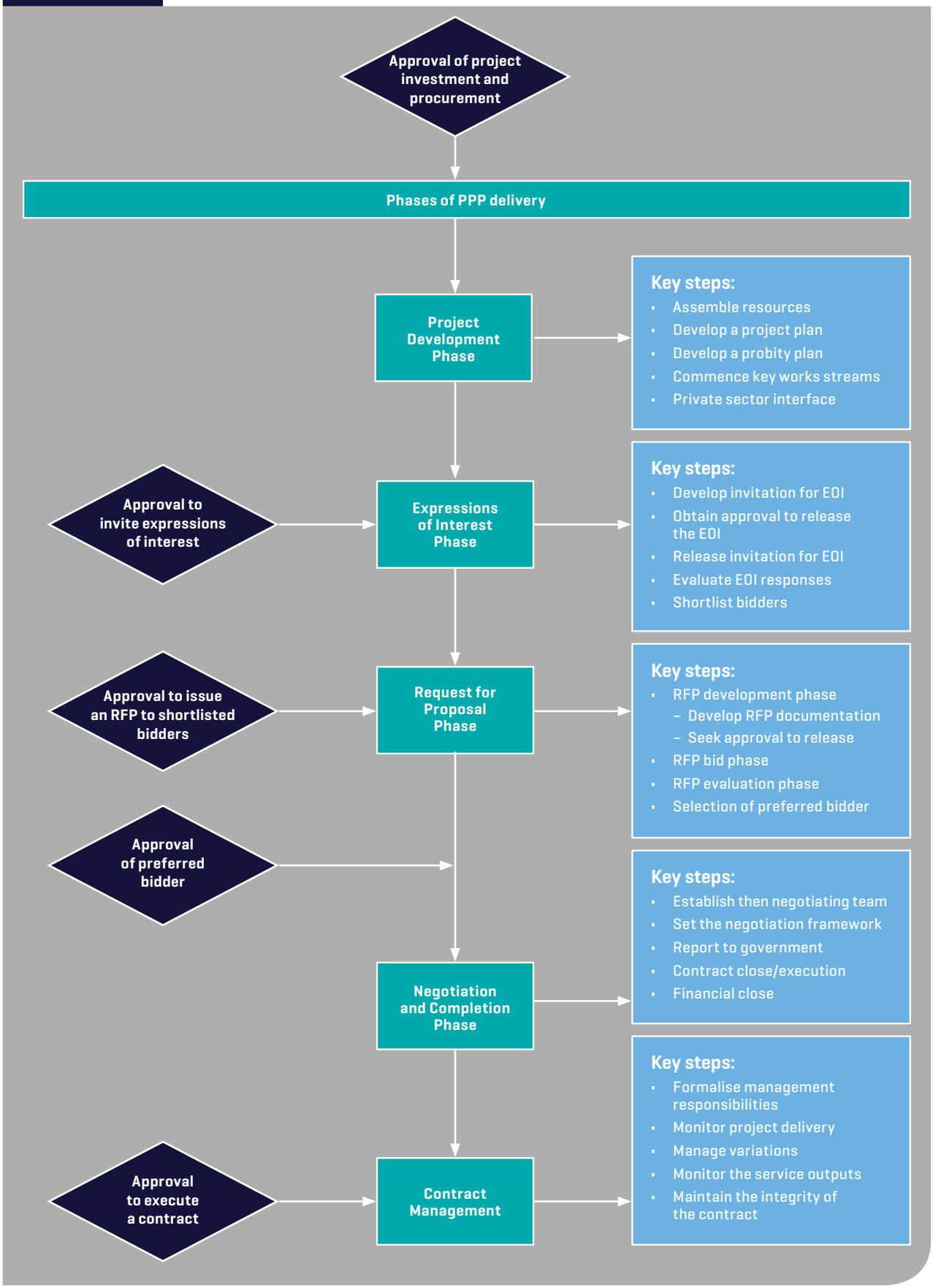
3.1 PPP process and models

PPPs are used when the public sector requires a private sector partner to design, build, finance, maintain, and perhaps operate, a public infrastructure. It covers all types of collaboration to share risk and deliver policies, services and infrastructure. Figure 2 shows the delivery process of PPP projects. The PPP procurement process involves five major stages. At every stage there are several interrelated activities. The process starts from the project development phase. It is at this stage that cost estimating is performed. Detailed lifecycle costs of the proposed project are estimated. The next stage is the expression of interest phase. At this stage, the private sector bidders submit their preliminary proposal for consideration by the public authority. After this stage, the request for the detailed proposal follows. At this stage the private sector bidder submits a detailed proposal for evaluation by the public authority. The negotiation and completion phase is where the preferred private sector bidder is selected, and detail contract terms including the sharing of risks and responsibilities are agreed. Contract management is the last stage, where the private sector bidder takes over the management of the contract and project.

There are two forms of models that are widely used by governments for the development of public infrastructure facilities and services. These are: (1) a finance-based approach that is aimed at using private finance to meet infrastructure needs; and (2) a service-based approach that is aimed at optimising the time and cost efficiencies in service delivery (Aziz, 2007). The first model relies on user fees and project demand to fund projects. For example, the earliest types of PPP were mostly finance-based and included Build-Operate-Transfer (BOT), Build-Transfer-Operate (BTO), and Build-Own-Operate (BOO) models (Zhang and Kumaraswamy, 2001).

The second model is service based, which is aimed at using the skills, innovations, and management of the private sector in optimising the time and cost efficiencies in service delivery. A good example of this approach is the Design-Build-Finance-Operate (DBFO) arrangement. Under this model, projects are funded mainly through government sources, with or without user fees, while still using private financing. Similarly, several arrangements of PPPs have been used including the Build-Operate-Transfer (BOT) model, which is most often cited when referring to PPPs, and its variants including Design-Build-Operate-Maintain (DBOM), Build-Own-Operate (BOO), Build-Own-Operate-Transfer (BOOT), Design-Build-Finance-Operate (DBFO), Rehabilitate-Operate-Transfer (ROT), and Build-Lease-Transfer (BLT) among others. Figure 3 indicates the PPP models with the level of private sector responsibility.

Figure 2 Phases of PPP delivery process



Source: Commonwealth of Australia (2016) National Public Private Partnership Guidelines – Vol. 2: Practitioners Guide, 2015, Department of Infrastructure and Regional Development, Canberra, Australia

Figure 3 PPP models

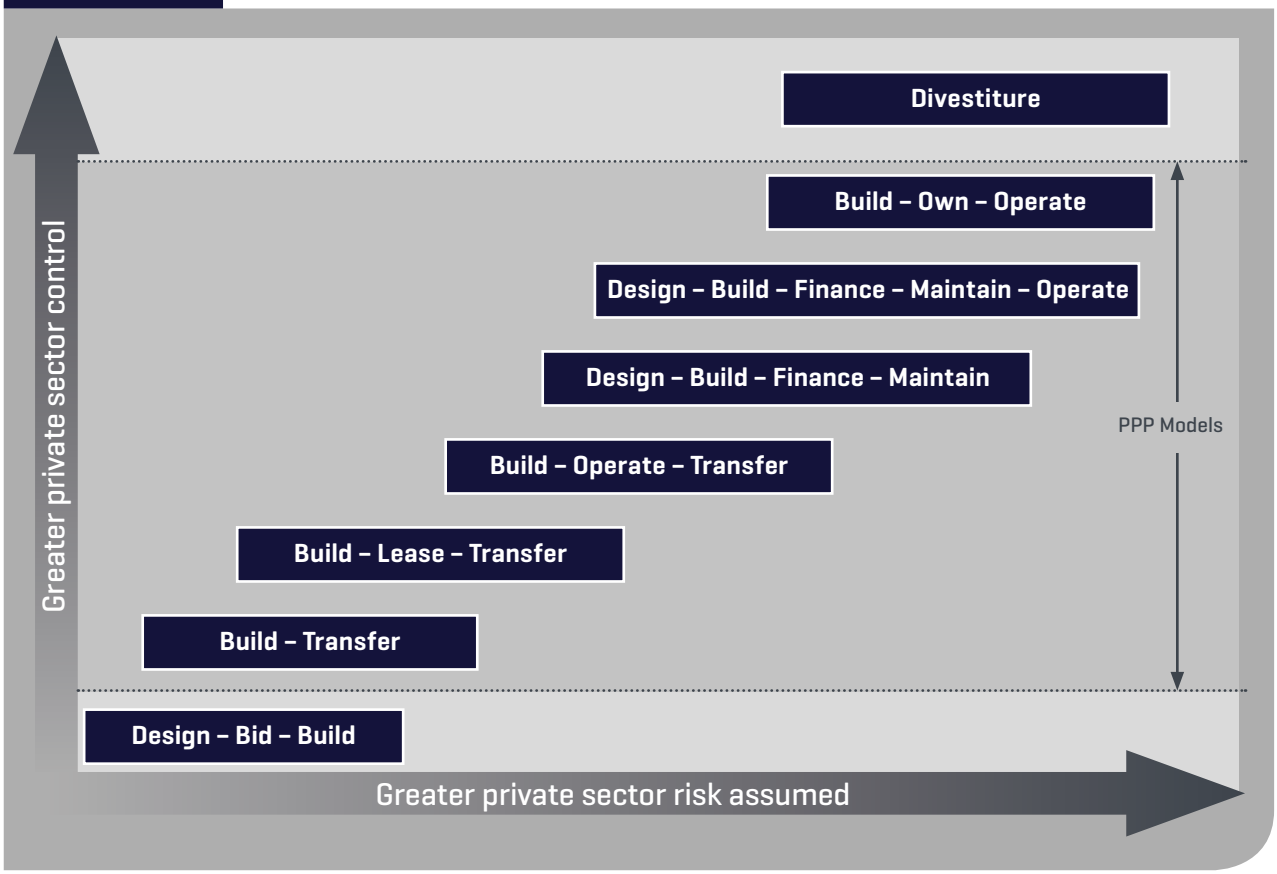


Figure source: Adapted from Siemiatycki, 2012, p. 5

3.2 Cost estimating practices in PPP

At the early stages of PPP projects, costs are estimated by both the public and private sectors. Specifically, the stage at which estimating for PPP projects costs takes place depends on the project party i.e. public or private sector. The public sector usually performs early-stage estimating at the conceptual stage of the PPP process. The public sector/contracting authority adopts the public sector comparator (PSC) to ascertain the possible lifecycle cost of the proposed PPP project. More details on the early-stage estimating by the public sector are provided in subsequent sections.

For the private sector, the early-stage estimating occurs at the pre-tender stage of the PPP process. At this stage, the private sector bidders ascertain the detailed lifecycle costs of the proposed projects. The proposed lifecycle costs of the projects are then assessed and evaluated by the contracting public authority and are used as one of the bases for selecting the right bidder. Importantly, BIM application at the pre-tender stage is very critical and should be introduced at this stage because it can dramatically improve time and cost savings. The PPP process involves diverse stakeholders working on separate information pools, thus, with the use of BIM, different views of the project are unified to a common platform, which will enable all stakeholders to effectively exchange the same information and work collaboratively (Smith, 2014).

3.2.1 Estimating for PPP projects in the UK

The launch of PFI in the UK in 1992 saw the development and extensive adoption of the PPP model for the procurement of public infrastructure projects. HM Treasury has indicated that PPP solutions should only be considered for projects with a capital value of £50m or more because less capital-intensive projects rarely justify the relatively high procurement and management costs (Department of Finance, 2017). Hence, accurate project cost estimation of the PPP project is essential.

During the early stage of a PPP project's development, generally preliminary estimates are carried out to estimate the project cost and to check for the value for money (Ashworth and Perera, 2015). The PSC, capital appraisal, financial analysis and affordability studies are based on such estimates (Boussabaine, 2007). It is suggested that in the absence of complete design and

specifications, preliminary cost plan and estimates that are lacking a rational basis may prove disastrous for project stakeholders (Li, Shen, and Love, 2005). Furthermore, it is well documented that the early-stage preliminary cost estimate will change around 20% with the final cost (Ashworth and Perera, 2015, 2018).

Generally, the success of a project largely depends on the accuracy of the early estimate of the project's Anticipated Final Cost (AFC) (HM Treasury and Infrastructure UK (2013)). Furthermore, early cost estimates are vulnerable to influencing behaviours when allied to the desires of key stakeholders to ensure a proposal secures funding and meets (sometimes conflicting) objectives. According to HM Treasury and Infrastructure UK (2013), AFC for any project or programme consists of two components (1) a Base Cost (which is the value the estimators believe represents the most likely expenditure required to deliver the requirement) and (2) a Risk Allowance. Furthermore, risk allowance is accounted for the course of action over the project's life such as the development of the design, the greater understanding of the solution's interfaces with its physical environment, scope changes and specific risks (HM Treasury and Infrastructure UK, 2013). Two steps are involved when developing the AFC. (1) Generating the initial estimate and (2) Testing the initial estimate against the appropriate project out-turn reference data. The initial cost estimate can be created at the inception stage from the Green Book Supplement. This estimate is usually created from the initial risk estimates and the reference class forecasting (Infrastructure Risk Group, 2013). Importantly, to cross check any early estimate, the out-turn data for comparable projects should be used (HM Treasury and Infrastructure UK, 2013).

3.2.2 Use of estimating in PPP projects in Australia

In Australia, the growing importance attached to PPP procurement at national and state level has led to formulating policy and guidelines and establishing separate groups and units to assist various government agencies in undertaking PPPs (Siddiquee, 2011). Australia's National PPP Working Group was established in 2004 with jurisdictional representation of the Australian government and all the states and territory governments to lead PPP policy development and process improvement (Infrastructure Australia, 2018). Subsequently, Australia developed a National PPP Policy Framework and National PPP Guidelines to provide a consistent framework that enables public and private sector collaboration to enhance public service delivery through private sector participation in provision of infrastructure and related services. According to the Commonwealth of Australia (2016), National Public PPP Guidelines – Overview (2008), PPP guideline publications comprise volumes (1 – 6) of National PPP Detailed Guidance Material. Deviations from the national guidelines are allowed as per the individual Jurisdictional Requirements Documents of states and territories *Commonwealth of Australia, 2016, Volume 6*. In this context, the Australian PPP market is widely accepted to be among the most sophisticated and mature PPP markets in the world.

The PSC is developed to test whether PPPs provide better VfM over traditional procurement options and to act as a benchmark against which bids are compared (Commonwealth of Australia, 2016). Since the PSC is a valuable tool for government in determining VfM, it is vital that the PSC is prepared carefully and comprehensively. The guideline publication *Commonwealth of Australia 2016, National Public Private Partnership Guidelines – Volume 4: Public Sector Comparator Guidance – 2008*, provides directions on the development and use of the PSC. The Australian government and all the states and territory governments require application of PSC to ensure VfM and high levels of integrity in PPP procurements. This is evident according to publication *Commonwealth of Australia 2016, National Public Private Partnership Guidelines – Volume 6: Jurisdictional Requirements – 2014,* which contains state and territory governments' specific PPP guidelines namely, New South Wales Requirements (2012), Partnerships Victoria Requirements (2013), Queensland Requirements (2011), Western Australian Requirements (2010), South Australian Requirements (2009), Tasmanian Requirements (2009), Northern Territory Requirements (2009), and Australian Capital Territory Requirements (2009).

It is important that estimated net capital costs should reflect the best available information and prevailing best practice, as incorrect estimates may lead to cost overruns and may adversely impact on the interests of project stakeholders. In the case of PPP projects, end users (or the public sector) generally bear the consequence of cost overruns by way of paying extra margins on services delivered. This is particularly evident in the operation of social and economic infrastructure projects procured through PPPs across many countries including UK and Australia (Doloi, 2011).

In Australia, based on data from 56 projects and a survey of 102 quantity surveying firms, Ajibade and Pasco (2008) revealed that the accuracy of pre-tender building cost estimates has not improved over time and the majority of the respondents were dissatisfied to a certain degree regarding the accuracy of estimates in the industry. Notwithstanding, the findings of research conducted in Australia by Doloi (2011) clearly highlighted the requirement for a radical shift in cost estimation of complex projects rather than relying on traditional cost estimation principles, which remain inadequate in addressing demand for cost management in modern complex projects. Thus, BIM being not new to Australia and having an abundance of advantages may help in enhancing the accuracy of early-stage cost estimates, avoiding unfavourable procurement decisions especially in case of PPPs that have direct impact on public interests.

3.2.3 Use of estimating in PPP projects in China

In China, the project investment estimate is based on the project design or feasibility study documents at the decision-making stage that define the composition of the proposed project in accordance with the prescribed procedures, programmes and bases. It is one of the important factors in project investment decision-making (Yan Ling and Yin Yilin, 2017).

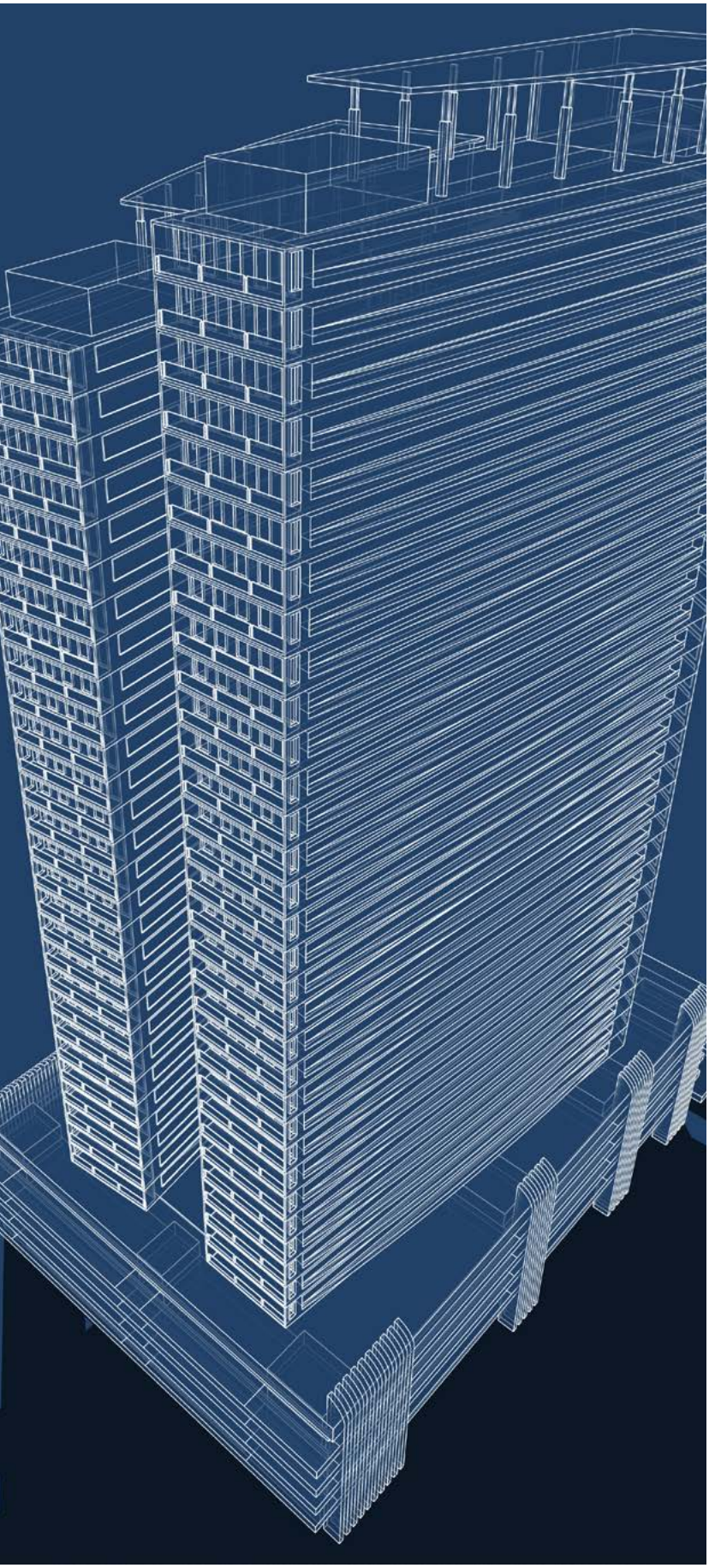
The Construction Project Cost Advisory Code (GB / T 51095-2015) provides that the estimated investment can be divided into construction project investment estimates, single project investment estimates, and unit project investment estimates. The investment estimate in the project proposal stage can be compiled using the index of production capacity, coefficient estimation, proportion estimation, index (quota) estimation or the hybrid method. The investment estimation in the feasibility study stage adopts the quota-based estimating method. These quotas are investment indicators or benchmarks that estimates can be evaluated against.

In the traditional investment management model, the investment decision-making (feasibility) stage usually constrains the investment estimation. However, because the project conditions are far from being certain at this stage, the project construction plan is not yet specific enough, and the proposed projects are generally not yet formed, it is very difficult to estimate investment and the error can be substantial. More often, in order to launch the project, investment is underestimated, and profits are overestimated, while the rigor of investment estimates is ignored.

Due to the inaccurate, sometimes missing, preliminary estimates of PPP projects in China, a series of problems have arisen. A corresponding benchmark (index) system is missing for the preliminary estimation of PPP projects. According to the information released by the Ministry of Finance, the Social Capital Cooperation Centre (CPPPC) and the National Development and Reform Commission (NDRC), such a benchmark system is very important for the development of the more advanced municipal PPP projects (such as rail transit, landscape greening, water supply, drainage, heating, hospitals, education, affordable housing PPP projects). Although China has national benchmarks for PPP projects such as rail transit, water supply, drainage, heating and underground integrated pipe corridors, the benchmark (index) system is not perfect enough to guide local practices. Furthermore, such a system has not been established for landscaping PPP projects. Although a clear estimation benchmark system has not been established for the PPP projects of hospitals, education and affordable housing projects, there are professional reference books (but their accuracy is unknown). In summary, it is imperative to establish a reasonable and sound estimation benchmark (index) system to guide the implementation of PPP projects.

Investment estimates are of paramount importance as a basis for VfM evaluation and measurement of financial expenditures. The vast majority of PPP projects in China are started once the feasibility study is completed. That is, the VfM Evaluation Report, the Financial Capability Demonstration Report and the PPP Implementation Plan are all based on the Feasibility Study Report and the investment estimates, measurement basis, project output, and operation and maintenance costs, economic evaluation parameters (Gong and Wei, 2016). Moreover, the pre-investment estimate, project output and operation and maintenance costs of PPP projects are the core basis for calculating government subsidies and feasible gap subsidies or adjusting users' payment quotas. If the estimation is not accurate, the data on project output and operation and maintenance costs will have a direct impact on the expenditures of the financial departments and will affect the experience of infrastructure users. Therefore, the investment estimation benchmark is the basis for the VfM to evaluate and measure the financial expenditure. Relevant industrial authorities are required to provide more accurate investment estimation benchmarks, project output, and operation and maintenance costs benchmarks to enable the implementation of PPP projects.

Inaccurate investment estimates will aggravate the Two Standard and One Standard investment in PPP projects and lead to the project investment being out of control. Both the Ministry of Finance and the NDRC have indicated in the relevant documents that Two Standards and One Standard in the practice of the PPP project is legal (that is, the social capital with corresponding capacity can build itself without further bidding by the contractor at the construction stage). However, Two Standards and One Standard also has its drawbacks. When selecting social capital, the basis for project investment and annual government operation subsidy (if any) during the project operation period comes from the feasibility study report and the project investment estimate General Index (Zhang, 2016). If the estimation of investment is still determined using the traditional pricing method (e.g., expanding the index method or quotas) and the accurate bidding price and pricing system cannot be set up, there is no effective government investment review of the whole process of cost supervision, resulting in the one-time gaming gambler mentality that exacerbates the social capital side to grab excess construction profits (Yu, 2012). At the same time, PPP projects in this context are similar to those projects of a general contracting arrangement – both winning bidders (social capitalists or general contractors) are identified at the pre-project stage (conceptual or preliminary design stage) to sign the total contract. It is similar to the method of cost management and investment control of engineering, procurement and construction (EPC) projects. Relevant industry authorities should formulate more accurate investment estimation indices applicable to various types of PPP projects in order to curb the risk caused by the Two Standard and One Standard. The earlier stage of the contracting phase of the project is estimated to be distorted and the project investment is out of control.



4.0 BIM-enabled cost estimating for PPP projects

4.1 BIM-enabled estimating for general construction projects

It is the practice to perform early-stage cost estimating based on schematic design to obtain initial budget prices of a project. However, schematic designs usually provide a rough design thereby making it extremely challenging to obtain enough information for a proper detailed cost estimate. As a result, involvement of the cost estimator's subjective decisions in the estimating process is inevitable. As BIM is widely used in the building construction industry, it could also be used in estimating so that more accurate estimating outcomes are achieved (Seul-Ki, Kim, and Yu, 2014).

Using level 3 BIM, cost estimating can be carried out through the 5D function by linking the model to an estimating database (Haque and Mishra, 2007). Ashworth and Perera (2015) states that early-stage cost estimating can be performed with the use of cost databases such as Building Cost Information Service in the UK (BCIS), Rowlinsons Australian Construction Handbook or Spon's Architects' and Builders' Price Book in the UK, to provide high-level cost information. Certain software providers are now publicising that it is possible to develop detailed cost plans through linking a '5D Cost Library' to BIM. Some leading software used for estimating in the UK are Navisworks, Autodesk QTO, CostX, Innovaya, iTWO, d-profiler, Vico, ProjectWise Navigator, Bentley ConstrucSim, Balfour Technologies (Abanda, Kamsu-Foguem and Tah, 2017). In Australia, Cost X and BuildSoft are the most dominant, while in China, Glodon estimating software is the most popular.

As indicated in Figure 4, with interconnected object quantities and estimate items, estimates are easily updated with each reloading of the modified 3D model from the BIM software. Therefore, it can be deduced that BIM estimating greatly improves accuracy of an estimate giving the estimator a better understanding of what is being estimated.

Figure 4 Traditional vs. BIM estimating method

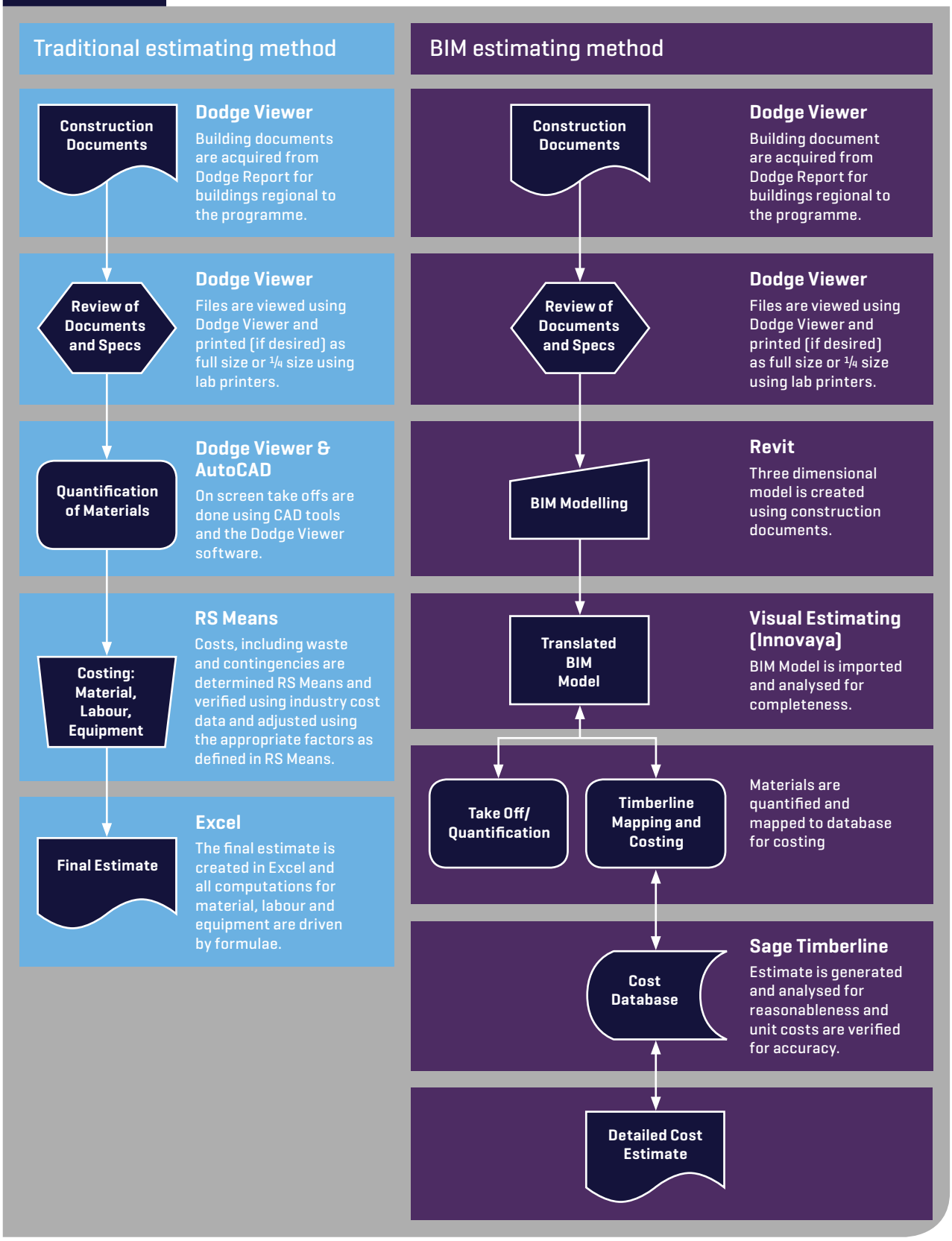


Figure source: Sylvester and Dietrich, 2010

4.2 BIM-enabled estimating for PPP projects

The three key choices for cost estimation using BIM can be categorised as: (1) move building object amounts to prediction software, (2) employ a BIM quantity take off resource, or (3) connect the BIM resource to the prediction software (Eastman et al., 2011). In the first two choices, information is extracted from the model and transported using a format that can be easily taken by cost estimating programs. For instance, there are several programs which are compatible with cost estimation processes: CATO, CostX, and Nomitech are among them (Exactal, 2017).

According to HM Government in the UK, (2013), the BIM Task Group was driven by industry and was supported with £4m of UK Government funding for implementation of the BIM strategy. Furthermore, HM Government has identified that effective usage of BIM in public sector projects could save money. As an example, collaboration with the Ministry of Justice has demonstrated significant savings in the design and procurement stages, with the £20m Cookham Wood prison reporting an 18% saving through effective use of BIM (HM Government, 2013). BIM is also considered a repository for knowledge and information that is useful during the operation and maintenance phase of the PPP project. However, in the UK, most PPP projects experienced cost and schedule overruns, though the government (as the client) was not liable for the increase in expenditure incurred (Love et. al., 2015). For example, the contractor John Laing was subjected to additional costs of £100m when it could not complete the National Physical Laboratory (Love et al., 2015).

Its dynamic cost management system enables more estimates of investment, improves cost management and helps owners to make the right decisions, laying a solid foundation for lifecycle cost management (Zhang Shuli 2016).

The preparation of PPP project investment estimation based on BIM technology relies mainly on the existing model database. Through the application of the model in the library, a visual model can be quickly set up and the investment project estimate of PPP can be compiled accordingly. The basic process includes:

1. Building units or design units to establish the preliminary design of the building in the BIM model and determine the optimal programme
2. Estimating the cost using the preliminary BIM model and database of costs
3. Investment estimates can then be integrated with the financial analysis tools to obtain the return on investment that will help in the project decision-making.

4.3 Contractual measures facilitating BIM-based management of PPP projects

For a successful BIM application in PPP contracts, proper contractual measures need to be in place. In simple terms, contractual measures refer to the strategies that are required to enhance the legal and mutual relationship existing among team members in a project. This implies that in every PPP contract, there is a mutual relationship among client, contractor and other stakeholders. Indeed, this contractual relationship needs to be properly coordinated in a BIM environment to ensure that the project objectives and BIM goals are achieved. McArthur and Sun (2015) identified a series of contractual measures that are applicable to PPP contracts. These include:

- Dedicate personnel from all partners to develop BEP (BIM Execution Plan)
- Foster an open environment for sharing and collaboration
- Develop guidelines to assist collaboration within the consortium and project stakeholders
- Early planning: especially regarding use case identification and selection and phased ownership assignments for model elements
- Review and update the BEP regularly and resolve outstanding issues
- Provide sufficient resources for BIM
- Ensure a consistent approach to BIM execution across all partners
- Modify model in 3D instead of 2D views to ensure model integrity etc.

Generally, PPP is considered as a method of financing, which is predominantly used for large infrastructure projects (Osei-Kyei and Chan, 2015). BIM is mostly encouraged in PPP contracts because it helps to minimise lifecycle cost and maximise the sustainability of the project. However, as previously emphasised by McArthur and Sun (2015), strong collaboration among project stakeholders is required to ensure that the BIM goals of PPP contracts are achieved.

4.3.1 Issues in the UK

A BIM Execution Plan (BEP) should be collaboratively developed at the early design stage (Wu and Issa, 2014), to identify key project tasks, outputs and model configuration. The Computer Integrated Construction (CIC) Research Program (2011) described a BEP as a tool to provide a standardised workflow and general guidance for strategic BIM implementation in a holistic approach for a project or a group of projects. It is evident that early development and effective use of a BEP has a strong influence on the success of a project BIM. Against this backdrop several BEP templates are developed. For instance, in Australia, NATSPEC (National Building Specification) (2012) developed the National BIM Guide, which aims to establish a set of considerations when using BIM in an Australian-based project. The National BIM Guide aims to assist clients, consultants and stakeholders to clarify their BIM requirements in a nationally consistent manner.

In the UK, the AEC (UK) (2012) BIM Protocol builds on the guidelines and frameworks defined by the UK standards documents including the Construction Project Information Committee (2013), and other BEP templates to include the Hong Kong Institute of Building Information Modelling (2011), Institute for BIM in Canada (IBC) (2013) and Indiana University Architect's Office (2015). These are reviewed within the context of this research.

A review of the BEP templates revealed a strong internal consistency among the templates. The consistency across templates included the need to: set project goals, define organisational roles, agree on model structure and BIM information exchanges, document technological infrastructure needs, document and schedule project deliverables, and identify specific use cases required to achieve these goals. Other requirements include: design reviews, programming, maintenance scheduling, facility energy analysis, cost estimation, site analysis, 3D design coordination, space management, 4D (phase) planning, design authoring, building system analysis, code validation, and sustainability evaluation among others.

4.3.2 Issues in Australia

One of the most reported obstacles to the successful adoption of BIM is the perceived legal risks associated with its integration and the need for implementation in a collaborative environment. Undoubtedly, many of the existing standardised construction contracts used in Australia were drafted before the emergence of BIM. Therefore, many of these contracts do not have BIM provisions, particularly on the need for a collaborative environment in contract administration. This has therefore been a major cause of delay in the successful adoption of BIM in the Australian construction industry. Manderson et al. (2015) studied the contractual and legal concerns associated with BIM implementation by looking critically at the GC21 2nd edition, an Australian standardised construction contract. The authors proposed several changes to the GC21 to suit the implementation of BIM in Australia. Some of the proposed changes include: the need to adopt a collaborative contract structure with equitable risk and reward mechanisms, recognition of the model as a contract document and the need for standardisation of communication/information exchange.

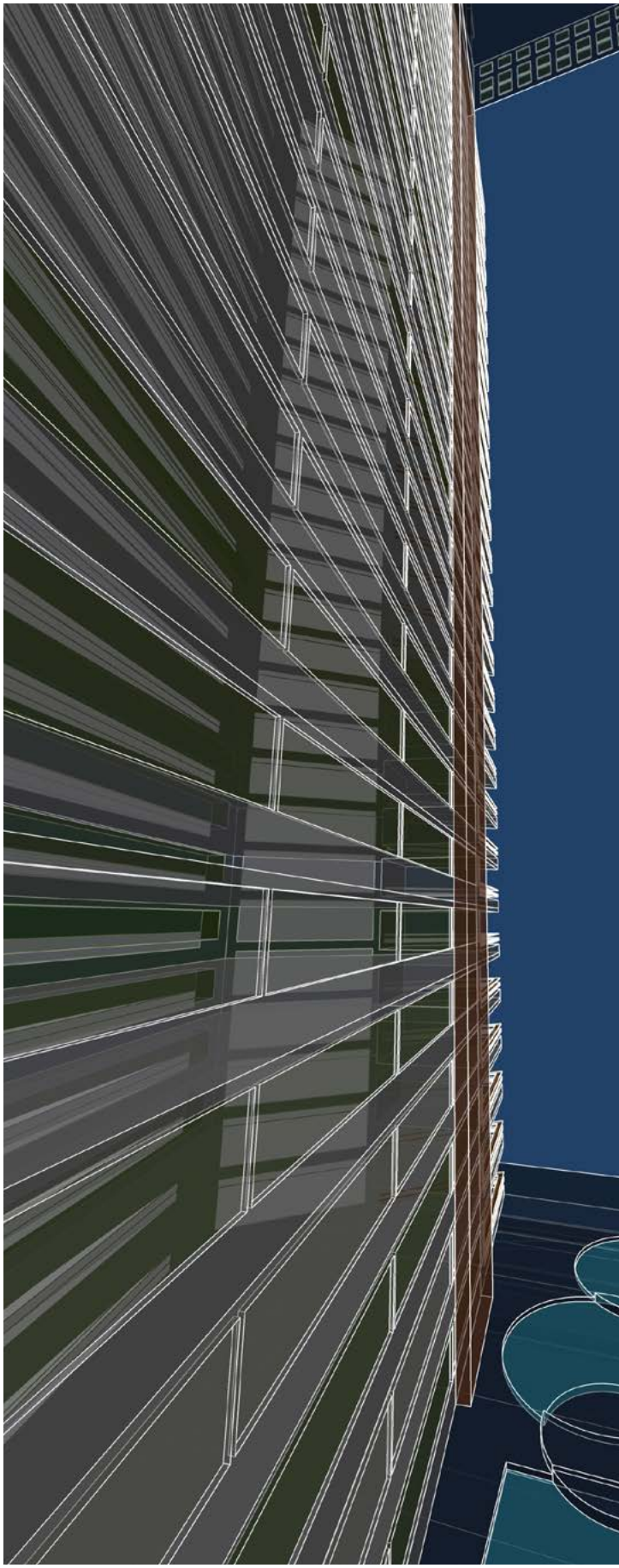
Currently, there is no published standard construction form that specifically stipulates BIM provisions, and this is certainly a major setback to BIM adoption for PPP projects in Australia (Kuiper and Holzer, 2013), (DIT, 2012). Notwithstanding, most BIM projects in Australia adopt requirements and standards from other countries with similar construction practices, including the UK Furthermore, other projects with BIM adoption, consider BIM as part of the design documentation (Kuiper and Holzer, 2013), (DIT, 2012). These notwithstanding, there have been attempts by industry stakeholders to develop guidelines for the implementation of BIM in the Australian construction industry. For example, NATSPEC (the National Building Specification) has developed the National BIM Guide, which aims to establish a set of considerations when using BIM in an Australian-based project (NATSPEC, 2011). The National BIM Guide is currently being used by clients, consultants and other project stakeholders who are interested in adopting BIM in their projects. Moreover, the guide informs project stakeholders of the BIM requirements for specific construction contracts in Australia (NATSPEC, 2011). Other efforts by industry stakeholders on BIM implementation in Australia includes the release of the *Building and Construction Procurement Guide: Project Team Integration and Building Information Modelling* at the Australian Construction Industry Forum. Essentially, this guide provides helpful guidance on BIM issues. Also, the *Australia and New Zealand BIM Best Practice Guidelines* published by the Australian Institute of Quantity Surveyors (AIQS) and New Zealand Institute of Quantity Surveyors, (NZIQS) (2018), highlight key knowledge areas and specifics about BIM, what to expect in a BIM project, quality assurance, legal issues to be aware of whilst working on BIM projects and information on what quantity surveyors need to know about BIM and a timeline of a quantity surveyor's role in the BIM Execution Plan. This document intends to provide a guide for quantity surveyors, cost managers or cost estimators looking to be involved with a project utilising BIM. Inevitably, these guidelines may complement the outcome of this research in proposing BIM-enabled cost estimating framework for PPP projects.

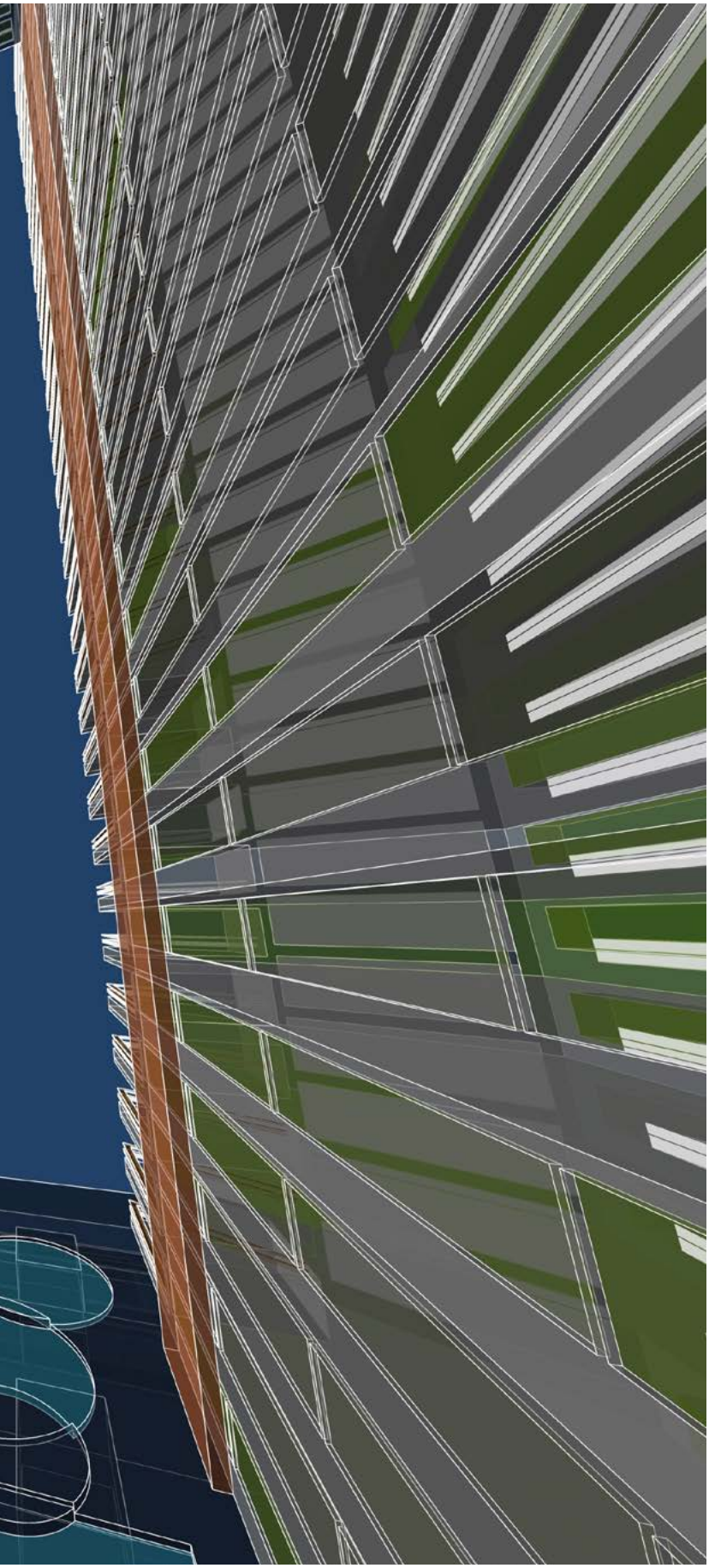
4.3.3 Issues in China

In China, the ultimate investment objective of social capital investment projects is to make economic gains. Government investment projects are more concerned with meeting the needs of society or with economic development, and are seldom merely for profit. For PPP projects, the lack of a specific and measurable investment objective poses difficulties for the project's goal management and contract management because of the different objective functions of social capital and government involvement.

Due to the imperfect laws and regulations of the PPP model and related institutional environment in China, there are not enough mature experiences to learn from. To achieve the effectiveness of BIM management in PPP projects, China could consider setting reasonable contracts during project preparation, including the terms enabling PPP project management based on BIM technology to truly take hold (Pang Jiali, 2016).

First, clarify the requirements for submitting the corresponding information from each participant, including how to submit the information, whether it is paper or electronic, the time submitted, the information creator who submitted the information, and the information that can be modified. Second, ensure that all parties are aware of the input and output of information in each process, and at the same time have the responsibility to ensure the integrity and accuracy of the information, as well as the terms of attribution of the relevant intellectual property and confidentiality of the information. In the meantime, to increase the enthusiasm of contractors to use BIM technology, some incentive provisions should be set in the contract to encourage contractors to use BIM technology for design optimisation. For example, the benefits of design optimisation using BIM technology agreed in the contract can be considered as a percentage of total cost to increase the enthusiasm of the contractor to apply BIM technology.





5.0 Organisational practice case studies

This section is focused on the findings of face-to-face interviews conducted in relation to cost estimating practice in PPP projects in different countries comprising the UK, Australia and China. Two organisations with involvement or experience in PPP projects were identified in the UK and Australia and three in China. A series of interviews with two key professionals per company involved in estimating were carried out. The results are analysed in the following key headings:

1. Cost estimating process used at PPP phases
2. Dealing with differences between cost estimates prepared at PPP phases and negotiations
3. Extent of computer usage in the estimating process
4. BIM application in estimating for PPP projects (project level/enterprise level)
5. BIM-enabled estimating practice in PPP projects (industry level)

The following sections of this chapter present the findings from the interviews conducted on a country basis. In presenting the results PPP projects were divided in to two stages as follows:

- **Stage A:** Approval of project investment and procurement selection [initial Public Sector Comparator (PSC) Development]
- **Stage B:** Project Development Phase to Request for Proposal (RFP) Phase (during which the upgraded project estimate is prepared to compare bids)

5.1 Cost estimating process used in PPP projects in the UK

5.1.1 Cost estimating process used at PPP phases

The following table summarises the status of cost estimating in projects in the UK.

Table 5.1 Status of cost estimating in PPP projects (UK)

UK	
Criteria	**Status**
Project team members involved in the cost estimating process	• Project manager, project architect, client, commercial lead, project estimator, project design team, site manager, and construction team members.
Information received to prepare the project cost estimate	• Mainly conceptual and schematic drawings at the early stage of the project and later on specifications.
Tools and techniques for cost estimating	• Use of norms from local authorities, benchmark the contractor's data against historical data or internal data and further benchmark against the contractor's pricing strategies, obtain specific cost from nominated suppliers, cost data from similar PPP project schemes, price books, past project cost data adjusting the time and location as well.
Level of detail of project cost estimate	• Nominal bills, subcontractor's quotes, cost analysis, schedules of quantities and early elemental cost estimate.

5.1.2 Dealing with differences between cost estimates prepared at PPP phases and negotiations

It is clear that the public authority responsible for the PPP has a primary responsibility to keep the project and the budget within scope. Therefore, they would go through details of relevant work and benchmarks, and afterwards compile a summary of differences to reconcile. Contractors would generally realise that they must work within the envelope, for the scheme to go ahead. The contractors (PPP consortia) would always be aware of the budgetary limits of the project and they usually attempt to be within these limits. They know that they must reconcile the cost plan back to the previous estimate that was based on the design phase development.

5.1.3 Extent of computer usage in the estimating process

Computers are utilised to a large extent at both stages of cost estimate preparation. Microsoft Excel and CostX are the most common software used for cost estimating and report generation. At Stage A, CostX and Excel are used extensively. At Stage B, Revit and Vico Office cost software are used as BIM-enabled estimating tools. Other software used in the preparation of cost estimate includes Navisworks, Vector5 and AutoCAD (some of which are used for measuring volumes of road and area etc).

5.1.4 BIM application in estimating for PPP projects (project level/enterprise level)

The following table summarises the BIM Application in estimating for PPP projects in the UK.

Table 5.2 Status of BIM-enabled cost estimating at early stages of PPP projects (UK)

UK	
Criteria	**Status**
BIM use	• Endeavour to use BIM on infrastructure project delivery especially for road and ports related projects.
Advantages	• Time (reduction), clash detection, production of base data, ease of effecting changes in design or amendment to quantities and rates. • Design changes or amendments to quantities and rates are very easy to deal with if BIM is used. • Cost or carbon implications can be generated from federated models. • BIM-enabled cost estimating tools would be quite quick and can have significant benefit at Stage B, thereby reducing the taking off time. • BIM model can be used as a basis of designing other similar projects in future if required.
Challenges	• Lack of availability of qualified personnel with relevant BIM and estimating knowledge. • Quantity surveying (QS) firms working with BIM need to be aware of the limitations of various BIM software from experience. • It is difficult and expensive to enforce adopting of standards and maintaining those, as a large number of designs come through in the form of sketches, which are not properly managed to expected level.
Recommended best practices	• Having proficiency in BIM authoring individual software. • Incorporate BIM-enabled estimating in the BIM Execution Plan. • Ensuring QS information requirement is ascertained in BIM development. • Having a thorough understanding of the software that you intend to use. • Deciding on how often the cost plan (stage basis or other) is updated. • Deciding on how implications of cost increases or any design changes are dealt with (revising model etc.).

5.1.5 BIM-enabled estimating practice in PPP projects (Industry level)

The following table summarises BIM-enabled estimating practice in PPP Projects at industry level in the UK.

Table 5.3 Status of BIM-enabled estimating practice in PPP Projects at industry level (UK)

UK	
Criteria	**Status**
Incompatibilities between BIM-enabled estimating output and the prevailing estimating practice requirements/standards in the local construction	• Not many incompatibilities exist between BIM-enabled estimating output and the prevailing estimating practice requirements. • Some issues of incompatibility of Bills of Quantity (BQ) items and how BIM provide quantities. • Mainly it is associated with the level of training, adopting and adapting, culture, government requirements and inconsistency. .
Recommendations for enhancing BIM-enabled cost estimating in local construction industry	• Better training and better understanding of what is in the market, cultural change, prompt adoption of BIM while challenging the barriers, federated model (the model that combines all dimensions of BIM), teaching and giving experience on BIM-enabled cost estimating software during the undergraduate or post graduate programmes and increasing BIM awareness within organisations .

5.2 Cost estimating process used in PPP projects in Australia

5.2.1 Cost estimating process used at PPP phases

The following table summarises the status of cost estimating in projects in the Australia.

Table 5.4 Status of cost estimating in PPP projects (Australia)

Australia	
Criteria	**Status**
Project team members involved in the cost estimating process	• Estimating manager, bid manager, project manager, design manager, design team, cost planners and estimators, subcontractors and supply chain participants, specialist consultants and estimators and financing institution and facilities manager. • Majority stay throughout the process to offer cost information and to help with cost estimates towards achieving the best output.
Information received to prepare the project cost estimate	• Mainly conceptual and schematic drawings, specification, design brief, schedule of areas and client's preference scheme.
Tools and techniques for cost estimating	• Start with looking at the design, cost implication, programme implications related to every aspect of the building. • High-level cost planning by means of costing ideas and options while providing feedback to the design team so that the most optimised solution is achieved at the start. • Benchmarking in terms of application of cost/m² • Rates based on other similar projects to form a view on an appropriate value for a project to guide the consultant's design to be in-line with the client's' expectations. • In the end, elemental bills with the ability to be coded on trade basis, so that market cost information is obtained easily on each trade.
Level of detail of project cost estimate	• A very high-level cost plan at the start and then progressed to more detailed bill of quantities. • Final estimate is more detailed than cost/m² of functional area. Elemental bill of quantities with the ability to change from elemental to trades.

5.2.2 Dealing with differences between cost estimates prepared at PPP phases and negotiations

There is limited room for negotiations between the client and the PPP consortia. Benchmark process and consultant evaluations are used to ensure prices are cut down to the minimum possible.

5.2.3 Extent of computer usage in the estimating process

Most commonly used software for bill of quantities and estimating are Buildsoft, CostX, Vectorworks, Plainswift, while some bespoke software is used by larger construction companies. CostX is the most popular software for estimating and cost planning other than the use of Microsoft Excel. MS Project was also cited as software used for planning and scheduling.

5.2.4 BIM application in estimating for PPP projects (project level/enterprise level)

The following table summarises the BIM application in estimating for PPP projects in Australia.

Table 5.5 Status of BIM-enabled cost estimating at early stages of PPP projects (Australia)

Australia	
Criteria	**Status**
BIM use	• BIM for estimating in PPP is in its infancy and not widely used in PPP bid preparation. • BIM is mainly used for design purpose and visualisation of some selective PPP projects. • BIM is used for various estimating purposes of other projects.
Advantages	• BIM enables electronic documentation, 3D visualisation, ability to easily detect change, manipulation of data, good decision-making and speed. • Quantities can directly be extracted from the model. • Fully updated model (including what is in that building) is handed over at the end of the project to the facilities manager/operating authority, making operation of the facility easier. • 3D BIM makes it possible to visualise, walk through and spin around the modelled designs making clients impressed with BIM (clients can look at it, feel it and see what is happening).
Challenges	• As the design consultants and the estimators have different thoughts on what should be included on the model, a lot of modification to the model is still required so that it can be utilised to extract cost information. • Having the model in a way that information could be extracted easily. • Lack of appetite for implementing preliminary concept designs into models by designers at the start of the project.
Recommended best practices	• Public authority to encourage adoption of BIM. • Design development with the use of BIM to be closely followed up with estimating (5D BIM).

5.2.5 BIM-enabled estimating practice in PPP projects (industry level)

The following table summarises BIM-enabled estimating practice in PPP Projects at industry level in Australia.

Table 5.6 Status of cost estimating in PPP projects at industry level (Australia)

Australia	
Criteria	**Status**
Existing incompatibilities between BIM-enabled estimating output and the prevailing estimating practice requirements/standards in the local construction	• Mismatch in data formats between different software.
Recommendations for enhancing BIM-enabled cost estimating in local construction industry	• Upskilling people and teaching BIM • Technological, including software issues and lack of BIM expertise, legal issues and acceptability, design liability, licensing, data security, economical cost, cultural resistance and lack of BIM awareness should be addressed.

5.3 Cost estimating process used in PPP projects in China

5.3.1 Cost estimating process used at PPP Phases

The following table summarises the status of cost estimating in projects in China.

Table 5.7 **Status of cost estimating in PPP projects (China)**

China	
Criteria	**Status**
Project team members involved in the cost estimating process	• Initial team includes professionals of various disciplines, technical personnel in engineering technology, engineering economy, cost and finance, implementation agencies, government-funded representatives, feasibility study units, consulting agencies and industry authorities. • The bidding team includes professionals from operation department, marketing department, legal department, commerce department, finance department, investment department and other departments related to the project.
Information received to prepare the project cost estimate	• Initially, relevant policy documents of the PPP project and project operating costs, feasibility study report provided by the implementing agency and relevant industry specifications and standards. • The consulting organisation collects the relevant policy documents of the PPP project, the relevant industry specifications, standards and project operating costs. Basic project operation information obtained through due diligence conducted by consulting organisation. • Usually, no drawings but simple sketches along with any relevant information, properties of the building including the structure, use, several floors above ground, several floors underground, decoration standards, etc. • At the bidding stage, additional information on project payment mechanism, price adjustment mechanism, project contract price determination method and adjustment method (if any), engineering quantity list (if any), distribution of rights and obligations and bidding indicator setting, etc. • Design drawings for some projects, for which the government completes preliminary works of the project prior to contract award.
Tools and techniques for cost estimating	• Initial project cost estimate using feasibility study and unit costs (cost/m²) based on relevant standards, historical cost indicators of similar projects, government-issued quota and current market prices. • The cost estimate at bidding stage compliant with government-issued quota and equivalent to investment estimate prepared at feasibility study phase.
Level of detail of project cost estimate	• Initial estimate including benchmark prices based on quantity determined by the feasibility study report and unit costs (cost/m²). • At the bidding stage, the cost estimate including financial data such as financing, loans, and interest % and cost indicators with reference to unilateral cost of similar projects.

5.3.2 Dealing with differences between cost estimates prepared at PPP phases and negotiations

At Stage A, the project cost estimate is usually based on the initial feasibility study. At Stage B, if the design documents are obtained, the quotation is generally based on the design budget. Where there is a difference, the design estimates supersede and if the feasibility study of Stage A is based on the quotation, the stage will be consistent. After the drawings are published, the construction and installation project fees will be re-determined, and the contract will be signed. After the project is completed, it will be settled with the construction party according to the actual situation. The preliminary estimate is only a reference.

Where there is a difference between the project costs estimate prepared at Stage B and the selected bidder's project cost included in the Bid Proposal, the purchaser shall determine the social capital selected, the difference between the social capital bid quotation and the purchase control price. This is only from the client's side. The bid price shall prevail, and the operating cost shall be adjusted according to the price adjustment mechanism stipulated in the PPP project contract.

The initial project cost in the bid proposal is subject to negotiation. Moreover, the project bidding will be accompanied by the project market test. The project bidding, that is, the project evaluation process will be accompanied by the project market test, the main purpose of which is to communicate the relevant core boundary conditions of the project, such as project financing cost and social capital fund. Costs such as operating costs, project cost determination, etc., are all core requirements related to the project lifecycle cost.

5.3.3 Extent of computer usage in the estimating process

Software is mainly used for project budgeting. At Stage A: historical data and indicators, the commonly used software is Excel, and Guanglianda engineering cost software. At Stage B: Guanglianda calculation software, Guanglianda engineering cost software, and material price information network are used.

5.3.4 BIM application in estimating for PPP projects (project level/enterprise level)

The following table summarises the BIM application in estimating for PPP projects in China.

Table 5.8 **Status of BIM-enabled cost estimating at early stages of PPP projects (China)**

China	
Criteria	**Status**
BIM use	• BIM is not used currently for estimating purposes. • Guanglianda estimating software is used to calculate the amount. • Even if some design adopts BIM, the information volume of the model is unable to meet the application of various stages such as cost and construction management.
Advantages	• Enterprises do not perceive many advantages of using BIM-enabled estimating when compared to the traditional use of Guanglianda software. • Future versions of BIM-enabled estimating will enable modelling costs from inception to final bid model. • There are many benefits during detailed design development and later operation and maintenance phases.
Challenges	• Absence of unified standard in adopting BIM. • Difficulty in supporting cost estimating due to low level of information carrying capacity of the designed BIM model. • Unavailability of BIM models at the early stage as it is expensive to create a model from an early stage.
Recommended best practices	• At Stage A, BIM cannot be effectively be used unless it is for a very similar building or structure for which a BIM model exists. • At Stage B, BIM models can be developed to support bids. However, the PPP practice in China does not allow for such level of detail at present. Therefore, to adopt BIM-enabled estimating, PPP practice needs to be changed through policy drivers.

5.3.5 BIM-enabled estimating practice in PPP Projects (industry level)

The following table summarises BIM-enabled estimating practice in PPP projects at industry level in China.

Table 5.9 **Status of cost estimating in PPP projects at industry level (China)**

China	
Criteria	**Status**
Existing incompatibilities between BIM-enabled estimating output and the prevailing estimating practice requirements/standards in the local construction	• Difficulty in using BIM to complete the investment estimating before determining the investment intention because of its holistic nature. Though it is used at some stage which is problematic. • BIM model standards completed by different design institutes are different, thus, unable to unify the index conditions (cost benchmarks and quota) associated with the cost library and the model.
Recommendations for enhancing BIM-enabled cost estimating in local construction industry	• Requirement to improve the BIM technology itself and integration with other software.

5.4 Comparative analysis of estimating practice in PPP projects in the UK, Australia and China

This section compares and contrasts the PPP project estimating practices between the three countries the UK, Australia and China.

The project team members involved in bid preparation stages are similar in all three countries. The notable difference here is that in China there were more agencies involved in these processes. Data provided at bid stages were much similar in the UK and Australia whereas in China drawings were usually not provided at this stage.

The findings on the extent of computer usage in the estimating process indicated that there is widespread computer usage at both stages (i.e. stages A and B) of cost estimate preparation. In the UK and Australia, Excel and CostX were commonly used at Stage A, while Revit and Vico Office were used as BIM estimating tools at Stage B in the UK. Microsoft Excel was commonly used at Stage A in China, whereas Guanglida engineering cost software was used at Stage B.

At Stage A, use of BIM for estimating purposes is not very practical due to the fact that single rate estimating techniques such as cost per m^2 is primarily used. However, there is a much more positive prognosis for the use of BIM-enabled estimating during the Stage B of PPP projects.

The UK showed the comparatively highest level of usage followed by China and Australia. Although, general usage of BIM is much higher in all countries, use of 5D BIM was limited and use in PPP projects even scarcer.

Designs at very early stages lack the detail that is required for a BIM model, making its usage at early stages limited. This is universal and common to all countries. The main challenges come from lack of knowledge in the construction industry on the use of BIM and the poor level of skills. Education was identified as one of the primary requirements. Policy and legislative support for BIM implementation was evident in the UK but such positive approaches were less prevalent in China and even non-existent in Australia. In China, it was clear that the absence of a unified standard was a main challenge even if the designer decides to adopt BIM. In Australia, it was seen that a BIM-enabled cost management best practice guide has just been introduced.

Policy frameworks and government pressure were seen as important recommendations for Australia and China. All countries would expect greater level of contractual support for implementation of BIM in projects and in particular PPP projects.

BIM usage in PPP projects was found to be moderate in the UK. In Australia, there was moderate levels of usage (especially for large-scale projects) for construction projects in general, but the extent of BIM usage was for PPP projects was very low. In China, the extent of BIM usage was high generally for construction projects but not significant for PPP projects.

6.0 Process protocol model for BIM-enabled cost estimating in PPP projects

6.1 Early-stage cost estimating practice in PPP project delivery process

In a typical PPP project environment, early-stage cost estimating is carried out at three main phases of the project delivery process prior to contract award. The first and the initial cost estimate is prepared at the PSC development stage during which the investment decision is taken, and the main project components and parameters are decided upon. At this stage, detailed project documents such as drawings and specifications are non-existent for estimating the capital construction cost of the project. The available project information could be limited to few sketches and a schedule of functional requirements. Thus, it is obvious that available project information is insufficient to develop a BIM at this stage and implementing BIM-enabled cost estimating is rather impracticable.

Subsequent to the PSC development, at the Expression of Interest (EOI) stage (Figure 2, see page 16) additional project documents are developed. These documents form part of the EOI and Request for Proposals (RFP) bidding document package issued to the bidders and form the basis for the pre-tender cost estimate to be prepared prior to RFP. The pre-tender estimate provides the basis for bid comparisons and may outline the indicative framework costs for various project components of the proposed PPP project. When compared to traditional project delivery, in PPP delivery there is not enough detailed project documentation available at the tendering stage to prepare the pre-tender cost estimate. This is due to the fundamental characteristics of the PPP project delivery, where the PPP bid proposal is envisaged to include a substantial design component, resulting in each bidder submitting their own distinctive design proposals. Thus, in PPP project delivery only a few design and specification documents are developed at the pre-tender stage (EOI and RFP documentation), making detailed BIM-enabled cost estimating an impracticable task.

At the RFP stage of the PPP projects, PPP bidding documents are issued to interested bidders/PPP sponsor consortia through open or selective tendering. Once the PPP bidding documents are obtained by PPP sponsor consortia, design development is progressively carried out parallel to cost the planning and estimating process. Both the design and cost planning processes are influenced by each other until a substantial design development is implemented and the detailed estimate is prepared for bid submission. Thus, the PPP bid proposal preparation stage provides an ideal platform for implementing BIM-enabled cost estimating practice in PPP projects. Implementing BIM at this stage would also help PPP sponsor consortia to use BIM for various other purposes such as resources planning, clash detection and 3D project visualisation apart from BIM-enabled estimating. In addition, for the winning bidder, BIM could also be used effectively for post-contract project management including cost management as well. Therefore, this research focused on implementing BIM-enabled estimating of capital construction cost by PPP sponsor consortia and developed a conceptual model for the process and thereafter a detailed model, which was validated by the experts and updated based on experts' comments through two rounds of Delphi-based expert forums.

6.2 Final process protocol model for BIM-enabled estimating

The final process model was developed through a detailed and iterative consultation with industry experts in estimating and those who had direct specific experience in PPP projects. The aim of the model is to create a process protocol for integrating BIM for estimating at the early stages of a PPP project. It will help in the systematic regularisation of estimating tasks for the PPP consortia bids.

The terms used in the model are explained in the Table 6.1. These terms must be read in conjunction with the process model presented in Figure 5.

Figure 5 Process protocol model for BIM-enabled estimating of capital construction cost of PPP projects

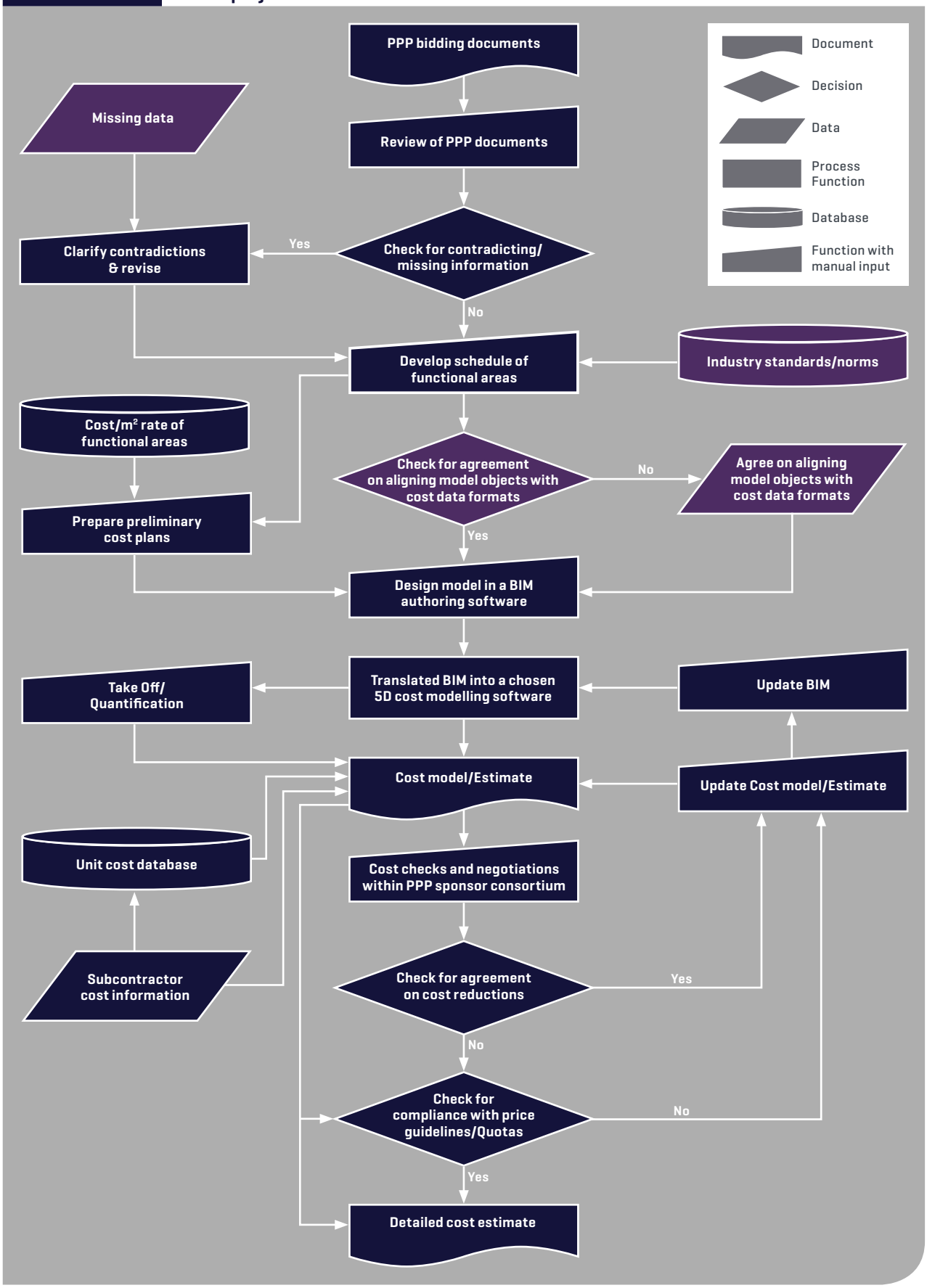


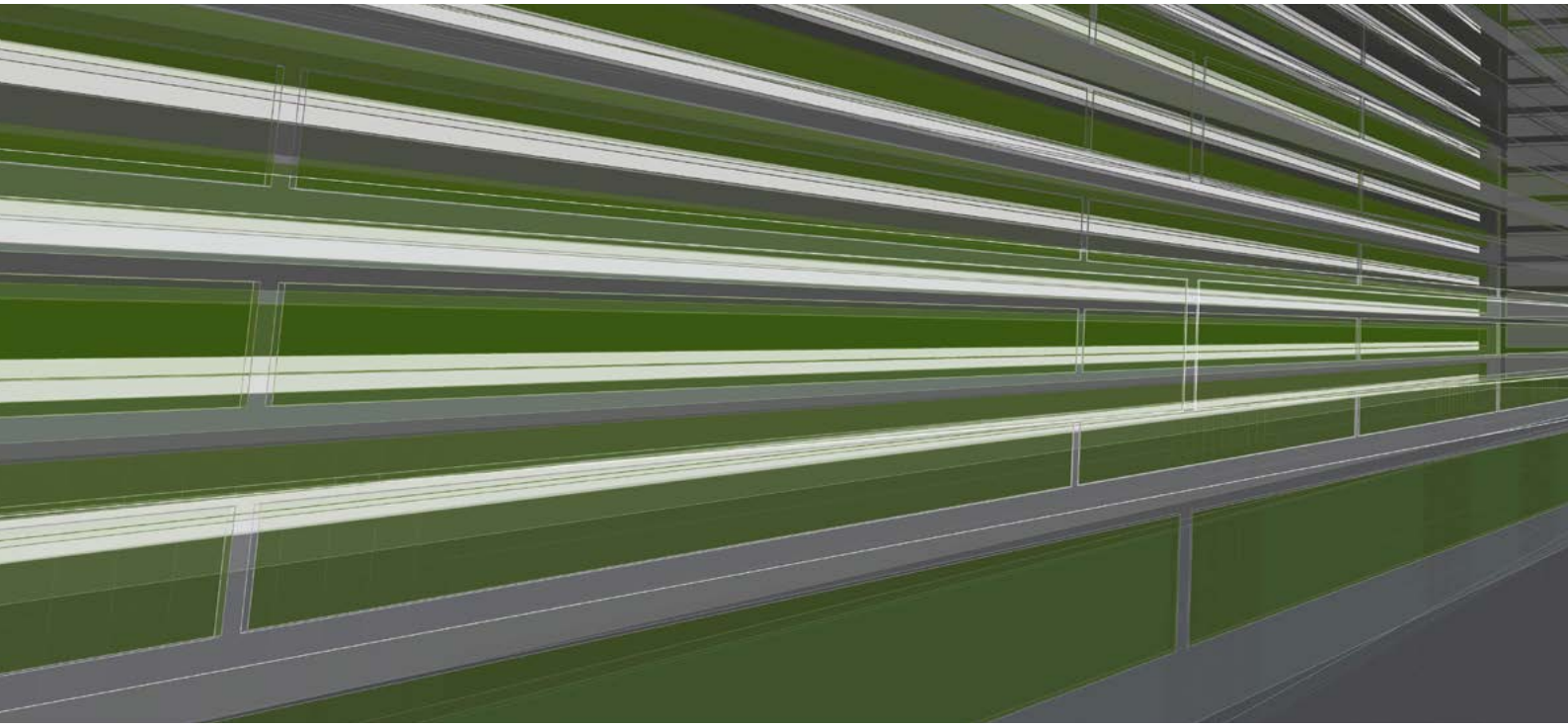
Table 6.1 Definition of terms for process protocol model for BIM-enabled estimating projects

	Term used in model	Definition/brief description
1	PPP bidding documents	PPP bidding documents usually include project-related documents in connection with design, specifications, specific performance requirements, relevant standards, project schemes and relevant state or government PPP guidelines on joint venture consortia, bidding process, procurement and overall PPP framework applicable to the project. The constituents of the bidding documents and the amount of the details included in PPP bidding documents may vary from project type, procurement arrangement, client organisation, geographical location and many other factors. PPP bidding documents are generally obtained from authorised private consultants (PPP advisory) or directly from public authority clients.
2	Review PPP bidding documents	PPP bidding documents are reviewed and checked by all partners of the PPP sponsor consortium including financier, construction contractor and facilities management contractor to determine if there is missing information that would be vital for bidding. Construction contractors may have their own teams including design, cost and management sub-consultants and various specialised subcontractors. PPP sponsor consortium liaise with authorised private consultants (PPP advisory) and public sector authority regarding clarifications on missing information.
3	Check for contradicting/ missing information	Similar checking process as described in above 2 is carried out for contradicting information as well.
4	Clarify contradictions and revise	PPP sponsor consortium liaise with authorised private consultants (PPP advisory) and public sector authority regarding clarification on contradicting information. After clarifications are made, relevant documents are revised as applicable. This process is continued until no further contradiction is found.
5	Missing data	Missing data is obtained from respective sources of information and issued to PPP sponsor consortium by authorised private consultants (PPP advisory) or public sector authority once clarifications are made.
6	Develop schedule of functional areas	The initial schedule of functional areas of the proposed project is developed based on drawings, specifications, applicable industry standards and norms. As for example, in cases of a school project, schedule of areas of classrooms, libraries, staff facilities, sports facilities etc., are developed based on prevailing industry standards and norms.
7	Industry standards, norms etc.	There are various prevailing standards and norms applicable to project types, specific functions, geographical locations etc. that are utilised in deriving schedule of functional areas of PPP projects.
8	Cost/m^2 rate of functional area	Cost/m^2 rates of functional areas are obtained from historical database information, price books, subcontractor quotations etc.
9	Prepare preliminary cost plan	This is a very high-level cost plan/estimate, which is prepared to establish the framework cost for the proposed PPP project. This preliminary cost plan also provides a guideline for cost control during design development.
10	Check for agreement on aligning model objects with cost data formats	It is important to ensure whether the design team (including BIM manager) and cost planning team are in agreement on aligning model objects with cost data formats to have compatibility between BIM model objects and cost data formats.
11	Agree on aligning model objects with cost data formats	Agreement between design team (including BIM manager) and cost planning team is expected in aligning model objects with cost data formats. This would save the time in estimating and helps to enhance the efficiency of the process.
12	Design model in a BIM authoring software	3D-type BIM is created using information from PPP bidding documents in BIM authoring software. At this stage, due consideration is given to factors such as construction approach, resource planning, complexities of design components, clash detection, programme etc., that would have direct impacts on project cost.
13	Translated BIM into a chosen 5D cost modelling software	Once the translation is done, the model is analysed and reviewed for completeness. 3D visualisation and virtual reality walk-throughs of the BIM can be used to keep the project team and client informed of the construction scenario, design, activities etc. Simulated BIM helps to control design and value engineering facilitating project costs to be within the framework cost. BIM data can automatically be exported into bills of quantities templates of computer aided estimating software. 5D cost model is derived by attaching time scale (to become 4D) and overlay of costs (to become 5D) to a 3D model.

continued

continued

	Term used in model	Definition/brief description
14	Take off/Quantification	This process might not be required with some cost modelling software, which automatically perform the quantification function. However, in some cases, components, materials, plant and equipment and other resources might be required to quantify and cross-check before mapping to cost database for costing. Apart from that, quantification is executed if BIM data is required to be manipulated to align with successive construction operations, phases, methods etc.
15	Cost model/Estimate	Cost model/estimate is derived applying unit rates to quantities on desirable templates.
16	Unit cost database	Unit rates of bills of quantity items are obtained from various cost databases, price books, etc. These rates are verified through various industry price information sources and subcontractor quotations.
17	Subcontractor cost information	Cost information on specialised trades/elements is obtained through quotations or price lists from nominated subcontractors/subcontractors.
18	Cost checks and negotiations within PPP sponsor consortium	This involves cost checks and negotiations within members of the PPP sponsor consortia towards seeking agreement on cost reductions. These cost reductions could be achieved by means of changes to designs, specifications, programmes, rates, overheads and profits etc.
19	Check for agreement on cost reductions	This is seeking the agreement on cost reductions subsequent to the process carried out in 18 above.
20	Check for compliance with Price guidelines/ Quotas	Prior to finalisation of the estimate, which represents the capital construction cost segment of the collective bid proposal, further checks are made to see whether the final estimate is in conformity with Price guidelines/Quotas issued by PPP clients.
21	Update Cost Model/ Estimate	Cost Model/Estimate is updated based on negotiated cost reductions within PPP sponsor consortium and/or if the Cost model/Estimate does not comply with Price guidelines/Quotas.
22	Update BIM	BIM model is updated, if the cost reductions result in design changes.
23	Detailed cost estimate	This is the estimate of the capital construction cost, which is included in the bidding price (among other price components) of the PPP sponsor consortium



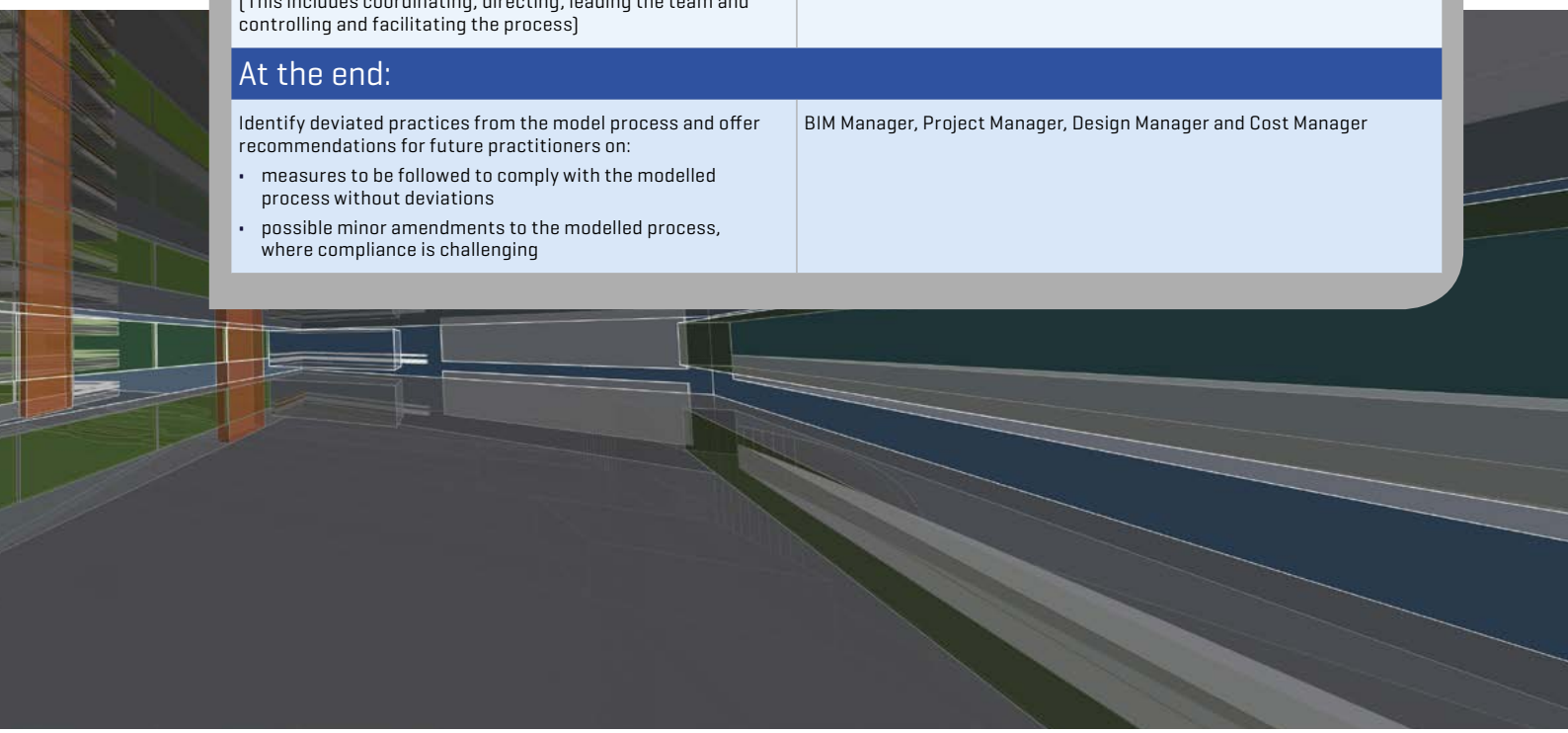
6.2.1 The usage of the process protocol model for BIM-enabled estimating

The process model is intended to be used for BIM-enabled estimating practice in UK, Australia and China for PPP projects. However, with each country having its own policies, practices and procedures for PPP project execution, caution should be taken to adapt it suitably.

Thus, the following guidelines (Table 6.2) offer useful insights for practitioners on how to use the model in their respective PPP project environments. The guideline begins with hiring a BIM Manager by a member of the PPP Consortia who is responsible for design, construction, cost management and project management. Their role is to guide the estimating process utilising the BIM-enabled estimating process protocol developed.

Table 6.2 **Guidelines on using the model**

Activity	Responsible Team Member/ Members (Designations may vary based on project/country)
At the start:	
Appoint a BIM manager to implement the BIM-enabled estimating process (Identified as a best practice in BIM-enabled estimating practices in PPP projects in Section 7.2 of the report)	Project Manager/Project Lead
Evaluate model steps against PPP project practices, policies and requirements	BIM Manager, Project Manager, Design Manager and Cost Manager
Identify practices, policies and requirements, those that deviate from the model and decide on how to deal with differences	BIM Manager, Project Manager, Design Manager and Cost Manager
Prepare coordinated BIM execution plan in line with model steps (as applicable) for designing and estimating processes	BIM Manager, Project Manager, Design Manager and Cost Manager
Inform each project participant of the model process and their role and responsibilities	BIM Manager, Project Manager, Design Manager and Cost Manager
During the process:	
Manage the overall process in accordance with model steps (as applicable) (This includes coordinating, directing, leading the team and controlling and facilitating the process)	BIM Manager
At the end:	
Identify deviated practices from the model process and offer recommendations for future practitioners on: • measures to be followed to comply with the modelled process without deviations • possible minor amendments to the modelled process, where compliance is challenging	BIM Manager, Project Manager, Design Manager and Cost Manager



6.2.2 Validation of model

In order to validate the model (from Expert Forum Round -1), experts from all three countries were invited to rank their extent of agreement with the model. Table 6.3 shows the overall results for their agreement with the model validation outcome. As shown in the table, the extent of agreement (second column) mean scores obtained for the overall top five rankings range from 4 (Agree) to 5 (strongly agree). Specifically, respondents strongly agree on the initial validation outcome which is "Very Good" with regard to flowing aspects of the model:

a. Comprehensiveness and adequacy of the model in representing every step of the BIM-enabled estimating process

b. Ease of understanding the model for use in guiding the process of cost estimating

Overall outcome of the Expert Forum Round -2 (Table 6.4) justifies model satisfaction (first column) validation results obtained from Expert Forum Round -1, those range from 3 (Good/Satisfactory) to 4 (Very Good), indicating their acceptance of the model for its intended practice in PPP projects.

In addition, respondents strongly agree on the initial validation outcome which is "Very Good" regarding overall satisfaction/benefits which could be achieved in using BIM-enabled estimating over traditional estimating practice in PPP projects. This outcome justifies furthermore, the high anticipation and optimism of the industry experts regarding BIM-enabled estimating in PPP projects.

Table 6.3 Extent of agreement results on overall satisfaction (Expert Forum Round - 1 Outcome)

	Model Validation Aspects/Questions	Overall Satisfaction (Expert Forum Round -1 Outcome)		Extent of Agreement with Expert Forum Round -1 Outcome	
		Mean score (round off to the nearest whole unit)	Interpretation	Mean score (round off to the nearest whole unit)	Interpretation
1	Does the Model comprehensively and adequately represent every step of the BIM-enabled estimating process adopted by PPP sponsor consortia in estimating Cost of PPP projects?	4	Very Good	5	Strongly Agree
2	Can the Model be easily understood and used by PPP sponsor consortia in guiding the process of cost estimating of PPP projects?	4	Very Good	5	Strongly Agree
3	Can PPP sponsor consortia achieve efficiency in estimating the cost of PPP projects, if the Model is carefully followed?	3	Good/ Satisfactory	4	Agree
4	How do you rate the overall applicability of the Model in your country? (All countries)	3	Good/ Satisfactory	4	Agree
	UK	4	Very Good	4	Agree
	Australia	3	Good/ Satisfactory	5	Strongly Agree
	China	3	Good/ Satisfactory	4	Agree
5	How do you rate the overall satisfaction/ benefits (over and above traditional estimating process) that can be achieved by adopting a BIM-enabled estimating process to estimate cost of PPP projects (by PPP sponsor consortia)?	4	Very Good	5	Strongly Agree

6.2.3 Validating the model amendments and the final model

As explained in Section 6.2.1, the model was updated and tested through Expert Forum Round - 2, with the following objectives:

a. To obtain agreement on amendments done based on Expert Forum Round -1 outcome

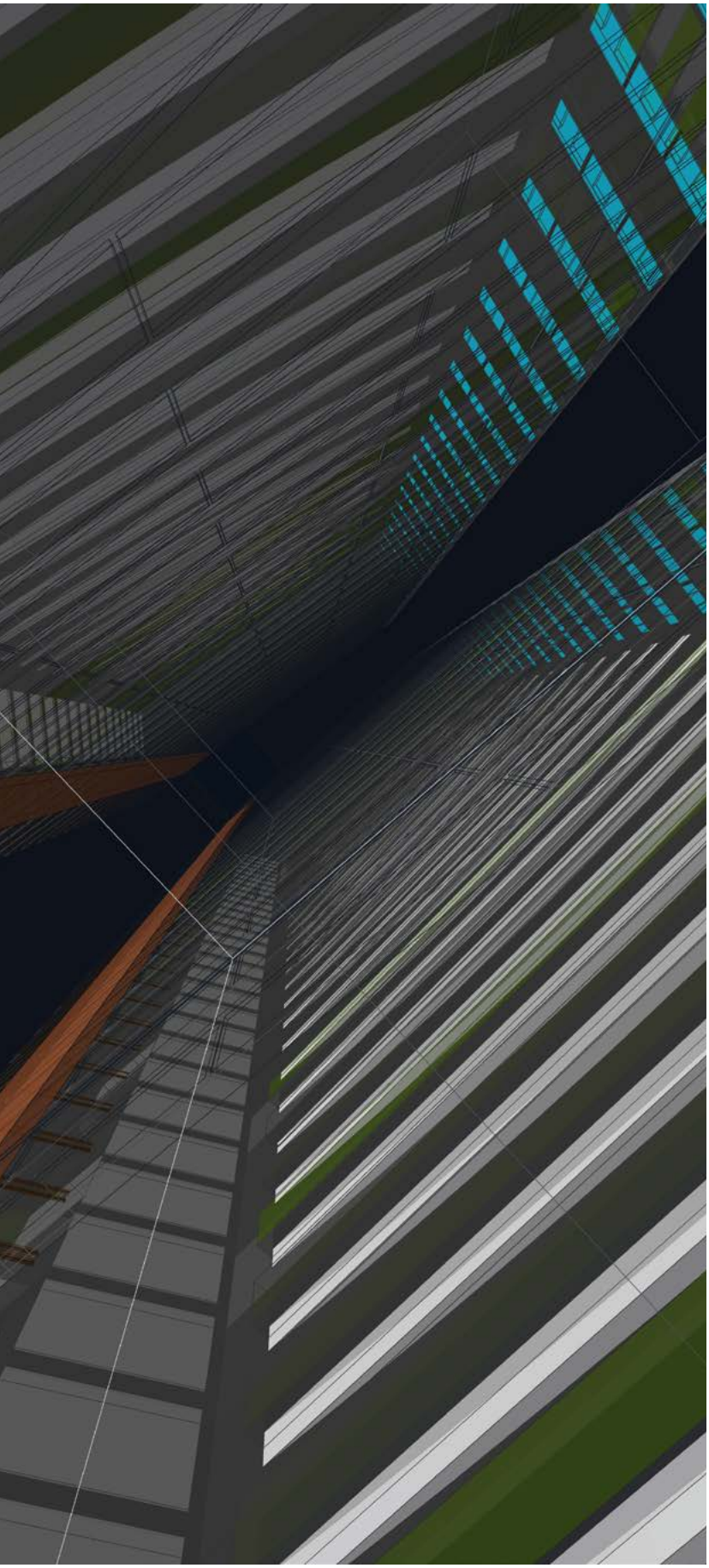
b. To obtain comments towards further improvements to the model

Table 6.4 Results on extent of agreement on model update

Validation Aspect/Question on Model Update	Round 2 Response (Extent of your Agreement)				
	UK	Australia	China	Mean Score (rounded to the nearest whole number)	Interpretation
Do you agree that the updated Model is an improvement to the previous model in terms of comprehensiveness, representation, efficiency and ease of understanding of the BIM-enabled estimating process adopted by PPP sponsor consortia in estimating the Capital Construction Cost of PPP projects?	4	4.5	4	4	(Agree)

Experts' responses as indicated in Table 6.3 reveal that they agree on the model update, which is intended to be an improvement in terms of comprehensiveness, representation, efficiency and ease of understanding of the BIM-enabled estimating process adopted by PPP sponsor consortia in estimating the Capital Construction Cost of PPP projects. There were no further comments on further improvements on the model. Thus, the model as indicated in Figure 5 (page 34) represents the final model for BIM-enabled Estimating Process for Estimating Capital Construction Cost of PPP projects.

Overall results on model validation and model updates indicate that experts from the UK, Australia, and China agree that the model would provide a beneficial outcome to their respective countries in influencing efficient and effective cost estimating practice through BIM-enabled cost estimating in PPP projects. This reveals high anticipation and optimism of the industry experts regarding BIM-enabled cost estimating in PPP projects, which would inevitably become a driver for enhancing BIM-enabled cost estimating in PPP projects.



7.0 BIM Execution Framework for estimating in PPP projects

The BIM Execution Framework for Estimating in PPP projects (BEFEP) consists of three main components.

1. Process protocol model for BIM-enabled estimating
2. Drivers and barriers for implementing BIM-enabled estimating in PPP projects
3. Best practice guidelines for BIM-enabled estimating

The first component of the framework was presented in the previous section (6.2). The remaining two components of the framework are presented here.

7.1 Drivers and barriers for BIM-enabled estimating practice in PPP projects

Drivers and barriers for BIM-enabled estimating were first identified through a literature review and then subsequently expanded through case study interviews of experts covering UK, Australia and China. These were further expanded and refined through the international expert forum following an iterative Delphi-based process.

7.1.1 Drivers for implementing BIM-enabled estimating practice in PPP in the UK, Australia and China

Drivers are defined as factors that help and encourage the adoption of BIM for estimating purposes in PPP procured projects. The following sections evaluate these barriers from the perspectives of estimating experts in each of the countries in this research.

7.1.1.1 The UK

The rankings for the drivers for implementing BIM-enabled estimating in PPPs are shown in Table 7.1. As presented in the table, the set of 20 drivers have mean values ranging between 2.25 and 4.25. Furthermore, they are ranked from 1st to 8th. Interestingly, four drivers emerged as the top two. Specifically, two are ranked first and two are ranked second. The top two drivers, with mean scores of 4.25, are 'Government pressure towards better practices' and 'Easier communication and collaboration between all stakeholders'. The joint-second ranked drivers were 'Cost savings and increased efficiency in monitoring with reduction of requests for information' and 'Greater access to information enabling earlier input into feasibility, planning, design, costs and environmental assessment'.

It is not surprising that government pressure is ranked very critical in the UK. This is because the UK government has made it mandatory for all publicly-funded projects to use a Level 2 BIM (Efficiency and Reform Group, 2011). Although this policy is geared towards traditional-bid-build projects as they are often funded by the government, PPP projects are also possibly to be included in the future. BIM certainly offers many benefits in early cost estimating; therefore, it has become essential for governments to encourage all stakeholders in the construction industry to adopt BIM in public projects including PPP infrastructure. PPP projects usually have a large group of stakeholders with multifaceted objectives (Zou et al. 2016). Importantly, the effective management and coordination of the numerous participants in a PPP project are essential to the success of the project (Osei-Kyei and Chan, 2015; Cheung et al. 2012). With the use of BIM, the large stakeholder of PPP projects can be effectively managed by enhancing communication and interaction. BIM application can help practitioners to communicate and resolve planning issues quickly online. Furthermore, all parties can make a contribution to the design without necessarily meeting physically. These indeed enhance collaboration and foster team coordination.

Table 7.1 Ranking of drivers by UK PPP experts

UK		
Drivers for implementing BIM-enabled estimating practice in PPP in the local construction Industry	Mean Score	Rank
Government pressure towards better practices	4.25	1
Easier communication and collaboration between all stakeholders	4.25	1
Cost savings and increased efficiency in monitoring with reduction of requests for information	3.75	2
Greater access to information, enabling earlier input into feasibility, planning, design, costs and environmental assessment	3.75	2
Client/competitive pressure	3.50	3
Improving the capacity to provide whole life value to client	3.50	3
Time savings in the preparation of cost estimates	3.50	3
Accurate construction sequencing and clash detection	3.50	3
BIM increases the accuracy in the quantity take-off, especially at the early stage of the design	3.50	3
Automation of schedule/register generation	3.25	4
Facilitating facilities management activities	3.25	4
Reducing variability in cost estimates	3.25	4
Desire for innovation to remain competitive	3.00	5
It allows precise future prediction of the construction costs	3.00	5
Improved financial forecasting	3.00	5
Facilitating increased pre-fabrication with information-rich BIM	2.50	6
Improving built output quality	2.50	6
Streamlining design activities and improving design quality	2.38	7
Designing health and safety into the construction process	2.25	8
Improving communication with operatives	2.25	8

7.1.1.2 Australia

Table 7.2 shows the ranking of the drivers for implementing BIM-enabled estimating in PPPs for Australia. The top three drivers in rank order are 'Desire for innovation to remain competitive', 'Accurate construction sequencing and clash detection' and 'Time savings in the preparation of cost estimates'.

'Desire for innovation to remain competitive' is ranked first with a mean value of 4.0. This driver implies the enthusiasm of practitioners or companies to remain at the forefront of innovation. Local PPP practitioners and consortia in Australia aspire to be at the forefront of BIM implementation. Also, BIM is seen by local practitioners as the means to remain competitive and be innovative in the PPP market. Moreover, a consortium that adopts BIM in PPP estimating is seen as more 'visionary' and 'purposeful' (Ruikar et al, 2005). Therefore, there is an urgency and aspiration by local practitioners in the Australian PPP market to adopt BIM for PPP cost estimating.

Table 7.2 Ranking of drivers by Australia PPP experts

Australia		
Drivers for implementing BIM-enabled estimating practice in PPP in the local construction Industry	Mean Score	Rank
Desire for innovation to remain competitive	4.00	1
Accurate construction sequencing and clash detection	3.50	2
Time savings in the preparation of cost estimates	3.00	3
Government pressure towards better practices	2.50	4
Client/competitive pressure	2.50	4
Facilitating increased pre-fabrication with information-rich BIM	2.50	4
Greater access to information, enabling earlier input into feasibility, planning, design, costs and environmental assessment	2.50	4
Designing health and safety into the construction process	2.00	5
Cost savings and increased efficiency in monitoring with reduction of requests for information	2.00	5
Improving communication with operatives	1.75	6
Automation of schedule/register generation	1.75	6
Facilitating facilities management activities	1.75	6
Improved financial forecasting	1.75	6
Easier communication and collaboration between all stakeholders	1.75	6
Improving the capacity to provide whole life value to client	1.50	7
Streamlining design activities and improving design quality	1.50	7
Improving built output quality	1.50	7
BIM increases the accuracy in the quantity take-off, especially at the early stage of the design	1.25	8
Reducing variability in cost estimates	1.25	8
It allows precise future prediction of the construction costs	0.75	9

7.1.1.3 China

Table 7.3 shows the rankings of the drivers for implementing BIM-enabled estimating in PPPs in China. The top three drivers in rank order are 'Desire for innovation to remain competitive', 'Improving the capacity to provide whole life value to client and Facilitating increased pre-fabrication with information-rich BIM.

'Desire for innovation to remain competitive' is ranked first with a mean value of 4.75. Essentially, because of the competitive nature of the Chinese PPP markets, local construction firms are forced to be innovative to gain competitive advantage in the market. In this regard, BIM technology is highly used in the Chinese construction industry. The use of BIM technology in Chinese PPP projects usually puts local construction firms at the forefront of innovation and, in recent years, Chinese local construction firms have boosted their innovation by adopting virtual reality technologies in the delivery of projects.

Table 7.3 Ranking of drivers by China PPP experts

China		
Drivers for implementing BIM-enabled estimating practice in PPP in the local construction Industry	Mean Score	Rank
Desire for innovation to remain competitive	4.75	1
Improving the capacity to provide whole life value to client	4.50	2
Facilitating increased pre-fabrication with information-rich BIM	3.88	3
Client/competitive pressure	3.75	4
Accurate construction sequencing and clash detection	3.75	4
Automation of schedule/register generation	3.63	5
Easier communication and collaboration between all stakeholders	3.63	5
Streamlining design activities and improving design quality	3.50	6
Cost savings and increased efficiency in monitoring with reduction of requests for information	3.50	6
Government pressure towards better practices	3.25	7
Time savings in the preparation of cost estimates	3.25	7
Designing health and safety into the construction process	3.00	8
Improving communication with operatives	3.00	8
Facilitating facilities management activities	3.00	8
BIM increases the accuracy in the quantity take-off, especially at the early stage of the design	3.00	8
Greater access to information, enabling earlier input into feasibility, planning, design, costs and environmental assessment	2.75	9
Improving built output quality	2.25	10
It allows precise future prediction of the construction costs	2.25	10
Reducing variability in cost estimates	2.25	10
Improved financial forecasting	1.25	11

7.1.1.4 Overall ranking and comparison of drivers for implementing BIM-enabled estimating practice in PPP among the three countries

Table 7.4 presents the overall rankings of the drivers for implementing BIM-enabled estimating practice in PPP by all respondents. Included in the table are the rankings for each country for the purpose of comparison.

The top three rankings in order are 'Desire for innovation to remain competitive', 'Accurate construction sequencing and clash detection' and 'Government pressure towards better practices'.

'Desire for innovation to remain competitive' is ranked first with a mean value of 3.92. It is also ranked first by the Australian and Chinese respondents, whereas the UK respondents ranked it fifth. This outcome shows that the Australian and Chinese experts considered this driver more important than their UK counterparts. This outcome is not very surprising because the UK PPP market is not as competitive as the Australian and Chinese markets. This could be as a result of the well matured and developed UK PPP market compared to the other two countries. In Australia and China, local investors face fierce internal rivalry. In this regard, there is an urgency for local investors and PPP consortia to be innovative to remain competitive.

Table 7.4 Ranking of drivers by all respondents (UK, Australia and China)

Drivers for implementing BIM-enabled estimating practice in PPP in the local construction Industry	UK Average	Australia Average	China Average	Overall Average	Rank
Desire for innovation to remain competitive	3.00	4.00	4.75	3.92	1
Accurate construction sequencing and clash detection	3.50	3.50	3.75	3.58	2
Government pressure towards better practices	4.25	2.50	3.25	3.33	3
Client/competitive pressure	3.50	2.50	3.75	3.25	4
Time savings in the preparation of cost estimates	3.50	3.00	3.25	3.25	4
Easier communication and collaboration between all stakeholders	4.25	1.75	3.63	3.21	5
Improving the capacity to provide whole life value to client	3.50	1.50	4.50	3.17	6
Cost savings and increased efficiency in monitoring with reduction of requests for information	3.75	2.00	3.50	3.08	7
Greater access to information, enabling earlier input into feasibility, planning, design, costs and environmental assessment	3.75	2.50	2.75	3.00	8
Facilitating increased pre-fabrication with information-rich BIM	2.50	2.50	3.88	2.96	9
Automation of schedule/register generation	3.25	1.75	3.63	2.88	10
Facilitating facilities management activities	3.25	1.75	3.00	2.67	11
BIM increases the accuracy in the quantity take-off, especially at the early stage of the design	3.50	1.25	3.00	2.58	12
Streamlining design activities and improving design quality	2.38	1.50	3.50	2.46	13
Designing health and safety into the construction process	2.25	2.00	3.00	2.42	14
Improving communication with operatives	2.25	1.75	3.00	2.33	15
Reducing variability in cost estimates	3.25	1.25	2.25	2.25	16
Improving built output quality	2.50	1.50	2.25	2.08	17
It allows precise future prediction of the construction costs	3.00	0.75	2.25	2.00	18
Improved financial forecasting	3.00	1.75	1.25	2.00	18

7.1.1.5 Validation of the overall rankings of drivers for implementing BIM-enabled estimating practice

Table 7.5 shows the overall validation results for the top five rankings of drivers for implementing BIM-enabled estimating practice in PPP. As shown in the table, the mean scores obtained for the overall top five rankings range from 3 (undecided) to 5 (strongly agree). Specifically, 'Desire for innovation to remain competitive' and 'Client/competitive pressure' received a score of 5, which implies that respondents from the three countries strongly agree on the position of the two drivers and their inclusion in the top five rankings.

'Accurate construction sequencing and clash detection' and 'Improving the capacity to provide whole life value to client' received a score of 4. This also means that the experts agree on their inclusion in the top five overall rankings and their respective positions. This is not very surprising because BIM is well noted for providing reliable outputs on construction sequencing and clash detection. 'Automation of schedule/register generation' received a score of 3, which means that respondents were not fully convinced that it should be ranked third. Nonetheless, BIM provides automation of register generation therefore it makes it easier for PPP practitioners to estimate the cost of PPP projects.

Table 7.5 Validation results of overall top 5 rankings of drivers for implementing BIM-enabled estimating practice in PPP

Rank	Overall Ranking for UK/Australia/China	UK Average	Australia Average	China Average	Overall Average
1	Desire for innovation to remain competitive	4.00	5.00	4.33	5 (Strongly agree)
2	Accurate construction sequencing and clash detection	4.00	3.50	4.33	4 (Agree)
3	Automation of schedule/register generation	4.00	2.50	3.67	3 (Undecided)
4	Improving the capacity to provide whole life value to client	5.00	3.00	4.33	4 (Agree)
5	Client/Competitive pressure	4.00	5.00	4.67	5 (Strongly agree)

7.1.2 Barriers to the adoption of BIM-enabled estimating practice in the UK, Australia and China

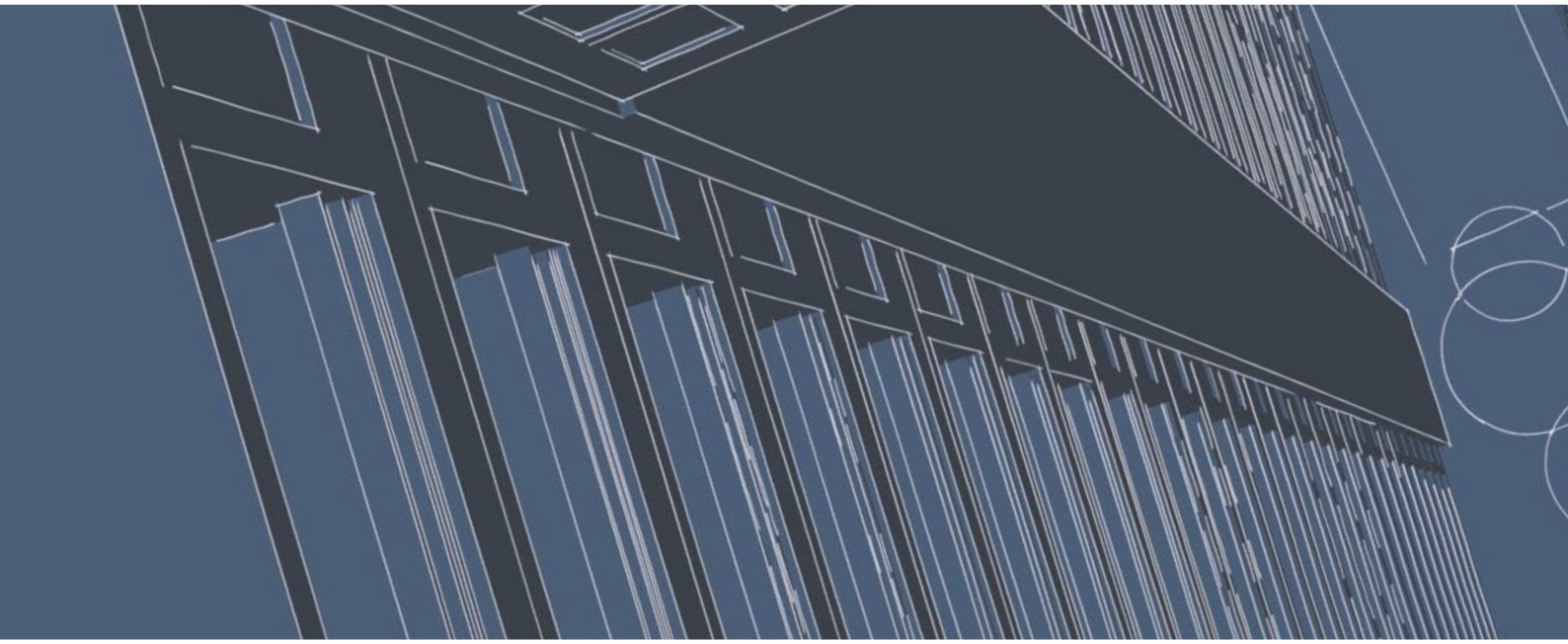
Barriers are defined as factors that inhibit the adoption of BIM for estimating purposes in PPP procured projects. The following sections evaluate these barriers from perspectives of estimating experts in each of the countries in this research.

7.1.2.1 UK

Table 7.6 shows the results on the ranking of barriers by the UK experts. Four barriers emerged as the top three. Two of these barriers are ranked second. The barriers include: 'Technological issues', 'Inadequate relevant knowledge and expertise in using BIM', 'Poor information sharing and collaboration issues' and 'Low quality of BIM data'. The first ranked barrier is 'Technological issues' with a mean value of 4.00. Technological issues refer to the lack of BIM protocols such as client-specific protocols for estimating the cost of PPP projects. The absence of detailed BIM protocol for PPP estimating hinders the urgency to adopt BIM for PPP estimating. Although there could be some BIM protocols in existence, these are not specifically designed for PPP projects. The technological interface among programs also contributes to the technological challenges in the use of BIM for PPP cost estimating. BIM requires many interrelated and cross-referenced information and interfaces, and these pose a lot of technological challenges. Estimating PPP project costs requires a lot of information and it is often difficult to acquire the information needed to input into the BIM-enabled estimating application.

Table 7.6 Ranking of barriers by UK PPP experts

UK		
Barriers for implementing BIM-enabled estimating practice in PPP in the local construction Industry	Mean Score	Rank
Technological issues	4.00	1
Inadequate relevant knowledge and expertise in using BIM	3.50	2
Poor information sharing and collaboration issues	3.50	2
Low quality of BIM data	3.00	3
Cultural resistance for using new technologies like BIM	2.50	4
BIM data ownership issues including data security	2.50	4
Implementing BIM is expensive/ Cost overrun with BIM	2.50	4
Lack of a check mechanism for designs	2.00	5
Liability issues including professional licensing, design liability and vulnerability to changes of BIM by unauthorised parties	2.00	5
Incompatibility between BIM data and standard practices	2.00	5
Culture of adoption	1.00	6



7.1.2.2 Australia

Table 7.7 shows the rankings furnished by experts from Australia. The rankings of the 10 set of barriers range from first to sixth. The top three barriers are; 'Inadequate relevant knowledge and expertise in using BIM for PPP estimating', 'Cultural resistance for using new technologies like BIM', 'Incompatibility between BIM data and standard practices' and 'Liability issues including professional licensing, design liability and vulnerability to changes of BIM by unauthorised parties'. These barriers have mean values ranging between 3.50 and 5.00.

'Inadequate relevant knowledge and expertise in using BIM for PPP estimating' is ranked first by the Australian experts with a mean value of 5.0. Undoubtedly, Australia has one of the most developed PPP markets in the world, however, the use of BIM for estimating in PPP projects is still emerging and has not properly developed. This is partially attributable to the low levels of BIM adoption in general construction practice. Although many Australian PPP practitioners have a wealth of experience and knowledge in PPPs, the application of BIM in estimating cost at the early stages of PPP projects has not properly been explored and developed. Most of the local practitioners are yet to understand the issues and practices involved in using BIM. This is quite unsurprising because BIM is a little complex and its application in PPP estimating requires a thorough understanding and years of training and practice.

Table 7.7 Ranking of barriers by Australia PPP experts

Australia		
Barriers for implementing BIM-enabled estimating practice in PPP in the local construction Industry	Mean Score	Rank
Inadequate relevant knowledge and expertise in using BIM	5.00	1
Cultural resistance for using new technologies like BIM	4.00	2
Incompatibility between BIM data and standard practices	4.00	2
Liability issues including professional licensing, design liability and vulnerability to changes of BIM by unauthorised parties	3.50	3
Low quality of BIM data	3.00	4
Poor information sharing and collaboration issues	3.00	4
Lack of a check mechanism for designs	3.00	4
Technological issues	2.00	5
BIM data ownership issues including data security	2.00	5
Implementing BIM is expensive/ Cost overrun with BIM	1.50	6

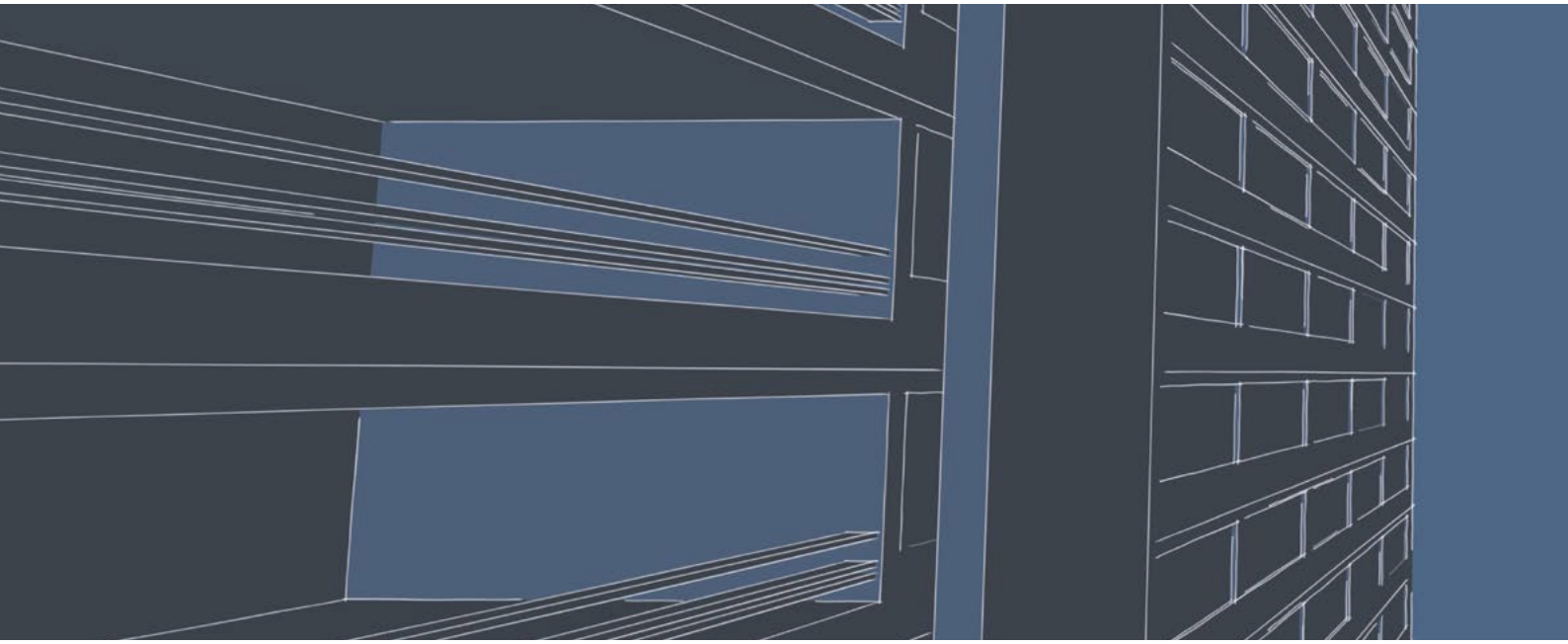
7.1.2.3 China

The rankings of the barriers by the Chinese respondents is shown in Table 7.8. Four barriers emerged as the top three ranked barriers among the set of the 10 barriers. The top ranked barriers are 'Technological issues', 'Inadequate relevant knowledge and expertise in using BIM', 'Implementing BIM is expensive/Cost overrun with BIM' and 'Low quality of BIM data'.

'Technological issues' is ranked first by the Chinese respondents. It has a score of 4.17. As mentioned earlier, the lack of protocols and technological interface among programs are the major technological challenges associated with the use of BIM for cost estimating in PPP projects. Like other countries including the UK and Australia, China does not have a clear BIM protocol designed to suit the characteristics and features of PPP projects in cost estimating and this impedes the effective adoption of BIM for PPP cost estimating.

Table 7.8 Ranking of barriers by China PPP experts

China		
Barriers for implementing BIM-enabled estimating practice in PPP in the local construction Industry	Mean Score	Rank
Technological issues	4.17	1
Inadequate relevant knowledge and expertise in using BIM	3.83	2
Implementing BIM is expensive/ Cost overrun with BIM	3.83	2
Low quality of BIM data	3.67	3
Lack of a check mechanism for designs	3.50	4
Liability issues including professional licensing, design liability and vulnerability to changes of BIM by unauthorised parties	3.50	4
Incompatibility between BIM data and standard practices	3.50	4
BIM data ownership issues including data security	3.17	5
Cultural resistance for using new technologies like BIM	2.50	6
Poor information sharing and collaboration issues	2.17	7



7.1.2.4 Overall ranking and comparison of barriers for implementing BIM-enabled estimating practice in PPP among the three countries

Table 7.9 shows the overall ranking of responses by the UK, Australian and Chinese PPP experts. The top three barriers ranked by all respondents are 'Inadequate relevant knowledge and expertise in using BIM', 'Technological issues' and 'Low quality of BIM data'. 'Inadequate relevant knowledge and expertise in using BIM' is ranked first with a mean value of 4.11. Also, it received a mean score of 5.00 for Australia (1st), 3.50 for the UK (2nd) and 3.83 for China (2nd). This shows that the Australian respondents ranked this barrier higher than their counterparts from China and the UK. This outcome is not surprising because BIM implementation has been quite well adopted and implemented in China and the UK compared to Australia. In this regard, the level of knowledge by practitioners in Australia on how BIM can be used for PPP cost estimating is high compared to China and the UK. Nonetheless, the overall ranking shows that inadequate relevant knowledge and expertise in using BIM for PPP cost estimating is high in all the three countries.

Table 7.9 Rankings of barriers by all respondents

Barriers for implementing BIM-enabled estimating practice in PPP in the local construction Industry	UK Average	Australia Average	China Average	Overall Average	Rank
Inadequate relevant knowledge and expertise in using BIM	3.50	5.00	3.83	4.11	1
Technological issues	4.00	2.00	4.17	3.39	2
Low quality of BIM data	3.00	3.00	3.67	3.22	3
Incompatibility between BIM data and standard practices	2.00	4.00	3.50	3.17	4
Cultural resistance for using new technologies like BIM	2.50	4.00	2.50	3.00	5
Liability issues including professional licensing, design liability and vulnerability to changes of BIM by unauthorised parties	2.00	3.50	3.50	3.00	5
Poor information sharing and collaboration issues	3.50	3.00	2.17	2.89	6
Lack of a check mechanism for designs	2.00	3.00	3.50	2.83	7
Implementing BIM is expensive/Cost overrun with BIM	2.50	1.50	3.83	2.61	8
BIM data ownership issues including data security	2.50	2.00	3.17	2.56	9

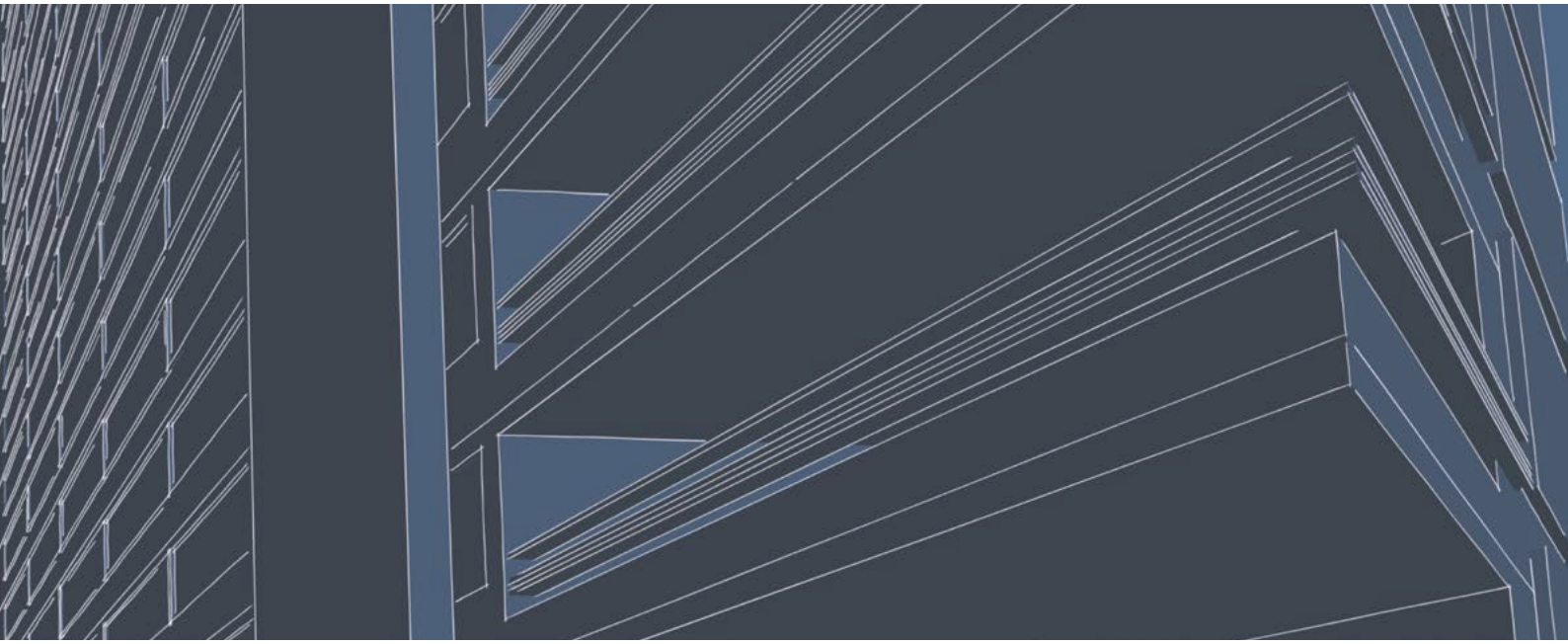
7.1.2.5 Overall ranking and comparison of barriers for implementing BIM-enabled estimating practice in PPP among the three countries

The overall rankings of barriers for implementing BIM-enabled estimating in PPP were sent to experts for validation. Specifically, experts from the UK, Australia, and China were invited to rate their level of agreement on the top five overall rankings of barriers. As shown in Table 7.10, the experts generally agree on the top five rankings of barriers for implementing BIM-enabled estimating practice. 'Inadequate relevant knowledge and expertise in using BIM' and 'Cultural resistance for using new technologies like BIM' obtained a score of 5 which signifies that the experts strongly agree on their positions.

Similarly, 'Incompatibility between BIM data and standard practices' obtained a score of 4, which implies the experts agree on its position and inclusion in the top five rankings. For two barriers, namely, 'Technological issues' and 'Low quality of BIM data', their scores are 3.0, which means that the experts were undecided concerning their positions.

Table 7.10 Validation results of overall top 5 rankings of barriers for implementing BIM-enabled estimating practice in PPP

Rank	Overall Ranking for UK/Australia/China	UK Average	Australia Average	China Average	Overall Average
1	Inadequate relevant knowledge and expertise in using BIM	5	5	4	5 (Strongly agree)
2	Technological issues	4	2	5	3 (Undecided)
3	Low quality of BIM data	3	2	4	3 (Undecided)
4	Incompatibility between BIM data and standard practices	5	3	4	4 (Agree)
5	Cultural resistance for using new technologies like BIM	5	5	4	5 (Strongly agree)
5	Liability issues including professional licensing, design liability and vulnerability to changes of BIM by unauthorised parties	4	3	4	4 (Agree)



7.2 Best practices in BIM-enabled estimating for PPP projects

The BIM Execution Framework for estimating in PPP projects comprises a component that highlights best practices in BIM-enabled estimating. This section presents the key factors estimators should consider in developing and designing estimating practices for BIM-enabled estimating in PPP projects. As presented in Table 7.11, the best practices are divided into three major categories, namely: Process, Practice and Policy.

Table 7.11 Best practices in BIM-enabled estimating for PPP projects and their country-specific rankings

Rank	Best Practice	UK Average	Australia Average	China Average	Overall Average
Process					
1	Prepare a list of bidding documents	4.00	5.00	3.50	4 (Agree)
2	Check for contradicting/missing information	4.00	5.00	4.00	4 (Agree)
3	Clarify contradictions and revise documents accordingly	4.50	5.00	4.00	5 (Strongly Agree)
4	Develop schedule of functional areas enabled on industry standards and norms	4.00	5.00	3.50	4 (Agree)
5	Prepare preliminary cost plans enabled on similar cost information	4.00	5.00	4.50	5 (Strongly Agree)
6	Appoint BIM manager to manage the BIM process	3.00	3.00	5.00	4 (Agree)
7	Check for agreement on aligning BIM model objects with cost data formats	3.00	3.50	3.50	3 (Undecided)
8	Agree on aligning BIM model objects with cost data formats	4.00	3.50	4.00	4 (Agree)
9	Translate BIM model into a chosen 5D cost modelling software which facilitate estimate/cost model in the required format	4.00	5.00	4.50	5 (Strongly Agree)
10	Liaise with sub-contractors to get direct cost information	4.00	3.50	4.50	4 (Agree)
11	Conduct cost checks and negotiations within PPP sponsor consortium for possible cost reductions and update the Cost model and BIM model enabled on the outcome	4.00	5.00	4.00	4 (Agree)
12	Check for compliance with price guidelines Quotas to be in line with project budget	5.00	5.00	4.00	5 (Strongly Agree)
Practice					
1	Make BIM-enabled cost management (including early stage estimating) a client requirement	3.00	3.00	5.00	4 (Agree)
2	Particular conditions include references to National level BIM guidelines, execution plans, etc as compulsory practices and procedures to be adhered to	4.00	5.00	4.50	5 (Strongly Agree)
3	Amend standard forms of contracts to facilitate BIM practices in construction contracts and BIM to be regarded as a contract document	3.00	5.00	4.00	4 (Agree)
Policy					
1	Government/Public Authorities to prepare BIM guidelines for various practices like estimating	4.00	4.50	5.00	5 (Strongly Agree)
2	Professional Institutions to support BIM implementation in construction practices and provide training	5.00	5.00	4.50	5 (Strongly Agree)

Best practices under the Process category are measures that practitioners need to carefully consider when they are in the process of using BIM for early-stage estimating. This includes instructions such as developing a schedule of functional areas based on industry standards and norms, liaising with sub-contractors to get direct cost information, preparing preliminary cost plans based on similar cost information etc. Practice is the second category of the best practice guide. It consists of practice that ensures the overall management of the use of BIM in early-stage estimating in PPP projects. Specifically, instructions under the Practice category inform practitioners of the measures to take into consideration when drafting PPP contracts and BIM guidelines. Examples of best practices under this category include the amendment of standard forms of contracts to facilitate BIM practices in construction contracts and the development of BIM-oriented contract documents. Best practices under Policy provide measures on how governments and external stakeholders could help to facilitate the use of BIM in early-stage estimating in PPP projects.

The *Australia and New Zealand BIM Best Practice Guidelines* published by the Australian Institute of Quantity Surveyors and New Zealand Institute of Quantity Surveyors, (2018), highlights best practice guidelines on following:

a. BIM process

b. What to expect from a BIM project (BIM as a contract deliverable or non-contract BIM)

c. Team collaboration

d. BIM Execution Plan contents and its use

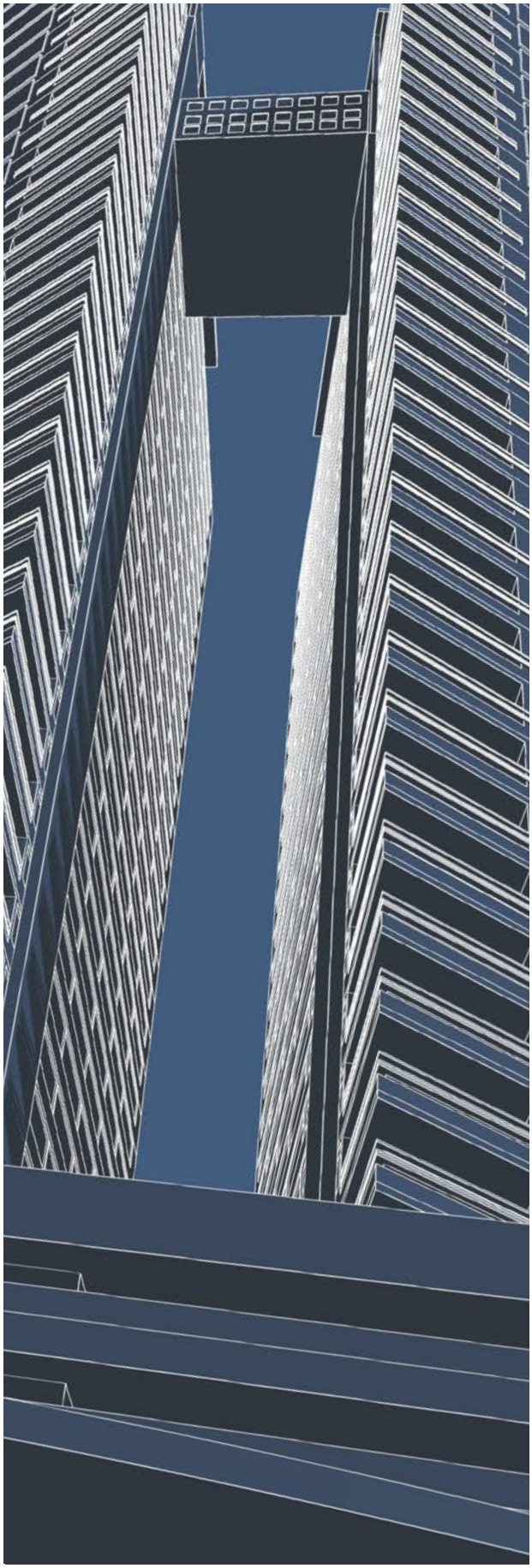
e. BIM contents and development process

f. BIM integration and validation

g. Legal considerations for use of BIM

These guidelines inevitably help to guide the identified best practices in PPP projects in Australia. Furthermore, China and the UK can also benefit if such guidelines are developed as applicable to their particular construction industries.

After developing the checklist of best practices, experts were invited to validate these practices. As shown in the Table 7.11, the mean values for the best practices range from 3 (undecided) to 5 (strongly agree). Essentially, the majority of the best practices received a score of 5, which implies the best practices are relevant and if they are carefully followed by PPP practitioners, the use of BIM for early estimating in PPPs will be highly successful. In other words, practitioners are likely to have a successful outcome if these best practices are carefully followed.



8.0 Conclusions

8.1 PPP projects and the state of construction industry

Governments worldwide are faced with satisfying increased demand for social and physical infrastructure, exacerbated by population growth and urbanisation. But they face the dichotomy of balancing tax revenue with public spending and consequently seeking alternative sources of funding. Using private capital for development of large-scale infrastructure projects is an age-old concept but received a new lease of life with the large-scale adoption by the UK in the early 1990s, resulting in the advent of the Private Finance Initiative. The common term use for using private capital for public sector projects is Public Private Partnership (PPP).

The onslaught of the 4th Industrial Revolution in the past decade saw the increased need for digitalisation in the construction industry. The need is aggravated by the construction industry being notoriously slow in digitalisation (second last among all sectors). The past decade saw the introduction of BIM as a primary way to achieve a stepwise change in the digitalisation of the construction industry. However, the level of adoption of BIM is not universal and significantly varies between subsectors of construction and countries. With this backdrop this research aimed at investigating the use of BIM in early-stage estimating for PPP projects.

8.2 Main research findings

This research investigated the practice of early-stage estimating in PPP projects in the UK, Australia and China. These three countries are seen as countries that have a fairly advanced and mature PPP practice. The primary methodology employed in this research was to conduct organisational practice case studies corroborated through a Delphi-based international expert forum of PPP estimators.

The research revealed there are different levels of BIM usage in the three countries, with the UK having the highest and most advanced level of usage followed by China and Australia. However, the problems faced in BIM adoption were very similar in all countries. The UK and Australia have very similar estimating practices (commonly identified through the British Commonwealth practice of quantity surveying). China has not yet fully transited to market-oriented commercial management practices and thus the legacy of quota-based estimating systems seems prominent (see Perera et. al 2015 for more details of cost management in China).

All countries had similar perceived benefits of BIM-enabled early-stage estimating with increased accuracy of estimates, better predictability and cost management, clash detection, among others. The main concerns revolved around the mismatch of estimator requirements to BIM data outputs, lack of skills, knowledge and capability to use BIM effectively in estimating and legal issues related to BIM adoption and use among others. There was greater expectation for governments to intervene and promote BIM adoption, as is the case of UK.

The research proposed a BIM Execution Framework for Estimating in PPP projects (BEFEP) comprising three components:

- A process protocol model for BIM-enabled estimating
- Drivers and barriers for implementing BIM-based estimating in PPP projects
- Best practice guidelines for BIM-enabled estimating.

The aim of the model is to develop a process protocol for BIM-enabled cost estimating specifically targeted at PPP projects. The model was developed in three stages of consultation with the industry experts and finally validated through the expert forum. The model will be a useful document to analyse estimating requirements in developing an overall BIM Execution Plan for a PPP project.

Drives and barriers for BIM-enabled early-stage estimating were evaluated for all three countries separately. The overall ranking of drivers and barriers vary slightly in importance between the three countries. The top five validated drivers in rank order are: **Desire for innovation to remain competitive**, **Accurate construction sequencing and clash detection**, **Automation of schedule/register generation**, **Improving the capacity to provide whole-life value to client**, and **Client/competitive pressure**.

In a similar way the top six barriers in rank order are: **Inadequate relevant knowledge and expertise in using BIM**, **Technological issues**, **Low quality of BIM data**, **Incompatibility between BIM data and standard practices**, **Cultural resistance for using new technologies like BIM**, **Liability issues including professional licensing, design liability** and **Vulnerability to changes of BIM by unauthorised parties**.

The research also identified seventeen best practice guidelines that were put into three categories as Process, Practice and Policy. These are measures that project managers, cost managers and BIM managers should consider in developing BIM Execution Plans for estimating costs in PPP projects.

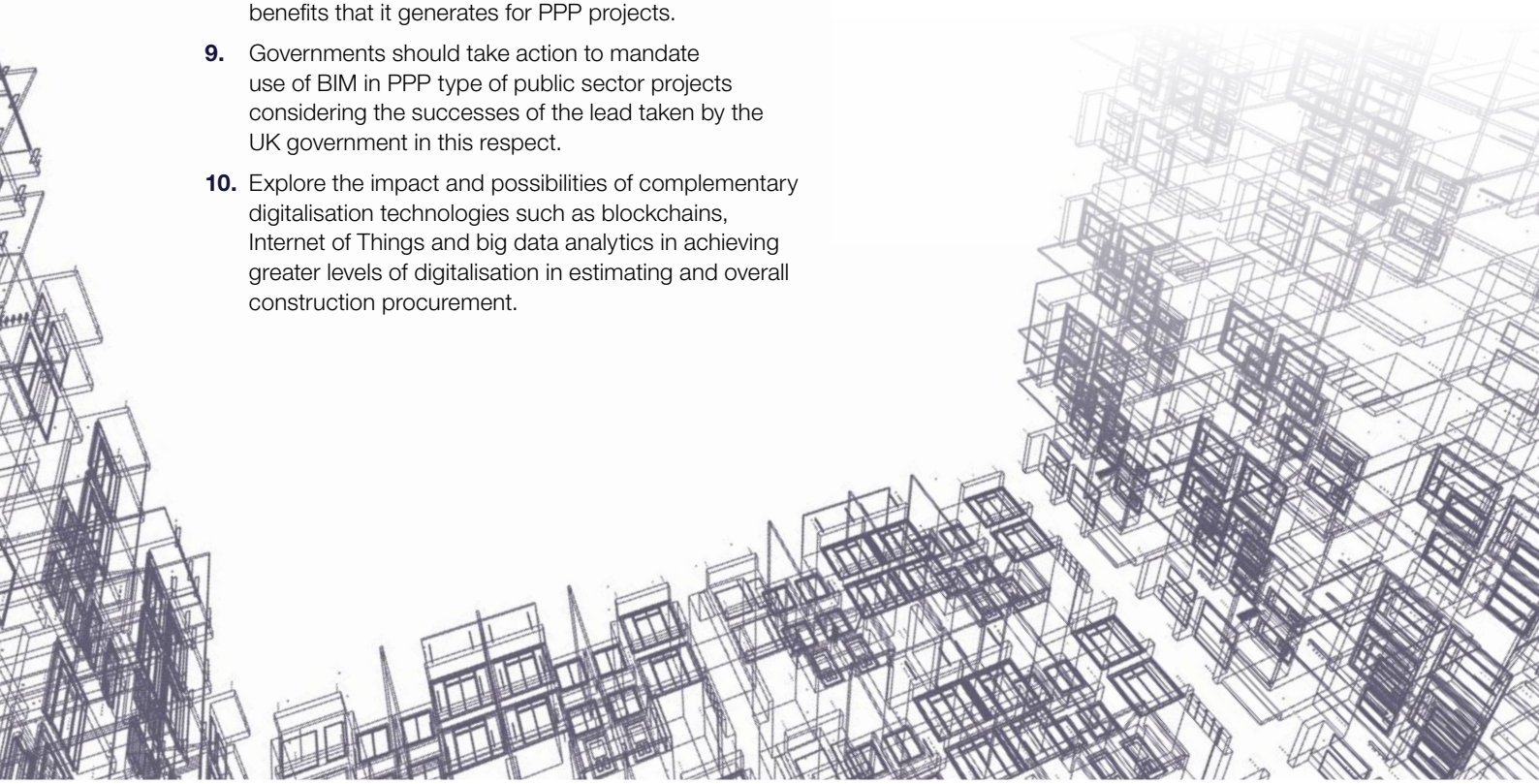
8.3 Recommendations

This study provided a comprehensive review of early-stage estimating in PPP projects and the use of BIM in enhancing the estimating process. The review covered three of the most advanced users of PPP as a procurement approach for large-scale public sector social and physical infrastructure projects. Using the findings of this research the following key recommendations are made.

1. Adopt the BIM Execution Framework proposed in this report and integrate it with the cost management processes of each country.
2. Start implementing the use of BIM during the Project Development Phase to Request For Proposals Phase of PPP projects.
3. Encourage or mandate the use of BIM and BIM-enabled estimates for consortia bids in PPP projects.
4. Develop country-specific standards for BIM-enabled estimating based on the process protocol proposed.
5. Use the guidelines provided through drivers and barriers for BIM-enabled estimating in developing BIM Execution Plans for projects.
6. Use the Best Practice Guide as a document providing guidance and a checklist in writing BIM execution plans for PPP projects.
7. Take steps in educating the workforce on BIM-enabled estimating with necessary training and academic programmes.
8. Encourage public authorities and construction clients to mandate BIM for projects considering the long-term benefits that it generates for PPP projects.
9. Governments should take action to mandate use of BIM in PPP type of public sector projects considering the successes of the lead taken by the UK government in this respect.
10. Explore the impact and possibilities of complementary digitalisation technologies such as blockchains, Internet of Things and big data analytics in achieving greater levels of digitalisation in estimating and overall construction procurement.

The research found that BIM is not very practical at the very early stage due to lack of adequate design detail. But it can be used at consortia bid proposal stage onwards. However, a separate class of visual modelling and cost estimating software is currently emerging (for example dRofus™ and DESTINI Profiler™). Although these software do not generate a COBie (Construction-Operations Building Information Exchange) or IFS (Industry Foundation Classes) compliant BIM as such, they are useful in understanding the concept of design and cost implications from an early stage itself. The interviewees for case studies indicated their use as well. It is therefore recommended that further research should be carried out in evaluating the potential use of such software for early-stage cost planning in large-scale projects including PPP projects.

Greater levels of digitalisation are imminent in the progress of the construction industry, and PPP projects have a greater role in implementing digitalisation and promoting such. Adoption of BIM provides a significant opportunity to achieve greater digitalisation. The construction industries of the UK, Australia and China are moving towards greater levels of BIM adoption and 5D BIM, where BIM provides an interface for estimating is already a reality. This research puts forward a framework that enables development of BIM execution plans for PPP projects to ensure efficient and effective BIM-enabled estimating at early stages of PPP Projects.



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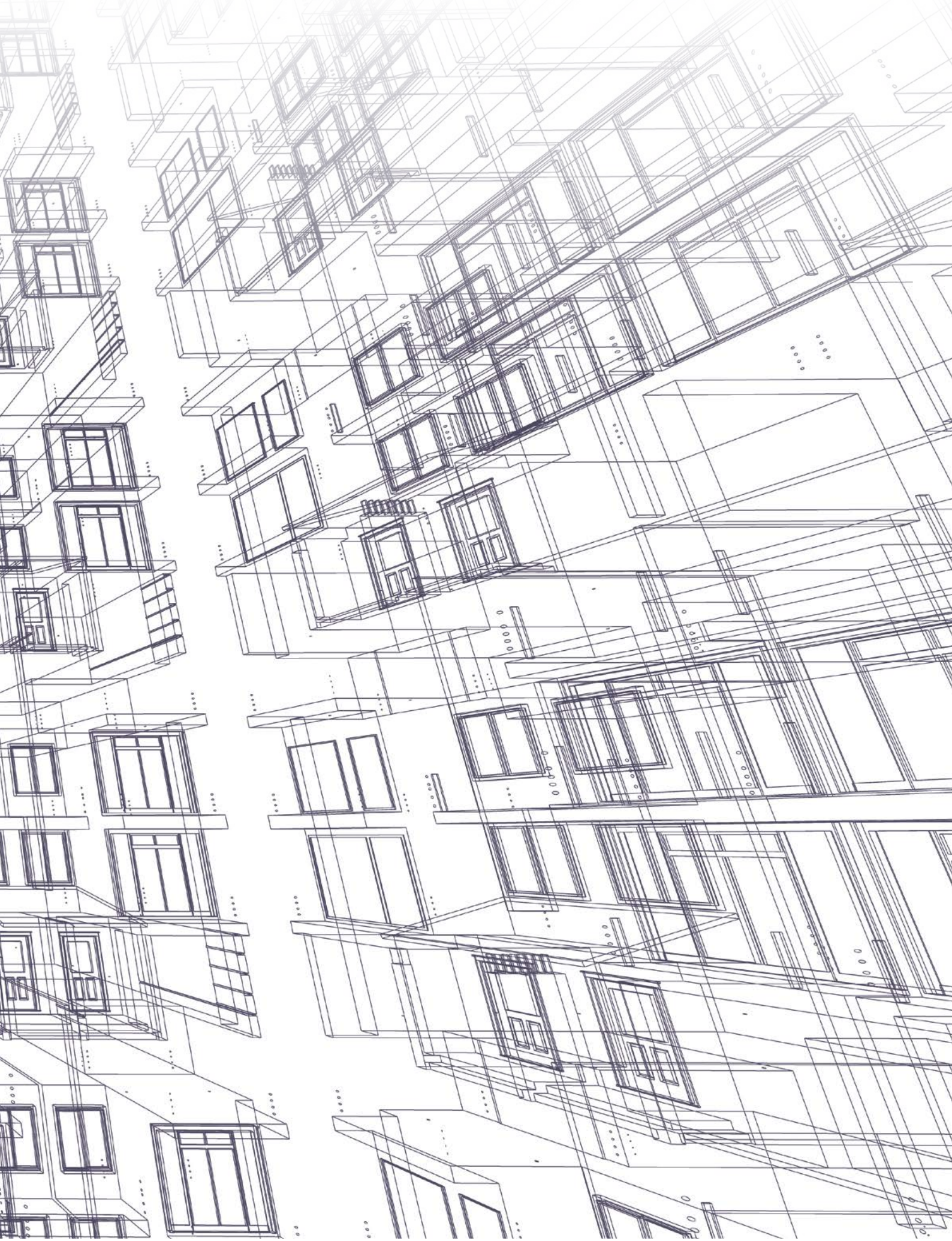

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