A new first-order decision-making model for the procurement of public sector infrastructure: Procedures and Testing

Poh Lian Teo[1], Adrian J. Bridge[2] and Jason Gray[3]

Given global demand for new infrastructure, governments face substantial challenges in funding new infrastructure and delivering Value for Money (VfM). As part of the background to this challenge, a critique is given of current practice in the selection of the approach to procure major public sector infrastructure in Australia and which is akin to the Multi-Attribute Utility Approach (MAUA). To contribute towards addressing the key weaknesses of MAUA, a new first-order procurement decision-making model is presented. The model addresses the make-or-buy decision (risk allocation); the bundling decision (property rights incentives), as well as the exchange relationship decision (relational to arms-length exchange) in its novel approach to articulating a procurement strategy designed to yield superior VfM across the whole life of the asset. The aim of this paper is report on the development of this decision-making model in terms of the procedural tasks to be followed and the method being used to test the model. The planned approach to testing the model uses a sample of 87 Australian major infrastructure projects in the sum of AUD32 billion and deploys a key proxy for VfM comprising expressions of interest, as an indicator of competition.

Keywords: decision-making model, infrastructure, procurement, value-for-money

1. Introduction

1.1 VfM challenge and weaknesses in MAUA approach to procurement

The global demand for infrastructure is increasing dramatically and governments are facing substantial challenges to fund public infrastructure and achieve value-for-money (VfM). OECD (2006) estimated USD3 trillion is required globally 2007-30 and in Australia there is an estimated pipeline of infrastructure projects amounting to more than AUD 770 billion (Infrastructure Partnerships Australia 2010). As such, leveraging private finance through Public-Private Partnerships (PPP) is considered to be a key mode of delivering new infrastructure in many countries (KPMG 2010). However, recent concerns have been raised in UK regarding uncertainties of PPP delivering VfM and criteria for early identification of projects suitable for PPP (House of Lords 2010). At the same time, PPPs have become largely a business as usual consideration in Australia, comprising separate contracts of design and construct; and operations and maintenance (Infrastructure Australia 2012).

[1] Ph.D. Candidate, School of Civil Engineering & Built Environment, Queensland University of Technology, QLD 4000, Australia; Email: pauline.teo@student.qut.edu.au
[2] Senior Lecturer, School of Civil Engineering & Built Environment, Queensland University of Technology, QLD 4000, Australia; Email: a.bridge@qut.edu.au
[3] Lecturer, School of Civil Engineering & Built Environment, Queensland University of Technology, QLD 4000, Australia; Email: jm.gray@qut.edu.au

Procurement options analysis (POA) in the National PPP Policy Framework in Australia provides an approach for selecting a suitable procurement mode including PPP, and tends toward using semi-quantitative measures (use of rankings/perceptual scales and non-monetary) of costs/benefits of alternative procurement modes. In other words, client requirements (project outcomes) are systematically matched with the relative merits of alternative procurement modes in order to select the preferred procurement mode. This approach is also known as the Multi-Attribute Utility Approach (MAUA). MAUA is supported by a large body of work with around 900 studies related to MAUA and procurement systems, and has been regarded as "the foremost technique and approach for examining the criteria of clients and the preferences of experts' weights for each method in the most objective way" (Love et al. 1998). However, MAUA has inherent problems of implementation, that is, a lack of generally agreed and accepted set of criteria among the experts and difficulty in reaching consensus in the set of utility scores for each procurement method (Skitmore and Marsden 1988; and Love et al. 1998). Additionally, the range of procurement methods in research may not be comprehensive; the scores produced may differ by narrow margins which results in limited differentiation and less reliable selection; and the analyses may be carried out on limited range of trial projects (Sweeney 2009). These issues arise from MAUA's fundamental weakness associated with its tautological nature. That is, matching project outcomes with the relative merits of alternative procurement modes to select the preferred procurement mode (Chang and Ive 2002; Teo, Bridge and Jefferies 2010). The preferred procurement mode is defined as a subset, or effectively in the same terms, as the desired outcomes of the project and is therefore tautological, that is, the relationship is circular and considered a truism that is not falsifiable (Popper 1959). In summary, MAUA lacks scientific maturity and can be decoupled from the risk management plan given a justifiable rationale and which may not be economic. The top three boxes in Figure 1 indicate the direction of the current approach where procurement selection is based on matching project outcomes with alternative procurement modes (right to left). In other words, rather than deriving the procurement mode from project attributes (bottom three boxes left to right), other factors such as time is driving the selection of the procurement mode. Hence, the current approach is susceptible to non-economic influences and undermines risk analysis being carried out. This creates a narrow approach to VfM, where VfM is determined by whether or not the selected procurement mode delivers the key performance outcome. Furthermore, the current procurement approach also requires risk analysis to be carried out at early stages of the project where information is lacking, and requires guessing the nature and extent of potential risk events occurring, and subsequently second guessing the value and extent of these risks.

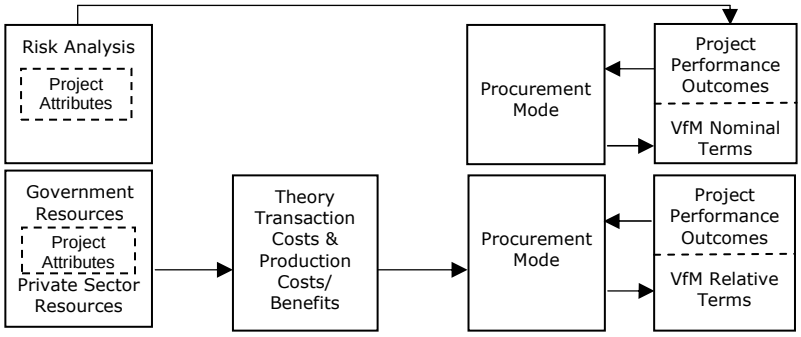

Figure 1 New model versus current approach

Hence from the above critique of MAUA, current research and practice appears to lack a sound basis to procure VfM across whole-of-life of the asset, and research in the construction literature is only beginning to show some signs that the dominant and Nobel prize winning theory from the New Institutional Economics field, that is, Transaction Cost Economics (TCE) and the dominant strategic management theory, that is, Resource-Based Theory (RBT), are being deployed in construction related sectors, for example, Chang and Ive (2002), Bridge and Tisdell (2004), Jin and Doloi (2008) and Sweeney (2009).

1.2 Compensating virtues of new first-order decision-making model

Given the weaknesses of MAUA, a new first-order procurement decision-making model (shown in Figure 2) has been developed and described elsewhere (Teo, Bridge, Gray and Rowlinson 2012; Teo, Bridge, Gray and Jefferies 2011; Teo, Bridge and Jefferies 2010). The new model deploys both TCE and RBT, to measure the technological and physical attributes of the project, as well as the relative capabilities and competencies of government versus the private sector with respect to the project, to identify a procurement strategy that is more likely to deliver a better ratio of production benefits to production costs and transaction costs across the whole-of-life of the asset, than procurement modes associated with the outcome of deploying MAUA. The key departure of the new model from MAUA is the model's analysis of make-or-buy decisions within the project at the individual activity level. That is, the focus is on production activities of design, construct, operations and maintenance of a first-order level, and not the organisation or management across activities which are considered second-order level. The project is divided into key activities. With knowledge of the key activities, the model measures the relative technical and/or organisational capabilities and competence of each activity across government and private sector, in terms of who is better placed to manage the activity. As such, the new model avoids issues arising from information gaps surrounding the new project during its early stages, and indirectly performs risk allocation at the activity level without having to guess with information missing at schematic stages and later second guessing when the buyer, for example, government or its agents, attempt to assess the nature and value of risks which are better understood by suppliers. In other words, the new model is more reliable and an appropriate level of analysis in terms of accessing who is better at dealing with inherent risks that might occur within the activity.

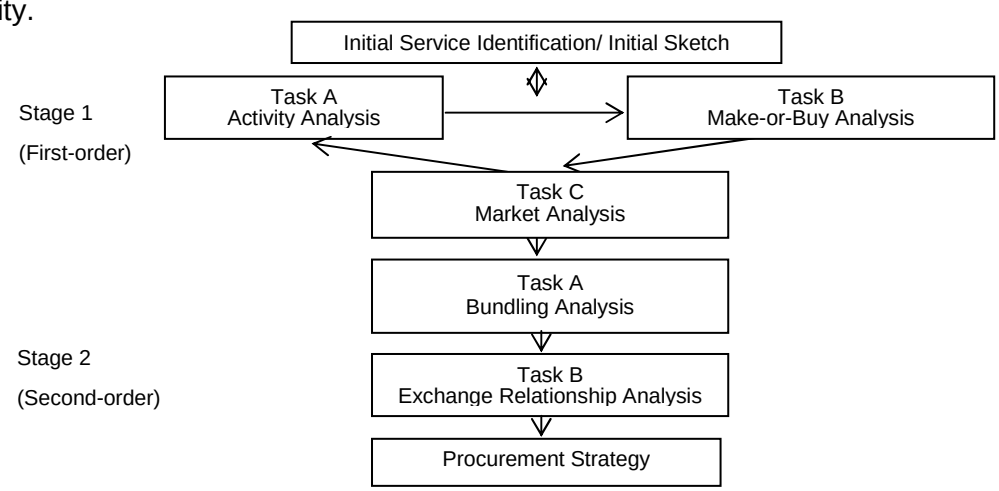

Figure 2 Schematic of new first-order procurement decision-making model

The model also provides a direct and clear connection between data gathering, including risk analysis, and the approach to procuring the project. As such, the procurement strategy is informed based on economical factors and not influenced by political goals, hence more likely to deliver superior VfM, or a better ratio of production benefits to production costs and transaction costs across the whole-of-life of the asset, than procurement modes associated with deploying MAUA. The paper aims to provide a step-by-step description of the new model and the approach of testing using competition as a dependent variable.

2. Procedures

2.1 Stage 1 Task A Activity analysis

The main purpose of Task A is to identify key first-order activities in the project. The distinction between key activities lies in the discrete technological boundaries, distinct knowledge base or skill sets, associated with design; construction; operations and maintenance (D,C,O,M) as the dominant source of adding value. Table 1 illustrates key activities of a typical road project. The key activity should be non-trivial in terms of significant cost relative to the capital cost of the project. The following are not a key activity: a milestone on the program, such as schematic design which covers many consultant disciplines; a building element which covers many trades; and organisational and/or management activity which includes planning/programming and supply chain management including procurement, as the main source of adding value. The scope of activity analysis is delimited to activities starting from and including schematic design (hence excludes upstream activities like planning and surveying site); to and including maintenance of built asset and operation to but excluding core/front-line activities (hence excludes downstream activities, such as clinical services in hospitals). This approach starts with focus on key production activities of D,C,O,M and is therefore first-order analysis, unlike current practice that starts at an organisational or second-order level, say managing contractor. Corresponding to the critique of inappropriate risk analysis, this approach avoids being too focused on individual risks and does not require guessing and second guessing of risks with information gaps. Furthermore, it provides a transparent framework based on economic principles, unlike MAUA where risk analysis can be overshadowed by the main concern of matching key opening day outcomes to procurement mode.

Design	Construction	Operations	Maintenance
Design of construction 1. Road civil engineering design 2. Traffic engineering design *Design of performance specification of maintenance* 3. Plan for routine maintenance, programmed maintenance and rehabilitation of road pavement, road furniture, drainage maintenance & ITS	4. Earthworks 5. Traffic management 6. Drainage and culverts 7. Retaining walls 8. Plant-mixed stabilised pavements 9. Sprayed bituminous surfacing and cover aggregate 10. Asphalt, including preparation, surfacing and grading 11. Roadside structures 12. Noise barrier 13. Line markings; markers 14. Electrical pits, conduits, fittings, including road lightings, ITS ducts and pits 15. Landscaping	16. Intelligent Transport Systems and traffic operations	17. Inspections & data collection, including reactive and programmed maintenance 18. Reactive maintenance 19. Rehabilitation

Table 1: List of typical key activities in a road project

2.2 Stage 1 Task B Make-or-buy analysis (on each activity)

This task involves measuring TCE and RBT attributes using a questionnaire instrument and then assigning an activity level for each key activity. The conventional approach in TCE views transaction costs which occurs across technological boundaries as the unit of analysis, and is mediated by governance structures (markets, hybrids and hierarchies) which lends itself to make-or-buy analysis (Chang 2013). Correspondingly, the first-order approach also leads into a make-or-buy analysis around the key activities/ transactions in Stage 1 Task B and which is effectively risk analysis using an indirect approach, by deploying RBT and TCE. RBT deals with technical/production risks, that is who is better at the key activity, either technologically or organizationally, and therefore better able to manage risks arising out of the key activity. TCE deals with external exchange risks arising out of hold-up as function of specific investment by one party to the key activity that creates a dependency of this party on the other party and which makes the less vulnerable party more powerful and able to behave in negative opportunistic ways on the occurrence of a change/variation. For example, changes in technology (high asset specificity), and demand and demographic changes (uncertainty beyond control), resulting in variations which causes potential for hold-up. Hence asset specificity and uncertainty are the more influential TCE variables in determining the possibility of hold-up in a key activity. Specifically, RBT measurements are concerned with relative capability and competence of government versus private sector and TCE deals with physical, technological or human asset attributes and addresses the issue of potential hold-up to the government by private sector. From applying the measurements, a pattern for each activity is matched with the closest theoretical/predicted pattern shown in Table 2. In doing so, the activity is suggested as internalised or externalised to achieve greatest efficiency, including the most efficient allocation of risks. Activities are internalised when the government uses its own resources to carry out the activity or when it owns more than fifty percent of the subsidiary firm, and externalised when contracted out to an external firm by the government directly or subsidiary indirectly. This approach of identifying the party best able to manage risks associated with an activity is a significant departure from current practice. Instead of identifying and assessing risks at the early stages of the project where information is missing, the emphasis is on resources owned by government versus private sector relative to each project activity. Hence, this approach is able to more reliably anticipate which party is better at managing the risks associated with each activity.

Level	Logic	Asset Specific (TCE)	Uncertainty (TCE)	Frequency (TCE)	Value (RBT)	Rare (RBT)	Costly To Imitate (RBT)	Mode of Govern'
1	Capability	+ / + + +	0 / + + +	+ / + + +	+ + +	+ / + + +	+ / + + +	Internal
2	Capability	0 / + + +	0 / +	+ / + + +	+ +	+ / + +	0	Internal
3	Transaction Costs/ Capability	0 / + + +	0	+ / + + +	+	0	0	Internal
4a	TCE	+ / + + +	+ / + + +	+ / + + +	0	0	0	Internal
4b	TCE	+ / + + +	+ / + + +	0	0	0	0	External
5	Transaction Costs/ Capability	0	0	0	-	0	0	External
6	Capability	0 / + + +	0 / + + +	0 / +	- -	+ / + +	0	External
7	Capability	0 / + + +	0 / + + +	0 / +	- - -	+ / + + +	+ / + + +	External

Table 2: Integrative framework of vertical integration (from Bridge and Tisdell 2004; Bridge 2008)

2.3 Stage 1 Task C Market analysis

From here on, the focus is the procurement of externalized activities. SCP analysis is used to corroborate the levels of activities identified, and consider any Level 7 activities arising out of large scale of this activity's work. If any of these activities are found, the model suggests attempting to break down into two or more smaller/sub-activities to reach the next tier of firms specialising in these activities. This avoids lack of competition due to size or possibly more powerful sub-market firm (for example, subcontractor) as part of supply chain by main-market firm (main contractor).

2.4 Stage 2 Task A Bundling analysis

The model then considers any potential troublesome activities that will lead to government becoming dependent/vulnerable and market firms becoming more powerful, that is, Level 4b activities that can potentially cause hold-up *ex post* arising out of high asset specificity and high uncertainty, or any residual Level 7 activities that cannot be further broken down because of physical/proximity issues or Level 7 activities arising out of rare technology leading to a lack of competition, and market power to set prices *ex ante*/pre-contract and which again can cause hold-up problems *ex post*/post-contract. Next, the model determines if any of the potential opportunistic behaviour by market firms associated in these troublesome activities be checked by the firm engaged at the head of supply that includes these activities, for example main contractor at the head of the supply chain that is coordinating/subcontracting these troublesome activities using threat of future work to attenuate any potential negative opportunistic behaviour. If not, then considering either 1) a special relationship with the firms providing these troublesome activities through the firm being engaged at the head of the supply chain that includes these troublesome activities (for example, use of PC Sum and a nominated subcontractor/supplier arrangement) which then drops down into an exchange relationship consideration; or 2) a separate contract between the firm/government and the firm providing the troublesome activity, that is, excluding the troublesome activities from any subsequent bundle.

This task refers to Property rights theory whereby creating greater ownership, such as bundling operations and/or maintenance (O&/M) together with design and construct contracts (D&C), the firm is likely to invest more to gain greater returns in investments in the long term. Conversely, less bundling means lower incentives to provide better quality or design. By bundling O&/M into the contract, such as DCM, DCOM or PPP, there is greater ownership which makes the contractor responsible for operations & maintenance of the asset, and so greater likelihood of investments in production and non-production related investments. In addition, Hart (2003) indicated that if a service delivery provision is not clearly specified, contractor has the flexibility to modify the nature/quality of the facility without violating the contract. In contrast, in D&C, the contractor does not internalise any operating costs and there is little incentive for investment, where they perform minimum production and non-production related investment. If there is a lack of specification of production quality and more focus on the service provision, contractors may have the flexibility to choose lower productive investments, that is providing a cheaper and lower quality solution for the client. Hence, property rights do not favour D&C contracts and where

contracts that cannot be specified clearly, favours conventional provision (or unbundling), for example, construct only instead of PPP (Hart 2003).

The next step is to bundle remaining key activities into main activities of D,C,O,M, and undertake second-order analysis (assess the activities of organizing/managing each of these main activities, such as, main contractor on construction). And similarly break down each activity if size and/or complexity of main activity leads to Level 7 (again, leading to lack of competition and market power to set prices ex ante and hold-up problems *ex post*). Next, the model identifies any potential viable major activities, that is, bundle(s) of either DCO main activities or DCM main activities or DCOM main activities as PPP(s), or otherwise via contract(s) and remainder as separate D/C/O&M main activities with each main activity organized by government (either directly and/or using market firm, such as, PM/consultant). In sum, there are three levels of activities; namely 1) key activities (about highest level of market specialization); 2) main activities (set of D or C or O or M key activities); and 3) major activities (set of DCO or DCM or DCOM main activities). Organisation and management of activities includes, planning and coordination of timing of tasks within activities; and across key activities in main activities; and across main activities in major activities.

2.5 Stage 2 Task B Exchange relationship analysis

This task involves re-measuring TCE variables at the exchange between government and the market firm that can provide each major activity (bundle) and/or each main activity and/or each key activity to determine the most efficient exchange ranging from 1) efficient relational exchange, such as, Alliancing or pain/gain share regime to 2) efficient discrete exchange (such as, arms-length exchange, or standard neo-classical contracting such as, lump-sum/fixed-price contracts with mechanisms to resolve dispute by third parties and 3) short-term inefficient discrete exchange, such as, non-standard contracts written with bespoke credible threats for non-performance (See Figure 3 for summary). This measurement now includes the task of planning and coordination *across* key activities and so this measure of main and major activities may produce a different result on the TCE variables than that recorded across the TCE results measured in the constituent key activities.

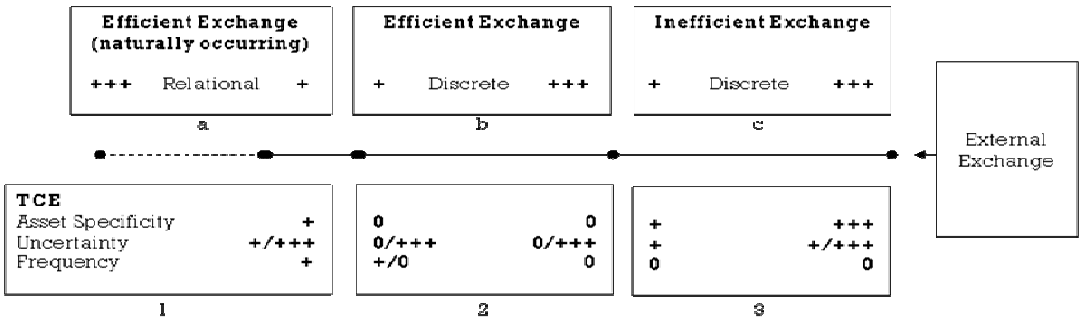

Figure 3: Exchange relationship analysis (Bridge 2008)

In Box 1, activities have a very high potential for hold-up due to high asset specificity and high uncertainty, that is Level 4b, and government can more efficiently seek to control these activities using more relational exchange, such as collaborative approaches or share risks in an alliance fashion. Main or major activities dominated by Level 5 and 6 activities are

reflected in Box 2 which can yield an efficient transfer of risk and control to the contractor. Standard neo-classical contracts can be deployed to obtain a fixed price for construct only and/or DC and/or DCOM package. If DCOM with private finance is being used in Pattern 5 and 6 activities, then a conventional PPP arrangement is appropriate. Box 3 reflects activities with a very high potential for hold-up (Level 7), but unlike Level 4b, government lacks in-house capability and access to agents to effectively collaborate with the contractor in terms of D,C,O,M. In transferring control to the contractor, government can seek assurances through writing contracts with credible threats concerning compliance with contracted performance, and hence a very arms-length and discrete exchange with the contractor/consortium.

3. Approach to testing the new first-order decision-making model

3.1 Developing competition as a dependent variable/proxy for VfM

The preferred method of demonstrating VfM is through estimation of costs and benefits associated with alternative procurement modes of a project over the whole life of the asset. However, a lack of quantitative and comparable data in operations and maintenance creates difficulties in measuring VfM using an absolute monetary value. In cases where the concept is not able to be measured directly, Remler and Van Ryzin (2011) recommended developing a proxy, that is a “measure that substitutes for another unavailable measure”. Competition has been widely recognised and accepted to be the determinant of value. Surveys regarding critical success factors for PPP have been conducted in many countries, including Australia, United Kingdom and Hongkong; and results have identified competition as one of the key VfM drivers (Andersen 2000; Cheung et al. 2009; Dixon et al. 2005). In economic terms, competition drives down marginal costs and creates downward pressure on prices. Not only does absolute level of competitive tension create downward pressure on prices but it also facilitates the crystallisation of innovations in the design that impinges on time, cost and quality and which will influence the overall performance of the project across its life-cycle. Studies have shown empirically that greater number of bidders have the effect of reducing value of lowest bid (McCaffer 1979; Skitmore 2002; Domberger and Rimmer 1994). Auction theory scholars have empirically demonstrated that in a sealed tender auction, perfect or intense competition leads to convergence of the true value of the object even when bidders have incomplete information about the value (Brannman et al. 1987). Gupta (2002) examined 1,937 highway construction projects over five year period, and results show that absolute level of competition creates downward pressure on price, that is the value of winning bids decreases as number of bidder increases and the effect on value becomes insignificant when the absolute number of bidders reaches a maximum, that is, competitive threshold. Gupta derived competitive threshold to be 6-8 bidders in an open tender, subject to factors, such as size of project and market conditions. Gupta (2002) made the important contribution of an optimal level of competition that is dependent on size and bundling of the project and market at the time of tender.

For the purposes of this study, actual competition is measured by the attractiveness of the project using the number of firms demonstrating their willingness to bid either through open tendering (OT) or Expressions of Interest (EoI). This avoids measuring competition based on

selective tendering, which does not reflect the level of interest in the market. The next section discusses competition and market failure before or *ex ante* and after or *ex post* a transaction/contract, and how the model is able to address potential market failure.

3.2 Market failure *ex ante*

In neoclassical economics, one major driver for market failure is lack of competition, resulting an inequilibrium in allocation of goods and services or Pareto inefficiency in a free market. In TCE terms, transaction costs in general impede the formation of the market (Arrow 1969). For example, in a monopoly or duopoly where there are only one or two competitors in the market, market equilibrium will not be considered Pareto efficient and indicates the potential for market failure due to a lack of competition or imperfect competition. There is lack of incentives for contractors to be innovative in order to be price competitive, and that can impinge on performance across the whole life cycle. The new model deals with lack of competition by dividing up the project/activity into bundles of activities mindful of the market or supply. For example, empirical results show limited numbers of contractors capable of AUD800 million and above in Australian major infrastructure market (Teo, Bridge, Gray and Rowlinson 2012).

3.3 Market failure *ex post*

A study of major infrastructure market in Australia shows that current contracting practice may have resulted in market failure *ex post* (Sweeney 2009). Market failure is not an absolute theory (Arrow 1969), and in addition to lack of competition, TCE envisages market failure occurring *ex post* due to post-contractual opportunistic behaviour. Opportunistic behaviour is not uncommon in the construction industry especially for complex projects associated with high uncertainty, and the market may perceive the project to be lucrative in terms of a potential for variation claims, and the opportunity to make superior profits post contract. Sweeney (2009) examined the Australian market and observed that contractors may use low bid tendering strategies to win contracts in an extremely competitive market (that is high EoI), and adopt a claim strategy resulting in high variation claims *ex post*. The new model deals with opportunistic behaviour in transactions susceptible to changes, when the environment is too complex or uncertain to be fully specified (Level 4 activity), or when the market is limited to a small number of players (Level 7 activity). Main contractors/ subcontractors can hold-up clients/main contractor, when the activity is on the critical path and susceptible to time and cost delays. In summary, as high EoI (over 6-8 EoI) have been shown to yield little production benefits in terms of lower prices and lower incentives for design innovations and at same time may indicate the prospect of *ex post* market failure, then 6-8 is derived as an optimal level of competition and consistent with VfM for purposes of this study.

3.4 Testing new first-order decision-making model

The new first-order decision-making model is tested using competition as the dependent variable as illustrated in Figure 3, and the corresponding hypothesis is given as:

- *In cases in which actual procurement matches the theoretical procurement (informed by new first-order decision-making model), then actual competition is expected to be closer to optimum competition (6 to 8 EoI), than in cases of an appreciable mismatch between actual procurement and theoretical procurement.*

Data has been collected on actual procurement (Box A), actual competition (Box D) in both road and health projects in Australia via questionnaire survey of government road and health departments; and also optimum competition (Box C) via nationwide contractor survey. Based on results Box A and Box D (a representative sample of 87 road and health projects worth AUD32 billion), Teo, Bridge, Gray and Rowlinson (2012) has already shown the general relationship between procurement and competition. That is, a significant relationship between EoI and size/value, bundling and payment terms.

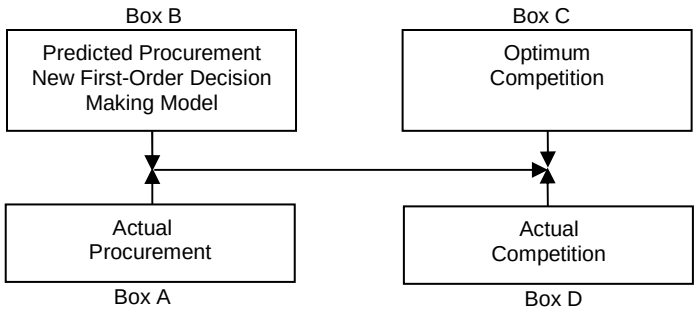

Figure 3: Procurement-tendering-competition hypothesis

In the final step of testing the hypothesis, case studies are selected from the sample of 87 projects. Multiple case studies are preferred as this approach can test theory in different sectors and attest reliability in different projects. If two or more cases have been shown to support the theory, then replication has been achieved. Based on theoretical replication and the spread of EoI in the sample (largely low levels of EOIs to around optimum levels), an approach is taken in which low/high EoI and optimum EoI are replicated, and based on literal replication, the same results will be duplicated, that is low/high EoI and optimum EoI are repeated for road and health sectors. The case study design is illustrated in the 2x2 matrix in Figure 4. The model is expected to predict a different procurement approach from practice at low/high level EoI and similar procurement approach at optimum level EoI.

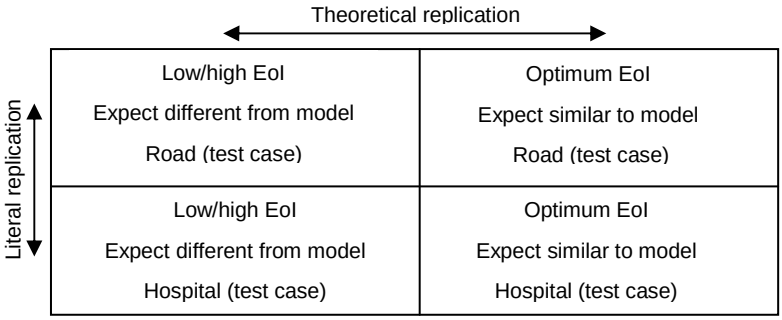

Figure 4: Multiple case studies replication design

4. Conclusion

In summary, the new first-order procurement decision-making model addresses the weaknesses of MAUA and provides a more reliable method of risk allocation which is based

on Nobel Prize winning economic theory. The new procurement model is not predisposed to any particular procurement mode, and identifies an efficient procurement approach, including size, bundling, and exchange relationship (including payment terms); by deploying TCE and RBT at a first-order level of the project. The model may uncover projects/bundles of activities within projects that may be investigated as potential PPP, and able to cope with changing market conditions and resources of government relative to private sector at the time of project and in any location.

5. Acknowledgement

This research was supported under Australian Research Council's Linkage Projects funding scheme (project number LP0989743).

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