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Validation of an instrument to measure governance and performance on collaborative infrastructure projects

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Abstract

Collaborative infrastructure projects use hybrid formal and informal governance structures to manage transactions. Based on previous desk-top research, the authors identified the key mechanisms underlying project governance, and posited the performance implications of the governance (Chen et al. 2012). The current paper extends that qualitative research by testing the veracity of those findings using data from 320 Australian construction organisations. The results provide, for the first time, reliable and valid scales to measure governance and performance of collaborative projects, and the relationship between them. The results confirm seven of seven hypothesised governance mechanisms; 30 of 43 hypothesised underlying actions; eight of eight hypothesised key performance indicators; and the dual importance of formal and informal governance. A startling finding of the study was that the implementation intensity of informal mechanisms (non-contractual conditions) is a greater predictor of project performance variance than that of formal mechanisms (contractual conditions). Further, contractual conditions do not directly impact project performance; instead their impact is mediated by the non-contractual features of a project. Obligations established under the contract are not sufficient to optimise project performance.

CE Database subject headings: Procurement; Partnerships; Australia.

Author's Keywords: Construction; Collaborative project; Project governance, Value for money; Project performance.

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Introduction

Over the past decade, collaborative procurement models (CPMs) have been increasingly used in many countries for delivering high value, complex infrastructure projects in industrial sectors such as road, rail, water, energy, mining and defense (Department of Treasury and Finance 2009; Love et al. 2011; Morwood et al. 2008; Scheepbouwer and Humphries 2011). A collaborative procurement model is designed to encourage relationships between project participants in an effort to maximise outcomes. The rise in the use of collaborative procurement reflects the increasing sophistication of construction projects to deliver infrastructure and the need to manage high levels of complexity and uncertainty (Morwood et al. 2008). Examples of CPMs are project alliances; program alliances; integrated project delivery (IPD); early contractor involvement (ECI); and traditional with partnering. CPMs have delivered significant community, environmental and social outcomes in conjunction with effective cost management and innovation (Davis and Love 2011; Hauck et al. 2004; Love et al. 2010). See Kent and Becerik-Gerber (2010); Love et al. (2010); Scheepbouwer and Humphries (2011); and Lahdenperä (2012) for a description of these delivery systems. The literature suggests that the alliances provide the most robust support of collaboration (Ross 2008), albeit with question marks over outcomes and the relatively high cost of implementation (Department of Treasury and Finance 2009).

The current paper focuses on Alliance-type procurement systems, which are currently attracting considerable interest across America and Europe after recent extensive use in the Australian context (Kelly 2011). The governance of these collaborative projects falls into two primary classes – formal and informal. Each project comprises distinct combinations of formal and informal mechanisms and underlying actions (Lahdenperä 2012; Love et al. 2010). Formal governance comprises contractual incentives for clear and equitable risk allocation (Lahdenperä 2010; Love et al. 2011). Informal governance comprises non-contractual incentives to enhance mutual trust, enable cooperation, facilitate open communication and share knowledge (Rahman and Kumaraswamy 2012). It is evident in the literature that different combinations of formal and informal mechanisms are applied within various transactional contexts (Love et al. 2010; Scheepbouwer and Humphries 2011). For example, high risk projects are likely to involve a greater concentration of informal mechanisms, like relationship workshops, to encourage trust.

Empirical evidence has not yet been established to clearly identify what roles the two classes of governance play in performance outcomes (Department of Infrastructure and Transport 2011; Kelly 2011; Lenferink et al. 2012; Nyström 2008). This is despite calls from prominent industry players (Department of Treasury and Finance 2009). The paper responds to this knowledge gap by addressing five research objectives:

1) To build a conceptual model showing the relationship between governance and performance;
2) To verify the essential mechanisms which define formal and informal governance for complex infrastructure delivery;
3) To verify the essential actions that underlie each mechanism;
4) To verify key performance indicators for collaborative infrastructure projects;
5) To investigate the association between project governance classes and project performance.

Previous literature on the topic has presented limited statistically rigorous evidence gathered by deductive means about the performance implications of collaborative procurement mechanisms (Eriksson and Westerberg 2011). Instead previous contributions rely on inductive methods such as interviews (e.g. Bresnen 2009; Davis and Love 2011; Hauck et al. 2004; Lenferink et al. 2012; Love et al. 2011; Love et al. 2010; Rose and Manley 2012). The current study provides much-needed statistical evidence about the performance implications of collaborative governance for infrastructure delivery. This extends the theory building cycle into a deductive phase. The findings reported here provide a more generalizable understanding of collaborative governance to maximise project outcomes, compared to inductive methods.

Building the Conceptual Model

Project Governance

Infrastructure projects are usually characterised by a high level of durable transaction-specific investment and a high degree of uncertainty (Morwood et al. 2008). In line with the perspective of transaction-cost economics (Williamson 1979), the construction management literature stresses the need to apply collaborative governance to manage the non-marketability challenges associated with infrastructure project transactions where duration, complexity and uncertainty are rapidly increasing (Chan et al. 2010; Lahdenperä 2012; Love et al. 2010; Rahman and Kumaraswamy 2012).

In practice, collaborative infrastructure projects adopt hybrid governance structures (Lahdenperä 2012; Lenferink et al. 2012) comprising formal and informal mechanisms, which utilise both market and hierarchical transactions (Williamson 1991) to facilitate the negotiation and execution of physical and human capital transactions (Chan et al. 2010). Formal mechanisms include market transactions through formal contracts and de-personalized exchange (Ferguson et al. 2005; Williamson 1991), and hierarchical transactions through performance measurement and dispute resolution procedures (Gulati and Singh 1998). Formal governance mechanisms are largely independent of the specific people involved, can specify outcomes (Hoetker and Mellewigt 2009), and are suitable for controlling physical capital, which is easily codified (written down) and transmitted (Hoetker and Mellewigt 2009).

By comparison, informal mechanisms focus on relationships (Hoetker and Mellewigt 2009; Macneil 2000), and include people and social-based hierarchical relations for enhancing mutual trust, open communication, cooperation and knowledge sharing (Gulati and Singh 1998). Informal mechanisms are normally applied as non-contractual stimuli designed to enable equitable allocation of risk through influencing the attitudes of individuals involved in the transaction, and are tightly bound to the specific individuals and their relationships (Hoetker and Mellewigt 2009). Hence the outcomes of informal mechanisms largely depend upon interactions between individual participants and cannot be pre-specified (Hoetker and Mellewigt 2009). These mechanisms are most suitable for controlling human capital transactions, which are idiosyncratic due to the tacit nature of the knowledge and the cognitive context involved (Williamson 1979).

Formal Mechanisms

A previous review of leading construction management literature by the authors (Chen et al. 2012) identified three essential mechanisms of formal governance: 'collective cost estimation', 'risk and reward sharing regime', and 'design integration'. These mechanisms are described below prior to verifying that they are a valid measure of formal governance.

Collective Cost Estimation

The cost of alliance projects are jointly estimated by an integrated team formed by the owner, designer, contractor and other service providers during the Target Cost Estimate (TCE) process (Love et al. 2011). The parties come together to develop the scope of work, define the time schedule, and agree on cost-reimbursable principles (Morwood et al. 2008). As an essential output of the TCE process, the target outturn cost (TOC) is developed to represent the expected cost of the project's scope at completion, including project specific costs and overheads, as well as service providers' profit margin and non-project related corporate overheads (Morwood et al. 2008). The TOC is used as the benchmark to assess performance and to determine how risk and rewards are shared by the parties (Department of Infrastructure and Transport 2011; Love et al. 2011). An actual outturn cost (AOC) close to the TOC also demonstrates value for money (Love et al. 2011).

ECI combines principles of Alliances and traditional Design and Build (DB) methods, and uses a two stage arrangement to manage initial risks. The collective cost estimation is primarily carried out in the collaborative stage, where the owner, contractor and designer work together to develop the design, program, budget and risk allocation model (Lenferink et al. 2012; Scheepbouwer and Humphries 2011). Alliance and ECI project structures are tailored to the unique characteristics of a given project, where owners ensure price competitiveness through selecting either one or multiple service provider teams to participate in the scoping and pricing stage (Lahdenperä 2010; Lenferink et al. 2012; Love et al. 2011; Scheepbouwer and Humphries 2011).

Engaging only one service provider team in the pricing stage has been found to enable better development of a trustful and cooperative relationship between the owner and the proponent (Kelly 2011; Ross 2008). However, this approach is also criticized for lacking sufficient incentive to achieve cost-effective pricing, which has been argued as the advantage of the multiple team approach, since the later builds competitive tension between the proponent teams (Department of Infrastructure and Transport 2011). The choice of approach depends largely on the transactional context of the specific project (Lenferink et al. 2012; Morwood et al. 2008).

Risk and Reward Sharing Regime

The risk and reward sharing regime constitutes the foundation of collaborative procurement's commercial framework (Chan et al. 2010; Lahdenperä 2012; Lenferink et al. 2012). In alliance projects, this regime enables the parties (including the owner) to share savings and overruns according to the set TOC. That is, any cost under- or over-run against this TOC is split in pre-agreed, specified proportions (Lahdenperä 2010; Love et al. 2011). Normally, the owner takes 50% of both the gain (profit due to cost underruns) and pain (loss due to cost overruns), and the remaining 50% is available to be split between the service providers (Department of Infrastructure and Transport 2011; Morwood et al. 2008).

Historically, most Alliance contracts cap the overall risk for each service provider at the loss of the service provision fee, which means that even in the worst case scenario, the service providers will still be reimbursed for the direct costs of the project (Morwood et al. 2008). The owner's non-price objectives are represented by Key Result Areas (KRAs) such as facility performance, safety, and timely completion, which are pre-agreed between the owner and service providers, and measured and rewarded based on Key Performance Indicators (KPIs) (Department of Infrastructure and Transport 2011; Morwood et al. 2008).

In the case of ECI projects, the payment to the contractor is based on actual cost at an agreed rate, plus an agreed amount for profit and overheads (Scheepbouwer and Humphries 2011). Similarly to project alliances, the contractor is financially rewarded for success in some KRAs from a performance pool (Edwards 2009).

Design Integration

Formal mechanisms are designed specifically to spur the parties to invest and cooperate in joint design during the development phase, which is critical for innovation and project success (Lenferink et al. 2012; Love et al. 2010; Morwood et al. 2008). Through collaborative pricing and scoping, risk analysis and investigation, and transparent costs and documentation, service providers are able to prepare a price based on a reasonable understanding of the project (Love et al. 2011; Scheepbouwer and Humphries 2011). This is essential for maximizing outcomes, since the owner benefits from a range of design scenarios, sensible risk management and appropriate contract development. Additionally, a secured margin increases financial certainty for contractors, thereby reducing the likelihood of margin recovery strategies such as claims (Lenferink et al. 2012; Morwood et al. 2008; Scheepbouwer and Humphries 2011).

The above discussion leads to two hypotheses specifically relating to formal governance:

Hypothesis 1 (H1): The implementation intensity of formal mechanisms is positively associated with project performance.

Hypothesis 2 (H2): Formal mechanisms are attributes of the governance structures of collaborative projects.

Informal Mechanisms

A previous review of leading construction management literature by the authors (Chen et al. 2012) identified four essential mechanisms of informal governance: ‘leadership’, ‘relationship manager’, ‘team workshops’ and ‘joint communication’. These mechanisms are described below prior to verifying that they are a valid measure of formal governance.

Leadership

A collaborative project adopts a special leadership structure to integrate project participants. The leadership structure of alliance projects is a typical example, where a Project Board is established to provide vision, governance and leadership. Further, a Project

Management Team drives operational project delivery. The Board and Team are formed by representatives from the owner organization and the service providers (Department of Infrastructure and Transport 2011; Morwood et al. 2008). In ECI projects, a significant level of design management needs to be passed to the design team jointly formed by the designer and contractor (Scheepbouwer and Humphries 2011). This arrangement requires the owner to appoint a design leader, who has the ability to communicate with the integrated design team, to ensure that the design is firmly aligned with the owner' objectives (Scheepbouwer and Humphries 2011).

Normally, project leaders are selected based on project specific experience and logistical skills (Morwood et al. 2008; Scheepbouwer and Humphries 2011). However, in collaborative projects other skills become important, such as leadership and communication capabilities; cultural alignment skills; and capacity to influence resources available to the project (Walker and Lloyd-Walker 2011).

Team Integration

Collaborative projects demand integration of the resources and capabilities of service providers from broad areas including design, construction, systems and controls, community stakeholders and environmental groups (Chan et al. 2010; Lahdenperä 2012). The management of relationships and culture are usually well planned at the beginning of the project (Love et al. 2010; Scheepbouwer and Humphries 2011). The team forming process considers not only complementary resources and capabilities of potential partners, but also the inter-relationships between partners and the client (Davis and Love 2011; Morwood et al. 2008). The client organizations often introduce a 'relationship manager' to the project team to align expectations and maintain relationships amongst all team members (Love et al. 2010).

Team Workshops

Relationship workshops are widely used in collaborative projects to facilitate open communication, build relationships and achieve mutual understanding (Chan et al. 2010). Independent facilitators are commonly engaged for team development activities and cultural alignment in workshops (Lahdenperä 2012; Morwood et al. 2008). In the early stages of Alliance and ECI projects, selection workshops and commercial alignment workshops are used to identify technical issues and build relationships between parties (Chan et al. 2010; Lenferink et al. 2012). Through these workshops, the owner and service providers collectively generate the vision for project delivery, develop the principles for the commercial arrangement, and design an innovation program (Davis and Love 2011; Edwards 2009). In Alliance projects, which tend to be of longer duration than ECI projects, workshops are extended into the project operation phase to promote effective coordination and innovation, as well as in the project evaluation phase to enable learning and reinforce relationships for future projects (Davis and Walker 2009; Morwood et al. 2008).

Communication Systems

Collaborative project governance emphasizes the principle of co-operative joint decision making, and demands an effective use of information system to support open communication, information sharing and organizational alignment (Hauck et al. 2004; Love et al. 2010). An integrated web-based IT system incorporating building information modelling (BIM) is increasingly needed to facilitate information flow (Kent and Becerik-Gerber 2010). Specific communication tools, such as an expectation matrix, are also developed for the team members to share and match their views, and align their commitments to each other (Love et al. 2010). The establishment and training needs for the IT system need to be addressed at project commencement (Morwood et al. 2008).

The above discussion leads to two hypotheses specifically relating to informal governance:

Hypothesis 3 (H3): The implementation intensity of informal mechanisms is positively associated with project performance.

Hypothesis 4 (H4): Informal mechanisms are attributes of the governance structures of collaborative projects.

Project Performance

The ultimate purpose in designing governance structures is to achieve project performance targets, which align with the owner's objectives (Department of Treasury and Finance 2009; Lenferink et al. 2012). The primary challenge associated with the execution of a collaborative project lies in creating an appropriate combination of formal and informal mechanisms (Bresnen 2009; Lahdenperä 2012). The heterogeneity of project performance is attributable to the differing implementation and composition of governance structures (Department of Treasury and Finance 2009; Eriksson and Westerberg 2011). Therefore, the following hypothesis is put forward:

Hypothesis 5 (H5): The implementation intensity of collaborative project governance structures, as defined by the combination of both formal and informal mechanisms, is positively associated with project performance.

The degree to which informal mechanisms are implemented is constrained by the formal mechanisms that are in place. Collective cost estimation and the risk and reward sharing regime have been shown to particularly affect the collaborative behavior of participants involved in collaborative projects (Lenferink et al. 2012; Morwood et al. 2008; Ross 2008). Alliance projects embrace risk by adopting a cooperative strategy in both project development and construction phases, use fully integrated project teams and communication systems, and carry out intensive workshops (Hauck et al. 2004; Love et al. 2010). In non-alliance environments, collaborative procurement in the form of conventional contracts with partnership agreements, or ECI, has a stronger emphasis on cost, with less use of collective cost estimation and risk sharing (Chan et al. 2010; Scheepbouwer and Humphries 2011). Further details concerning procurement model development are reported in Chen et al (2012). Thus, it is hypothesised that:

Hypothesis 6 (H6): The implementation intensity of formal mechanisms is positively associated with that of informal mechanisms.

Based on these hypotheses, the conceptual model shown in Fig. 1 was developed. The model shows that there are two main types of project governance – formal and informal, and seven mechanisms sitting under them. There are three formal mechanisms and four informal mechanisms. The model shows the four hypotheses (H1-4) specifically relating to the identified positive influence of formal and informal governance mechanisms on project performance. Hypothesis H5 is that variation in project performance is dependent on the implementation and composition of governance structures, both formal and informal. Finally, hypothesis H6 is that formal and informal governance are complementary.

[Insert Fig. 1]

Methods

Operationalization of the constructs

This section describes how the key constructs were operationally defined. The operational definitions were used to construct the survey questions.

Project governance

Based on the seven governance mechanisms previously identified by the authors (Chen et al. 2012), the current research involved identifying the action items that underpin each mechanism. The Project Governance construct was operationalized through directed content analysis (Krippendorff 2004), where well established theories and findings of prior research were used to identify key variables as initial coding categories. The analysis involved three steps. The first step drew on transaction-cost economics theory (Williamson 1979, 1991), relational contract theory (Feinman 2000; Macneil 2000), and strategic alliances literature (e.g. Gulati and Singh 1998; Hoetker and Mellewigt 2009) to derive the initial dimensions for the operationalization.

The second step considered papers published between 2000 to 2013 by construction management journals reporting studies related to alliances, cooperative procurement, relational contract and partnering. During this period collaborative procurement is considered to have been most active. The analysis canvassed papers published in sources including but not limited to: *Journal of Construction Engineering and Management; Journal of Management in Engineering; Construction Management and Economics; Engineering, Construction and Architectural Management; International Journal of Project Management.* The third step analyzed government publications and industry reports published over the same time period in Australia, Europe and the US, as the three primary locations using collaborative contracts.

Nvivo 10, a qualitative data analysis software (Bazeley 2007; QSR International 2013), was used to support the systematic coding process. The software helped the authors to classify, arrange and sort information found in the literature. It combined analysis through searching, shaping, linking, and cross-examination functions (QSR International 2013). The coding process was checked independently by the two authors and then cross-referenced between them. Care was taken to identify the action items that were mutually exclusive, limited in number, and clearly aligned with a specific governance mechanism. Coding continued until the number of new action items found substantially diminished with further reading or cross referencing. The validity and reliability of findings was supported by the traingulation process. Further integrity was provided by refining the codes following feedback from an expert panel that comprised three senior construction industry executives, drawn from the industry association supporting the research process. The coding process identified a total of 43 action items under the seven mechanisms to operationally define the construct of Project Governance. Of the 43 items, 23 are formal governance items and 20 are informal governance items.

Project performance

The operational definition of Project Performance construct was developed based the measures used by a recent empirical study within the collaborative contracting context in Australia (Department of Treasury and Finance 2009). The measures were assessed against the discussions about both cost and non-cost associated performance evaluation of collaborative projects in the construction management literature (Chan et al. 2010; Morwood et al. 2008). The measures were also compared with the criteria recently proposed by Eriksson and Westerberg (2011) for measuring the success of collaborative projects. This assessment identified eight performance indicators to operationalize the Project Performance construct. The eight indicators cover major themes of performance evaluation for collaborative projects without duplication or omission.

Survey Design and Data Collection

The unit of analysis was a collaborative infrastructure project. The survey was distributed in 2013 by email to 1,688 participants on such projects. The survey was structured to capture 1) respondent and project characteristics; 2) respondents' project performance; and 3) the implementation intensity of governance mechanisms within respondents' projects. The contact database of the Alliancing Association of Australasia (AAA) was used to build the sampling frame. The database contains most of the senior construction sector practitioners with collaborative project experience in Australia, comprising public and private sector clients, contractors, consultants and suppliers.

The operational definitions of the two primary constructs, Project Governance and Project Performance were used to design the survey. A total of 43 action items covering formal mechanisms (FM) and informal mechanisms (IM) were constructed. The survey required respondents to rate the degree to which each of these items was implemented in their most recently completed collaborative project, on a 7 point Likert scale (1 = strongly disagree; 7 = strongly agree). Similarly, eight items operationalizing Project Performance were constructed, being 'time efficiency', 'cost efficiency', 'quality of work', 'team collaboration', 'innovation', 'safety', 'environmental impact', and 'community impact'. The eight items were assessed as performance targets by respondents on a 7 point Likert scale (1 = substantially below target; 7 = substantially above target).

Following the advice of Neuman (2003), a pilot study was carried out to evaluate the clarity and relevance of the survey to the target respondents, in order to ensure the face validity of the measurement items. Practitioners from the industry were invited to pilot test the survey at an industry conference in 2012. Written feedback was received from 8 practitioners, informal verbal feedback from 12 practitioners, and detailed interviews were subsequently conducted with 2 expert practitioners in collaborative procurement. The feedback was used to increase the clarity of the final survey and to improve the functionality of the electronic survey instrument. At this point, description of measurement items and scales was finalised.

Sample Size and Response Rate

Bartlett et al. (2001) suggests that a suitably rigorous sample size and corresponding response rate is that which achieves an alpha level of 0.05 with a 3% margin of error, when determined using Bartlett's sample size estimation formula. Bartlett's formula was applied to the early responses received by January 2013 to estimate the response rate that would ensure an appropriate error level. For the sampling frame of 1,688 prospective respondents, the target was estimated to be approximately an 18.5% response rate, an equivalent sample size of 312 responses.

At closure of the survey, 357 responses had been received. Of these, 37 responses were eliminated due to either a) containing a large proportion of missing values pertaining to project performance items, or b) pertaining to a project excluded from the geographic scope of the survey (i.e. outside Australia). The remaining 320 responses were considered suitable for inclusion in that they had less than 5% missing values (as stipulated by Tabachinick and Fidell (2001)) with a non-significant Little's MCAR test indicating the missing values were not dependent on other data values (i.e. missing at random) (Little and Rubin 2002). The 320 valid responses constituted an overall response rate of 19.0%, meeting the estimated target response rate.

Participant and Project Characteristics

The survey posed a series of questions to characterize the nature of the respondents and the nature of their most recently completed project to which their subsequent survey responses pertained. The responses to these items are presented in Table 1. Table 1 shows that 86% of nominated projects were completed between 2009 and 2013, and 79% were delivered by using alliance contracts. The majority of the projects were delivered for public sector clients (86%) and clients that were experienced in asset procurement (89%). This is consistent with expectations reported in the literature (Department of Treasury and Finance 2009; Morwood et al. 2008; Scheepbouwer and Humphries 2011). Table 1 shows that 89% of the respondents had been involved in the delivery of at least 1 collaborative project prior to the project they reported on in the survey, with 17% having worked on 10 or more collaborative projects. Responses were approximately equally distributed between representatives of client, contractor and consultant organizations (34%, 34% and 31%, respectively) while sub-contractor and supplier organizations were infrequently represented. Overall, the data in Table 1 indicates that the responses gathered represent a broad cross section of participant organizations and collaborative project types, across a range of sectors, locations, and project values.

[Insert Table 1]

Data Analysis Strategy

Data analysis comprised two stages. In the first stage, both exploratory and confirmatory factor analyses (EFA and CFA) were undertaken to develop reliable and valid measurement scales for the two primary constructs: Project Governance (PG) and Project Performance (PP). The EFA identified the underlying factors of the two constructs, while the CFA confirmed the factorial structures of both constructs. The CFA models of the PG construct addressed hypotheses H2 and H4, and provided statistical evidence to test if formal and informal mechanisms are attributes of Project Governance. Both first- and second- order

CFA models were tested to assess if the underlying formal and informal governance mechanisms derived from the literature were an appropriate fit to the survey data.

In the second stage of data analysis, the measurement scales of the two validated constructs were used to test the relationships proposed by hypotheses H1, H3, H5 and H6. Correlation and regression analyses were used to test the hypothesised relationships between Formal Mechanisms (FM) and PP (H1); Informal Mechanisms (IM) and PP (H3); PG and PP (H5), and the relationship between the FM and IM constructs (H6). The literature suggested that project value in particular may affect the degree of mechanism implementation and subsequent project performance (Kelly 2011; Morwood et al. 2008). 'Project value' was thus included as a control variable in these regression models to assess its impact on the above relationships. The measurement scale of 'project value' is presented in Appendix B. Finally, path analysis was used to confirm the relationships identified by the exploratory approaches. This process resulted in the determination of a refined model that improves upon the conceptual model by identifying alternate relationship pathways between the constructs that are strongly supported by the data.

IBM SPSS 20.0 was used to perform the exploratory analysis (i.e. EFA, correlation and regression analysis). Version 21 of AMOS (Analysis of Moment Structure), a structural equation modeling (SEM) software, was used to perform the confirmatory analysis (i.e. CFA and path analysis).

Results

Confirmation of measurement items and factors

EFA was used to validate and clarify the components of the PG and PP constructs derived from the literature. The EFAs of the PG and PP constructs reported a significant Bartlett test of sphericity. The assessment of Kaiser-Meyer-Olkin measure of sampling adequacy (> 0.6) and the inspection of the anti-image correlation matrix established the factorability of the correlation matrices. Following the advice of Hair et al. (1998: 110), principal component analysis and Varimax rotation were adopted in the EFAs to derive a clear separation of the factors. The cumulative percentage of total variance extracted by the factors in the EFAs were much higher than the proposed threshold of 60% (Hair et al. 1998: 104). The individual items within each construct were considered 'essential' where the analysis assigned a factor loading of 0.50 or above, indicative of statistical significance at the 0.05 level, with a power of 80% within the sample of 320 cases (Hair et al. 1998: 112).

Project Governance (PG)

The conceptual model (Fig. 1) proposed that collaborative projects are managed by formal and informal mechanisms, comprising seven types, designed to improve project performance. All of the 43 mechanism items were input into the EFA to identify the underlying factors in the data structure. As presented in Appendix A, the EFA validated eight factors, rather than the seven mechanisms in Fig.1: 'risk and reward sharing regime (7 items)', 'collective cost estimation (2 items)', 'risk sharing of service providers (2 items)', 'leadership (6 items)', 'team workshops (6 items)', 'relationship manager (2 items)', 'joint communication systems (2 items)', and 'design integration (3 items)'. Thirteen items were removed due to low factor loadings (< 0.50) and cross-loadings. For example, the 'team integration' mechanism of the conceptual model was operationally defined with 5 items. During the EFA, one item was assigned to 'leadership' factor; two items were deleted due to low factor loadings (< 0.50). The factor was renamed as 'relationship manager' since the 2 items left in the factor specifically focus on the functions of relationship manager. In the end, the eight factors comprised the 30 items shown in Appendix A. In the PG scale, they accounted for 68.5% of total variance, and are of good internal reliability (Cronbach's Alpha =

0.87). The EFA results of the PG construct also verified the existence of formal and informal governance as shown in Fig. 1.

Project Performance (PP)

As presented in Appendix A, the EFA identified three factors among the 8 PP items: ‘sustainable operation’ (3 items), ‘innovation and collaboration’ (3 items), and ‘cost and time efficiency’ (2 items). No variable was deleted due to low factor loadings (< 0.50) or cross-loadings. These three factors account for 76.9% of total variance among the included items, with the scale showing overall good internal reliability (Cronbach’s Alpha = 0.86).

Confirmation of construct structure

CFAs were conducted to confirm the factorial structure and validity of the PG and PP constructs, by verifying the nature and strength of the relationships between each construct and their proposed underlying factors. Both first-order and second-order CFA models were tested for the two constructs. Even though in the analysis, the review of the kurtosis values revealed no variable to be substantially kurtotic (i.e. kurtosis value > 7) (Byrne 2010: 103), the assessments on the values of normalized estimate of multivariate kurtosis revealed that the data were slightly multivariate non-normal in the CFAs. Following the advice of Byrne (2010), the bootstrap procedure was performed across 1,000 bootstrap samples to assess the stability of the parameter estimates and goodness-of-fit indices thereby reporting their values with a greater degree of accuracy.

Factorial Structure of Project Governance

The sample size of 320 cases failed to meet the minimum sample size in terms of the ratio of cases to free parameters (10:1) (Kline 2005: 178) for testing total disaggregation CFA models of the PG construct. In view of this fact, the partially aggregated CFA models were tested to confirm the factor level structure. The principal advantage of the partial aggregation model lies in its capacity to reduce the number of parameters to be estimated and to decrease measurement error, particularly when the sample size is relatively small (Bagozzi and Edwards 1998).

The initial first-order CFA model (Model s1) hypothesised a *priori* that responses to the PG construct could be explained by two first-order factors; FM and IM, respectively, as presented in Fig. 2. These two factors in turn were then proposed to be explained by the aggregated manifest variables derived by the EFAs, with the mechanisms' operationally defined based on the conceptual model (Fig. 1). Fig. 2 shows, the factor of FM was explained by the four aggregated manifest variables, of 'risk and reward sharing regime', 'risk sharing of service providers', 'collective cost estimation', and 'design integration.' The factor of IM was explained by four aggregated manifest variables of 'leadership', 'team workshops', 'relationship manager' and 'communication system'. The fit indices of Model s1 are presented in Table 2.

[insert Table 2 and Fig. 2]

Based on the indication of the modification indices, 'design integration' was re-specified as an underlying variable of both FM and IM factors for testing. As presented in Fig. 2, the final first-order CFA model (Model s2) was generated after the removal of the insignificant link (at $p < 0.05$ level) between 'design integration' and FM. Subsequent to the model re-specification, Model s2 presented much better fit indices in comparison with the initial model (Model s1) as presented in Table 2. This finding suggests that according to the opinions of the respondents, 'design integration' is an underlying factor of IM rather than FM. The correlation value between the FM and IM factors in Model s2 is 0.46, which is much lower than the high limit of 0.85. This is evidence for discriminant validity in that the two distinct governance constructs are not highly correlated (Kline 2005: 73). The analysis also presented a sound feasibility of the parameter estimates, which were statistically different from zero at the level of 0.05. The standardized estimates and correlation values of Model s2 are presented in Fig. 2.

Based on the factorial structure of Model s2, the second-order CFA model of the PG construct (Model s3) was tested to further demonstrate the factorial validity of the construct. As presented in Table 2, the fit indices of Model s3 have the same values as those of Model s2, again indicating a good fit to the data. The 99% bias-corrected confidence intervals for both the unstandardized and standardized regression weights indicate that the regression weights are significant at the $p < 0.01$ level. Shown in Appendix A, the standardized estimate of factor loadings based on the original sample are significant at $p < 0.01$ level.

The CFAs confirmed the factorial structures of the PG construct, thereby upholding Hypotheses 2 and 4. The analysis supported that within the empirical context of collaborative infrastructure projects in Australia, formal and informal mechanisms are two attributes of project governance. The valid and reliable measurement scale was used to measure the PG construct, as well as the FM and IM factors in the subsequent analysis for relationship identification.

Factorial Structure of Project Performance

Total disaggregation CFA models of the PP construct were tested to confirm the factorial validity. The construct was first tested by a first-order CFA model (Model s4). The relationships between the performance measurement items and the underlying factors identified by the EFA were postulated a *priori* and then tested by the CFA. The analysis indicated that parameter estimates were of sound feasibility. Modification indices reveal no factor-cross loading or error covariance. The correlation values between the three factors in

Model s4 ranged from 0.47 to 0.76, which are lower than the high limit of 0.85, and indicative of satisfactory discriminant validity (Kline 2005: 73).

Building on the findings of Model s4, a second-order CFA model (Model s5) was tested to further confirm the factorial validity of the PP measurement scale. In the analysis, 99% bias-corrected confidence intervals for both the unstandardized and standardized regression weights indicate that the regression weights are significant at $p < 0.01$ level. The significant ($p < 0.01$) standardized estimates of factor loadings derived based on the original sample are presented in Appendix A. The fit indices of Models s4 and s5 present the same values, which indicate both models fit the data well. In view of the findings, the measurement scales represented by the second-order CFA model are considered of good validity and reliability to measure the project performance of the research population.

The CFA results confirmed that 'cost and time efficiency', 'innovation and collaboration', and 'sustainable operation' are three major aspects of project performance evaluation according to experienced practitioners within the context of collaborative infrastructure projects in Australia. The underlying items of this reliable and valid measurement scale were used to measure PP construct within this empirical context.

Relationship identification within and between constructs

Relationship Exploration

Correlation and regression analyses were employed to explore the relationships between the PG and PP constructs, as well as those between the FM and IM factors and the PP construct. As presented in Table 3, the correlation analysis results indicate significant positive associations ($p < 0.01$) between PG, FM, IM and PP, thereby providing initial support to Hypotheses 1, 3, 5 and 6. The control variable of 'project value' is significantly associated with PG, FM and IM, whilst its association with PP is insignificant at $p < 0.05$ level. The significant correlations provide the basis for undertaking the regression analysis.

[insert Table 3]

The independent variables of the models presented in Table 4 were entered in their respective regression models for testing at the same step. As shown in the left hand side of the table, the Models r1, r2 and r3 are significant at the $p < 0.01$ level, respectively explaining 5.5%, 12.1% and 12.7% of the variance in the PP construct. The results respectively support Hypotheses 1, 3, and 5 in that the measures of the intensity of the implementation of FM, IM and the combined PG were all positively and significantly related to PP. A comparison of the results of Models r1 and r2 also indicated that compared to IM, FM had relatively lesser explanatory power in terms of the proportion of variance accounted for in PP. The comparison between Models r2 and r4 further indicates that FM only explains 0.8% ($p < 0.05$) of the variance of PP in addition to what is already explained by the IM construct. 'Project value' does not provide an additionally significant explanation (at $p < 0.05$) of PP variance in Models r1-4.

[insert Table 4]

As presented in the right hand side of Table 4, the regression Model r5 demonstrates that 'project value' ($p < 0.05$) and FM ($p < 0.01$) significantly explains 19.4% of the variance in IM. The results are indicative of the potential mediating effect of IM on the relationship between FM and PP. The findings of the correlation and regression analyses support that both formal and informal mechanisms, as well as overall project governance, can be used to explain and predict the variance of project performance. Higher implementation intensity of the governance mechanisms is associated with higher project performance, a finding in support of Hypothesis 5. The implementation intensity of informal mechanisms explains and predicts more variance of project performance, than that of formal mechanisms. The findings also imply that formal and informal mechanisms represented by the PG measurement scale play essential positive roles in achieving project performance targets.

Relationship Confirmation

Path models were analyzed to test the potential mediating effect of IM on the relationship between FM and PP. The initial path model was specified with links supported by the results of the regression analysis. The estimation of the initial model identified that the path from FM to PP was not statistically significant (p = 0.11). Hence Model s6 was re-specified without this insignificant link. The standardized regression weights of the re-specified model based on the original sample are presented in Fig. 3. The 95% bias-corrected confidence intervals computed across 1,000 bootstrap samples indicate that both the unstandardized and standardized regression weights in the fitted models are significant at $p <$ 0.05.

By including the significant, however relatively weak (β = 0.11, p = 0.03) impact of ‘project value’ on IM, Model s6 is indicative of a mediocre fit to the data, as presented in Table 2. After removing the impact of ‘project value’, Model s7 (see Fig. 4) shows a very good overall fit. Hence following the procedures suggested by Kenny et al. (1998), the path analysis confirmed that the influence of FM on the PP construct indicated by regression Models r1and r4 (see Table 4) is completely mediated by IM. A Sobel test (p < 0.01) confirmed that IM significantly carries the influence of FM to PP (Sobel 1982; Soper 2013). While Hypothesis 6 was thus supported by the previously established positive association between FM and IM, the relationship of these two factors to PP is more complex. The findings of the path analysis suggest that, within the empirical context, the influence of formal mechanisms on project performance seems indirect, and need to be enabled by conducive informal mechanisms.

[insert Figs. 3 and 4]

Discussion

The analysis validated that both formal and informal mechanisms were perceived by the practitioners to be attributes of collaborative project governance used to manage complex infrastructure projects in Australia. The research has also confirmed the essential mechanisms which define formal and informal governance for collaborative infrastructure projects. Three market mechanisms define formal governance (1) collective cost estimation, (2) risk and reward sharing regime, and (3) risk sharing of service providers; while five social-based hierarchical mechanisms define informal governance (1) leadership, (2) relationship manager, (3) team workshops, (4) joint communication systems, and (5) design integration.

Design integration is normally specified as a formal mechanism in collaborative contractual arrangements. However, given the strength of social-based hierarchical mechanisms, the extent to which 'design integration' is implemented is dependent upon human capital investment. The outcomes of 'design integration' implementation are also largely dependent upon interactions between individual participants, hence are difficult to pre-specify. This appears to be the reason why the respondents perceived 'design integration' to be an informal mechanism in the current study. The validated model therefore shows that formal mechanisms are now comprised entirely of market mechanisms.

The analysis also validated that 'cost and time efficiency', 'innovation and collaboration', and 'sustainable operations' are three major aspects of performance evaluation on collaborative infrastructure projects in Australia and New Zealand. The regression analysis confirmed that the implementation intensity of formal and informal mechanisms as well as that of project governance has a significant positive influence on project performance.

The statistically significant associations of the PG construct, and its underlying FM and IM factors, with the PP construct, are consistent with the relationships proposed by the conceptual model. The findings derived by correlation and regression analysis provide empirical evidence to support the nomological validity of the measurement scale of the PG construct and its factors. In other words, the PG measurement scale demonstrates the relationships asserted in theory. The qauntitative evidence from the infrastructure project delivery context supports arguments about the need of both market and social-based hierarchical mechanisms for collaborative project delivery in the construction management literature. The findings are also in line with the assertions about the governance of complex human and physical capital transactions in the theories of transaction-cost economics and relational contracting.

While both formal and informal mechanisms have positive impacts on performance, the implementation intensity of informal mechanisms is a greater predictor of project performance variance, than that of formal mechanisms. The strength of this finding was unexpected, and certainly supports more extensive use of collaborative delivery systems. Furthermore, the influence of formal mechanisms on project performance was found to be mediated by informal mechanisms. Consistent with recent work examining project governance, the study found that hybrid project governance, which combines both formal and informal mechanisms with both market and hierarchical transactions, is needed to achieve project performance targets. The study advances the frontier of knowledge by identifying and explaining the different roles played by the two types of mechanisms. The findings imply that formal and informal governance are not interchangeable; each has a distinctive role. Thus they rely on each other to maximise project performance.

Using market transactions, formal mechanisms provide a framework for governing depersonalized exchange. This framework facilitates and frames the implementation of informal mechanisms. Conversely, formal mechanisms may only achieve clear and equitable risk allocation, when enabled by the collaborative cognitive context created by social-based hierarchy governance. In other words, the degree to which collaborative contractual incentives affect project performance largely depends on the intensity of informal mechanisms. This finding explains the performance heterogeneity of very similar projects, such as highway projects delivered by the same CPM. The difference lies in the social context created by informal mechanisms. This underscores the importance of strong leadership as well as effective relationship management and team integration in achieving clients' objectives.

Conclusion

This paper has successfully:

- built a conceptual model showing the relationship between governance and performance;
- verified the essential mechanisms which define formal and informal governance for complex infrastructure delivery;
- verified the essential actions that underlie each mechanism;
- verified key performance indicators for collaborative infrastructure projects;
- demonstrated the association between project governance and project performance.

The study found that informal mechanisms (non-contractual conditions) were a greater predictor of project performance than formal mechanisms (contractual conditions). Further, the impact of contractual conditions on project performance is mediated by the non-contractual features of a project. This proves that obligations established under a contract are not sufficient to optimise project performance.

The measurement items provided in Appendix A constitute a valid and reliable instrument for measuring governance and project impact, making them appropriate for use in the scientific community for future empirical research. This new instrument will enable fine-grained research, particularly for testing the performance implications of various combinations of mechanism items within different project contexts. The study also has many practical implications. Client organisations need to shift away from a conventional approach to governance design, which primarily focuses on market mechanisms and specific actions, such as inviting single or multiple team/s to participate in the pricing stage. There is a need to increase emphasis on informal mechanisms, since these are a stronger predictor of performance outcomes. Required actions include making decisions on a ‘best-for-project’ basis, seeking consensus across the supply chain in decision making, and effectively engaging community stakeholders. In addition, a relationship manager with sufficient authority and resources to build and maintain cooperation over the life of the project improves project outcomes. Appendix A shows the specific actions necessary to develop comprehensive workshops, communication systems, and full supply-chain involvement in design. These actions enable fairer risk and reward sharing and a greater degree of collective cost estimation, even when more conventional procurement approaches are used, such as DB.

The results also indicate that construction businesses providing services on projects should emphasize their competence in implementing collaborative governance, which is often overshadowed by firms’ overwhelming emphasis on their technological and contract management capabilities. The governance measurement instrument shown at Appendix A enables firms to evaluate their collaborative abilities, thereby facilitating better positioning strategies. Improved awareness of their collaborative competence will assist firms in lobbying their clients for more informal mechanisms on construction projects.

The statistical generalizability of this research gives it an authority missing from earlier studies based on inductive methods. While the findings are valid and reliable in the Australian setting, replicability studies are required internationally to determine if the relationships observed here hold elsewhere. That being said, if projects were being governed similarly, for a similar range of infrastructure in another developed economy, it is hard to imagine that the results reported here would not hold. Further research is warranted to test this proposition. A limitation of the current research is that it examined only collaborative procurement methods; further research that compared the performance of collaborative with traditional methods would also be useful, particularly if the delayed litigation costs associated with the latter could be taken into account when calculating costs.

Acknowledgements

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Figures

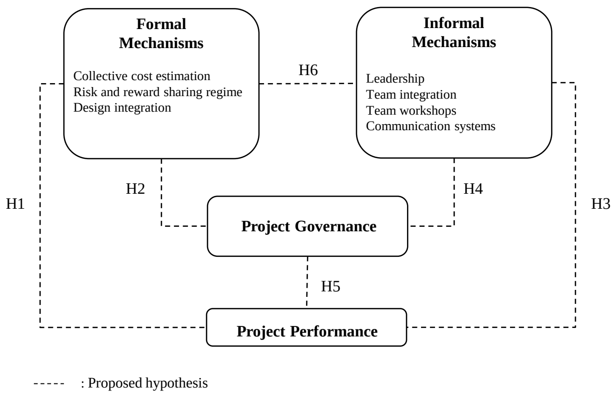

Fig. 1 The conceptual model

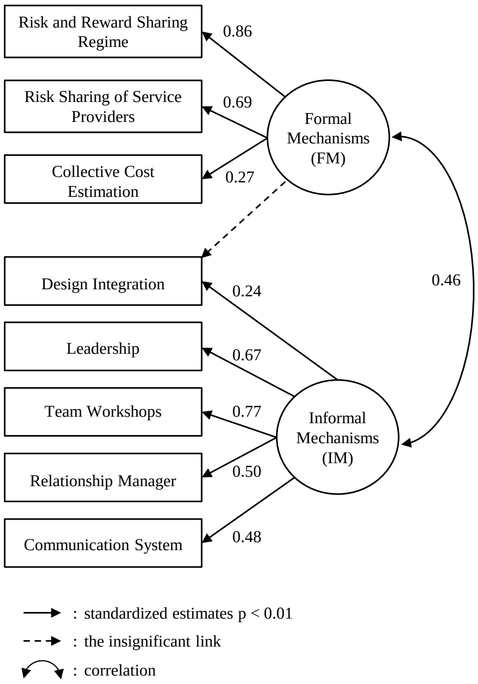

Fig. 2 First order CFA model of contractual governance structures (Model s2)

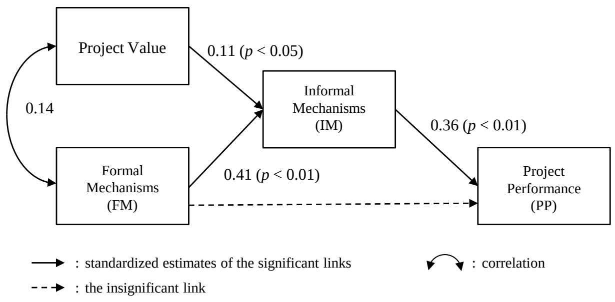

Fig. 3 Fitted path model with 'project scope' (Model s6)

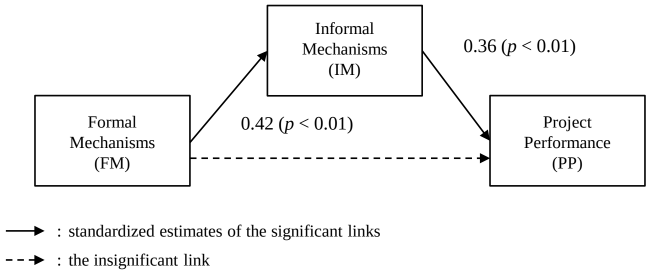

Fig. 4 Fitted path model without ‘project scope’ (Model s7)

Tables

Table 1 Project and respondent characteristics (N=320[a])

	n	%		n	%
Project characteristics					
Type of client			**Project completion time**		
Public sector	276	86.3	2008 and before	12	4.3
Private sector	44	13.8	2009	16	5.8
			2010	44	16
Experience of client in asset procurement			2011	35	12.7
Experienced	285	89.6	2012	113	41.1
Inexperienced	33	10.4	2013	29	10.5
			2014 and after	26	9.4
Type of contract			**Project Sector**		
Project alliance	155	51.8	Road	113	38.0
Program alliance	80	26.8	Water	89	30.0
Early contractor involvement	27	9.0	Rail	52	17.5
Design and construct with collaboration	16	5.4	Energy	14	4.7
Cost plus incentive fee with collaboration	8	2.7	Building	10	3.4
Early tender involvement	8	2.7	Mining	10	3.4
Lump sum with collaboration	4	1.3	Oil & gas	4	1.3
Other contracts with collaboration	1	0.3	Waste management	3	1.0
			Defence	2	0.7
Project Value (m = million)			**Project Location**		
< $5m	7	2.3	NSW	98	30.7
$5m to < $10m	3	1.0	Qld	85	26.6
$10m to < $50m	18	5.9	WA	71	22.3
$50m to < $100m	41	13.5	Vic	43	13.5
$100m to < $500m	142	46.9	NZ	9	2.8
> $500m	92	30.4	SA	8	2.5
			ACT	2	0.6
			NT	2	0.6
			Tas	1	0.3
Respondents characteristics					
Number of collaborative projects the respondent had previously worked on prior to this project:			**Type of organisation you worked for on the collaborative project:**		
0	35	10.9	Client	108	34.3
1	38	11.9	Contractor	106	33.7
2	60	18.8	Consultant	98	31.1
3	42	13.1	Supplier	2	0.6
4	28	8.8	Subcontractor	1	0.3
5	29	9.1			
6	22	6.9			
7	5	1.6			
8	5	1.6			
9	1	0.3			
> 10	55	17.2			

[a] Totals for each variable may not sum to 320 due to non-responses to specific survey items.

Table 2 Fit indices of the CFA and path models

	Value representative of a well-fitting model*	Model s1[a]	Model s2[b] & Model s3[c]	Model s4[d] & Model s5[e]	Model s6[f]	Model s7[g]
Sample adequacy						
Ratio of parameter estimate to sample size	1:10	1:19	1:19	1:17	1:40	1:64
Hoelter's critical N (CN) at 0.05 level	> 200	280	491	232	308	478
Model fit indices						
Chi-square (χ^2)		34.455	23.549	37.968	6.212	2.566
Normed Chi-square: χ^2/ df (df: degree of freedom)	1.0-3.0	1.813	1.239	2.233	3.106	2.566
p (probability level)	> 0.05	.016	.214	.002	.045	.109
Bollen-Stine bootstrap *p (*computed across 1,000 bootstrap samples)	> 0.05	.061	.339	.056	.054	.117
GFI (goodness-of-fit index)	>0.90	.974	.982	.972	.990	.995
AGFI (adjusted goodness-of-fit index)	>0.90	.950	.966	.940	.952	.968
NFI (normed fit index)	>0.90	.926	.950	.968	.949	.976
CFI (comparative fit index)	close to 0.95	.965	.990	.982	.964	.985
RMSEA (root mean square error of approximation)	(<0.05: good fit; 0.080 – 0.10 : mediocre fit; > 0.10: poor fit)	.050	.027	.062	.081	.070

Notes: * Source of references: Byrne (2010), Hair et al. (1998), and Kline (2005).

[a] Model s1: the initial first-order CFA model of the PG construct.

[b] Model s2: the final first-order CFA model of the PG construct.

[c] Model s3: the second-order CFA model of the PG construct.

[d] Model s4: the first-order CFA model of the PP construct.

[e] Model s5: the second-order CFA model of the PP construct.

[f] Model s6: the initial path model including 'project value' testing mediating effect of the IM construct.

[g] Model s7: the final path model excluding 'project value' testing mediating effect of the IM construct.

Table 3 Descriptive statistics and correlations

	Mean	Std	MIN	MAX	1	2	3	4
1. Project value	4.98	1.10	1	7				
2. Formal mechanisms (FM)	4.93	1.20	1.00	7.00	.135*			
3. Informal mechanisms (IM)	5.41	0.91	2.05	7.00	.170**	.425**		
4. Project governance (PG)	5.24	0.86	2.33	6.90	.182**	.794**	.888**	
5. Project performance (PP)	5.14	1.03	1.25	7.00	-.035	.224**	.349**	.348**

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 4 Regression analysis results (standardized coefficients (*β*))

	Effect of PG on PP				Effect of FM on IM
Dependent variable	PP				IM
	Model r1	Model r2	Model r3	Model r4	Model r5
Hypothesis	H1	H3	H5	H1 & H3	H6
Control Variables					
Project value	-.069	-.096	-.103	-.104	.113*
Independent variables					
Formal mechanisms (FM)	.247**			.118*	.416**
Informal mechanisms (IM)		.359**		.309**	
Project governance (PG)			.369**		
R^2	.061	.126	.133	.140	.199
Adjusted R^2	.055	.121	.127	.129	.194
F change	10.041**	22.276**	23.589**	16.347**	38.231**

** Significance at $p < 0.01$ level
* Significance at $p < 0.05$ level

Appendix A

Factorial structure of Project Governance and Project Performance

	EFA factor loadings	Second-order CFA factor loading (standardized estimates, significant at $p < 0.01$)
Factorial structure of Project Governance (PG)		
Factor 1 Formal Mechanisms (FM)		0.91
Factor 1-1 Risk and reward sharing regime		0.91
· Any profit due to cost under-runs that was allocated to the key service providers was shared fairly between the key service providers.	0.81	
· Any share of loss due to cost over-runs that was allocated to the key service providers was shared fairly between the key service providers.	0.81	
· The client and key service providers shared equal proportions of profit due to cost under-runs.	0.78	
· The client and key service providers shared equal proportions of loss due to project overruns.	0.78	
· Each key service provider's overall downside risk was capped at the loss of its fee.	0.72	
· A single agreement was developed to acknowledge that the parties would collectively share project risk.	0.70	
· There were incentive mechanisms to meet project goals.	0.55	
Factor 1-2 Collective cost estimation		0.26
· The client selected only one service provider to participate in the pricing stage.	0.83	
· The client and the key service providers collectively estimated the expected project cost.	0.76	
Factor 1-3 Risk sharing of service providers		0.66
· The key service providers paid a penalty if completion dates were not met.	0.78	
· The key service providers solely carried the risk of rising costs.	0.77	
Factor 2 Informal Mechanisms (IM)		0.49
Factor 2-1 Leadership		0.66
· The project leaders had strong communication skills.	0.86	
· The project leaders had strong logistical skills.	0.83	
· The project leaders made decisions on a ‘best-for-project’ basis.	0.80	
· The project leaders encouraged cooperation between parties.	0.72	
· The project leaders sought consensus across the supply chain in decision making.	0.72	
· The project leaders effectively engaged with community stakeholders.	0.64	
Factor 2-2 Team Workshops		0.77
· Where appropriate, workshops involved all levels of seniority.	0.86	
· Where appropriate, workshops involved a broad range of	0.85	

	EFA factor loadings	Second-order CFA factor loading (standardized estimates, significant at $p < 0.01$)
participant types.		
· Workshops were used for post-review assessment.	0.71	
· Workshops were used for innovation development.	0.67	
· Workshops were used for integration of key service providers.	0.65	
· Workshops were run by an independent facilitator.	0.62	
Factor 2-3 Relationship Manager		0.51
· There was a relationship manager to maintain cooperation over the life of the project.	0.88	
· There was a relationship manager to build cooperation in the early stages of the project.	0.87	
Factor 2-4 Communication System		0.49
· An integrated web-based IT system was established, including Building Information Modelling (BIM).	0.80	
· Communication tools (such as an expectation matrix) were developed to allow participant organisations to align their commitments to each other.	0.71	
Factor 2-5 Design Integration		0.32
· Construction subcontractors were involved in design.	0.84	
· Suppliers were involved in design.	0.78	
· The main contractor was involved in design.	0.70	
Total variance explained (rotation sums of squared loadings)	68.5%	
Cronbach's Alpha (α)	0.87	
Factorial structure of Project Performance (PP)		
Factor 1 Sustainable operation		0.82
· Environment impact	0.86	0.89
· Community impact	0.80	0.83
· Safety	0.79	0.73
Factor 2 Innovation and collaboration		0.93
· Innovation	0.81	0.75
· Team collaboration	0.80	0.74
· Quality of work	0.72	0.78
Factor 3 Cost and time efficiency		0.58
· Cost efficiency	0.89	0.74
· Time efficiency	0.86	0.85
Total variance explained (rotation sums of squared loadings)	76.9%	
Cronbach's Alpha (α)	0.86	

Appendix B Measures of control variable

Project value

1: Project value < $5m;   2: $5m <= Project value < $10m;   3: $10m <= Project value < $50m

4: $50m <= Project value < $100m;   5: $100m <= Project value < $500m; 6: Project value < $500m.

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