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Collaborative Learning to Improve the Governance and Performance of Infrastructure Projects in the Construction Sector

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Abstract: Collaborative learning helps construction organizations adapt their governance structures (GS) to maximize project performance. While previous studies indicate governance directly influences performance, and that learning directly influences performance, there is little deductive evidence exploring the relationship between all three variables, especially at a high level of disaggregation. A conceptual model is developed based on the literature, which defines collaborative learning capability (CLC) as an absorptive capacity construction organizations develop to explore, transform and exploit knowledge through 18 specific learning routines that influence formal and informal governance types and ultimately, three different performance metrics for projects. This study is based on a survey of 320 experienced practitioners on Australian collaborative infrastructure projects in the construction sector. Statistical tests demonstrated the CLC measurement scale developed by the authors is reliable and valid. CLC in this context is found to be based on 18 confirmed individual learning routines, organized into six learning factors and three learning phases. The study confirmed CLC influences project performance through project governance structures. However, the usage intensity of individual learning routines was found to be lacking on Australian collaborative infrastructure projects. The specific and important role of CLC in project performance has been highlighted for the first time, but construction organizations need to invest more heavily in their CLC, through stronger mobilization of individual routines.

Author Keywords: Absorptive capacity; Dynamic capability; Collaborative learning; Learning routines; Collaborative projects; Project governance structures; Project performance; Learning; Procurement; Project management; Organizations; Infrastructure; Australia.

Introduction

This study seeks to explain the performance implications of collaborative learning capability (CLC) through the theoretical lenses of absorptive capacity (Cohen and Levinthal 1990; Zahra and George 2002; Lane et al. 2006; Lewin et al. 2011). The concept of absorptive capacity has emerged from the resource-based view (Barney 1991) and the dynamic capability view (Helfat et al. 2007). According to the resource-based view (Barney 1991) performance heterogeneity between organizations is caused by different resource configurations, in particular, the configuration of knowledge-based resources (Grant 1996). The dynamic capability view (Helfat et al. 2007) further posits superior project performance can be sustained when organizations are capable of keeping an advantageous knowledge configuration over time through organizational learning. In this view, absorptive capacity is defined as a dynamic capability purposely developed by organizations to explore, transform and exploit knowledge from both internal and external sources to achieve superior performance outcomes (Cohen and Levinthal 1990; Zahra and George 2002; Lane et al. 2006; Lewin et al. 2011). The absorptive capacity concept has been successfully used in the past to study innovation and performance heterogeneity on construction projects (Unsal and Taylor 2011; Kraatz and Hampson 2013).

The current study extends that literature by focusing on CLC as a particular type of absorptive capacity, and by looking at its influence on a particular type of project – collaborative infrastructure projects. Effective collaboration is important on infrastructure projects because such projects address large and complex tasks, involving a wide range of construction organizations, including public and private client organizations, as well as construction organizations such as consultants and contractors (Morwood et al. 2008; Love et al. 2010; Walker et al. 2015). While inductive studies in construction management literature acknowledge the importance of learning for collaborative infrastructure delivery (Hartmann et al. 2010; Love et al. 2015), there is little deductive evidence on implications of collaborative learning on project governance and performance. While previous studies indicate governance directly influences performance, and that learning directly influences performance, there is little deductive evidence exploring the relationship between all three variables, especially at a high level of disaggregation. The knowledge gap is important to resolve in an environment of global resource shortages and rising expectations of project delivery efficacy from construction clients.

The current study's focus on collaborative learning supports the lean construction agenda that also seeks to improve project performance. Lean Construction methods focus on continual improvement in production and project management (Ballard and Howell 2003; Dave and Koskela 2009; Zimina et al. 2012). Optimization of such methods requires improved collaboration on projects (Abdelhamid et al. 2008). The current study contributes to this research need.

Collaborative infrastructure projects are defined as infrastructure projects employing collaborative governance structures in their procurement models. Collaborative procurement models, like Alliances, Partnering and Integrated Project Delivery, have been increasingly used to deliver infrastructure projects due to their advantages in managing high levels of complexity and risk during construction, compared to more conventional models, such as Lump Sum (Love et al. 2010; Lahdenperä 2012; El-adaway 2013). The Australian infrastructure sector has applied collaborative procurement models intensively over the past 15 years (Morwood et al. 2008; Kelly 2011; Walker et al. 2015). The form of these models is determined by the GS underpinning them.

Project governance structures contain both formal contractual mechanisms and informal social mechanisms (Rahman and Kumaraswamy 2008; Chen and Manley 2014). Recent research confirms the existence of eight mechanism overall. Formal governance mechanisms comprise 1) collective cost estimation, (2) risk and reward sharing regime, and (3) service provider penalties. Informal mechanisms comprise (1) relationship managers, (2) leadership skills, (3) team workshops, (4) communication systems, and (5) design integration (Chen and Manley 2014).

A survey study design was used to explore the CLC of construction organizations working on Australian collaborative infrastructure projects. To investigate CLC, the authors followed the advice of the absorptive capacity literature to focus on the observable and practiced collaborative learning routines that underpin CLC (Abell et al. 2008; Lewin et al. 2011). Two primary research questions arose from an in-depth literature review:

1. Does CLC directly influence project performance, or indirectly through project governance structures?
2. To what degree are collaborative learning routines used by construction organizations for delivering collaborative projects?

In order to answer the research questions, the study was designed to achieve four research objectives:

1. To conceptualize and operationalize the CLC concept based on an in-depth literature review;
2. To develop a reliable and valid measurement scale for the CLC concept;
3. To clarify whether there is a relationship between CLC, governance and performance;
4. To identify the learning routines that are implemented in collaborative infrastructure projects in Australia, and the extent to which they are used.

The paper first explores the theoretical lens of CLC as an absorptive capacity, and presents a new conceptual model, which hypothesizes the mediating effect of project governance structures on the relationship between CLC and project performance. The deductive research design is introduced. The findings show collaborative learning increases the scope for GS to improve project performance. The measurement scales generated advance the literature on absorptive capacity and can be used by construction organizations as a self-assessment and bench-marking tool to evaluate the extent to which collaborative learning is occurring in their organizations.

Absorptive Capacity

The influential absorptive capacity concept was proposed by Cohen and Levinthal (1990) as an organization's ability to recognize, assimilate and apply new knowledge from an external environment. Zahra and George (2002) later conceptualized absorptive capacity as a dynamic capability, thereby recognizing its capacity to influence the creation and reconfiguration of organizational routines and mechanisms. Lane and Koka (2006) further proposed the three sequential learning phases underpinning absorptive capacity to *explore*, *transform* and *exploit* valuable knowledge outside the organization. More recently these conventional absorptive capacity assertions have been integrated with knowledge management propositions on internal knowledge creation, dissemination and application (Nonaka 1994; Grant 1996; Zollo and Winter 2002). This led to an integrated view of the micro-foundations of absorptive capacity, with learning routines that leverage both external and internal knowledge (Lichtenthaler and Lichtenthaler 2009; Lewin et al. 2011). *Exploratory learning* routines identify, acquire, analyse, and understand critical external knowledge (Zahra and George 2002), and help the members of an organization to externalize knowledge for new knowledge creation (Nonaka 1994; Zollo and Winter 2002). *Transformative learning* routines select, retain, disseminate, and codify both internally generated and externally acquired new knowledge (Lewin et al. 2011). *Exploitative learning* routines integrate newly acquired and generated knowledge into the existing operating routines, so as to refine and extend those existing routines and technologies (Lane et al. 2006).

Learning routines are structured and persistent patterns of learning behavior that characterize organizational reactions to variegated, internal or external stimuli (Zollo and Winter 2002). Learning routines are considered to be organization-specific due to their interdependence, complementarities, and by virtue of developing in conjunction with an organization's unique evolutionary path and internal social governance structures (Lewin et al. 2011). The heterogeneous and imperfectly mobile nature of absorptive capacity enables an organization to sustain advantageous learning, which matches governance mechanisms and business operations to the needs of a changing market more effectively than their competitors (Lichtenthaler and Lichtenthaler 2009). Therefore superior absorptive capacity helps to sustain above average performance in the long run (Lane et al. 2006).

The deductive studies reported by the project management literature have primarily focused on the direct business outcomes of absorptive capacity rather than its governance implications (e.g. Leal-Rodríguez et al. 2014; Popaitoon and Siengthai 2014). Only a very recent study on research and development (R&D) projects looks at this issue, finding a positive association between project management governance and the transformation and exploitation of previously acquired external knowledge (Vicente-Oliva et al. 2015).

Project Governance

Collaborative project governance has been applied to manage non-marketability challenges of infrastructure project transactions (Love et al. 2010; Lahdenperä 2012). GS of collaborative infrastructure projects comprise formal and informal mechanisms to facilitate the negotiation and execution of human and physical capital transactions (Rahman and Kumaraswamy 2012).

Formal mechanisms govern depersonalized exchanges (Chen and Manley 2014). These mechanisms use contractual arrangements, performance measurement and dispute resolution procedures to achieve clear and equitable risk allocation (Morwood et al. 2008; Love et al. 2011). Collaborative procurement models such as Project Alliances facilitate collective cost estimation. During the estimation process, the owner, contractor and designer work together to develop the design, program, and risk allocation model, and to determine the target outturn cost (TOC), i.e.

the expected project completion cost (Love et al. 2011; Love et al. 2014). Under the risk and reward sharing regime any cost under- or over-run against this TOC is split in pre-agreed, specified proportions among the parties (including the owner) (Lahdenperä 2010; Love et al. 2011).

Informal mechanisms govern human capital transactions (Williamson 1979). These mechanisms provide non-contractual stimuli to enhance mutual trust, collaboration and knowledge sharing between the project participants (Love et al. 2010; Lahdenperä 2012). Socially-based hierarchical transactions create a collaborative cognitive context that enable the informal mechanism to achieve its objectives more effectively (Chen and Manley 2014). Collaborative projects require strong leadership with a capacity to make decisions on a 'best-for-project' basis and encourage cooperation between parties. Relationship managers and team workshops are widely used to facilitate open communication and relationships building (Morwood et al. 2008). Co-operative decision making demands an effective application of information systems to support knowledge sharing and organizational alignment (Hauck et al. 2004; Love et al. 2015). During the project development phase, joint design plays an essential role for innovation and project success (Morwood et al. 2008).

It is evident in the literature that learning trajectories of construction organizations with collaborative project delivery could shape their perceptions on the performance implications of different formal and informal mechanisms (Ross 2008; Department of Infrastructure and Transport 2011), thereby influencing their strategies of mechanism deployment (Manley and Chen 2016).

Collaborative Learning Capability and Routines in the Construction Industry

Absorptive capacity can be considered as an important dynamic capability for organizations participating in infrastructure construction (Rose and Manley 2012; Too 2012). Construction sector observers suggest construction organizations leverage collaborative learning with varying degrees of effectiveness (Morwood et al. 2008; Kelly 2011). This observation agrees with the absorptive capacity view that learning routines are unique and imperfectly mobile, potentially providing sustained competitive advantage (Lewin et al. 2011). Nevertheless, there are no previous deductive studies that conceptualize and operationalize the capability of collaborative learning as a type of absorptive capacity within the construction context. Other studies develop specific learning routines for other contexts (e.g. Kale and Singh 2007; Vicente-Oliva et al. 2015), but it is important for construction organizations to understand the nature of effective learning routines in their sector, even if such routines are only imperfectly mobile.

In this study, CLC is conceptualized as an absorptive capacity construction organizations purposefully develop to *explore*, *transform* and *exploit* knowledge about collaborative project delivery both inside and outside their organizational boundaries. The evidence in the construction management literature is reviewed here to develop specific hypothesized learning routines for the three learning phases in the construction context.

The qualitative studies on collaborative project cases revealed the learning of participant organizations not only reconfigures formal governance via contract development (Hartmann et al. 2010), but also improves informal governance such as leadership structure (Love et al. 2015). This evidence of learning causing changes in governance dominates the relevant literature; nevertheless, it is reasonable to expect feedback loops operating in the other direction, with project conditions framing learning capability. Regardless, the current study focusses on the CLC to GS causation given the weight of evidence supporting it. The literature emphasizes the long term impact of learning is its capacity to improve the people, systems and processes of organizations participating on infrastructure projects, so they become more competent in collaborative project delivery (Love et al. 2015; Walker and Lloyd-Walker 2016). The qualitative evidence also shows more intensive *exploratory learning* is carried out in the early stage of the project life cycle in project formation and development; *exploitative learning* becomes more intensive in the operational stage; and *transformative learning* connects and balances knowledge exploration and exploitation (Hartmann et al. 2010; Love et al. 2010).

Exploratory learning enables construction organizations to identify, acquire, analyze, and process new knowledge which is critical for collaborative project delivery. Exploratory learning routines such as meetings are widely used in collaborative projects to enable open communication and to achieve mutual understanding (Chan et al. 2010; Eriksson 2010). A wide range of external advisors are usually engaged in various stages of the collaborative procurement process to leverage new knowledge in the market (Morwood et al. 2008). These learning routines help employees to externalize and articulate their experiences and lessons learnt, and integrate their knowledge with that of external advisors (Love et al. 2015). This knowledge exploration is particularly beneficial for identifying innovations in project formation and development (Love et al. 2010), when a business case is demonstrated and a procurement model is selected (Morwood et al. 2008). In general, the higher degree of uncertainty that is involved in a project, the larger the degree of collaboration required for project governance, demanding more intensive knowledge exploration (Edwards 2009; Lahdenperä 2012). Enhanced exploratory learning helps to select GS that suit specific regional transactional contexts (Hartmann et al. 2010).

Transformative learning enables construction organizations to select, retain, disseminate, and codify new knowledge for project governance improvement. For example, client organizations use formal auditing systems to capture lessons from completed contracts for future contract development (Hartmann et al. 2010), and codify the learning outcomes into public policy documents to provide guidelines for procurement processes (Department of Infrastructure and Transport 2011). Typical examples of transformative learning routines in project delivery processes include project review, performance assessment, bench marking as well as knowledge codification and dissemination (Ballard and Howell 2003; Love et al. 2015). Regular formal project reviews are used to identify mistakes and problems, highlight optimal solutions, and make decisions for action (Ballard and Howell 2003; Abdul-Rahman et al. 2008). Performance assessment examines the efficiency and effectiveness of operating routines in achieving the performance targets and the client's expectations (Morwood et al. 2008; Zimina et al. 2012). Benchmarking and other continuous improvement approaches are often integrated into project performance evaluations in order to disseminate learning more effectively (Love et al. 2010). Best practice and problem solving solutions are often codified into explicit forms such as manuals to guide the improvement of project governance (Love et al. 2015). IT systems are often used to disseminate knowledge within the organization (Dave and Koskela 2009; Love et al. 2010).

Exploitative learning ensures knowledge gained from previous collaborative projects through exploratory and transformative learning can be used to match governance mechanisms with the needs of the present market. For example, internal training is used to internalize and exploit transformed knowledge including technical elements of new contract types, collaborative attitudes and behaviors (Hartmann et al. 2010; Walker and Lloyd-Walker 2011). The training programs usually involve mentoring by staff members who have collaborative contracting experience, and engagement of external facilitators/behavioral consultants to guide knowledge sharing discussions (Morwood et al. 2008; Love et al. 2015). The internalized knowledge helps decision making at the strategic level such as that involved in development of new GS (Hartmann et al. 2010), as well as those at the operational level such as project governance mechanism modification (Leiringer et al. 2009). Knowledge exploitation plays a critical role to test and validate the knowledge gained from previous projects, and generate new knowledge such as more suitable governance for a changing market (Leiringer et al. 2009; Hartmann et al. 2010).

The above discussion reviewed qualitative literature on learning routines in the construction sector generally, and in collaborative infrastructure delivery particularly. This discussion applies to both public and private sector clients and service providers, on the basis that both not-for-profit and for-profit organizations may face and/or initiate changes (Green et al. 2008; Hartmann et al. 2010; Kelly 2011). The discussion leads to the proposed relationships shown in Fig. 1 and two main hypotheses:

Hypothesis 1 (H1): Collaborative learning capability has a direct positive influence on the performance of collaborative infrastructure projects;

Hypothesis 2 (H2): The positive influence of collaborative learning capability on the performance of collaborative infrastructure projects is mediated by project governance structures.

Methods

In order to test the veracity of the model shown in Fig. 1, an in-depth literature review was first undertaken to conceptualize and operationalize the CLC concept. A survey was then designed based on the operational items, and administered in the Australian infrastructure sector. The unit of analysis is a construction project. The survey directly examines project performance, project governance and the role of organisational learning on projects. Keep in mind that the organisations surveyed for this study arrange production around projects. Their primary method of delivering value is through construction projects. The study examines the organisations' project-based learning. Hence, in this instance the organisational and project units of analysis are very closely entwined, making it valid to base analysis on project performance, project governance and organisational learning processes during projects. The survey data was analyzed quantitatively to identify the factorial structure of the CLC concept and to test the hypotheses that propose the relationships between the three key concepts of CLC, GS and project performance (PP). The confirmed CLC measurement scale was used to assess the degree to which CLC is implemented in the Australian infrastructure sector.

The study employs T-tests and ANOVA, as commonly used methods of assessing difference between means, stemming from the influential statistical work of (Fisher 1928). These methods are held in high regard and often employed in current social science literature to check for bias in results and to ensure the soundness of data. These initial tests where employed prior to exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA and CFA are two high quality methods of factor analysis that are frequently employed in the social sciences to reduce large data sets to a smaller number of latent variables (Kline 2005). Ultimately CFA is employed to determine if the data fit the hypothesised model.

Operationalization of CLC

In order to operationalize the CLC concept, an in-depth literature review was conducted to identify the routines underpinning each of the three phases of exploratory, transformative and exploitative learning. A directed content analysis approach (Krippendorff 2004) was used to explore the literature. Well established theories and findings of prior research provided guidance to define the coding categories of learning routines (Krippendorff 2004). The literature review involved two steps.

The first step drew on recent research advances in (1) absorptive capacity (e.g. Zahra and George 2002; Lewin et al. 2011), (2) dynamic capabilities (e.g. Helfat et al. 2007; Teece 2007), (3) knowledge management (e.g. Nonaka 1994; Grant 1996), and (4) strategic alliance management (Kale and Singh 2007; Hoang and Rothaermel 2010). These research works provided a theoretical foundation for CLC. The measurement scales developed by Lichtenthaler (2009) for managing external knowledge, and those developed by Kale and Singh (2007) for managing internal knowledge, provided coding categories to enable the operationalization of the CLC concept.

The second step focused on literature related to the application of CLC in the empirical context of the infrastructure sector, particularly in Australia. The learning practices of both client organizations and construction firms (contractors, suppliers, consultants) were reviewed. The review covered construction management journals, books, government documents, sector reports and guidelines.

The two-step review derived a total of 19 learning routines to operationlize the CLC concept: six routines for the exploratory learning dimension, seven routines for the transformative learing dimension, and six routines for the exploitative learning dimension. These categories are the result of triangulation across four theoretical disciplines, two types of literature (academic and industry), and two author perspectives, where each author undertook independent coding that was later compared and refined. This literature review fufiled research objective 1.

Sampling and Survey Procedures

A quantitative survey was conducted in 2013 to identify the learning routine application, governance and project performance of collaborative infrastructure projects in Australia. The survey was distributed to the contact database of the Alliancing Association of Australasia (AAA), a total sampling frame of 1,688 prospective respondents, including senior construction sector practitioners representing public and private sector clients, contractors, consultants and suppliers. The database is considered to capture the majority of stakeholders with significant experience across all major types of collaborative contracts in Australia. The distribution of collaborative project types covered by the study is shown in Table 1. The sample is considered to be focused on the Australian experience, as the majority of respondents were based in Australia (< 3% based in New Zealand).

Following the advice of Neuman (2003), a pilot study was conducted to evaluate the clarity and relevance of the survey to the target respondents, thus reducing respondent bias, and to ensure the face validity of the measurement variables. Practitioners of collaborative contracting were first invited to test the pilot survey at the 2012 Annual AAA Convention;

formal written feedback was received from eight participants, and additional informal verbal feedback was received from a further 12 participants. Detailed interviews were subsequently conducted with two expert practitioners. Feedback was received from eight academics to improve the functionality of the electronic survey instrument.

The final survey was distributed by email as a link to an online form, and was open for response of a period of 12 weeks. Reminder emails were dispatched throughout this period so as to prompt responses and maximize participation in the study. Following the advice of Neuman (2003) and Lindner et al. (2001) this procedure helped to reduce non-response error. At closure of the survey, 357 responses had been received, of which 37 responses were eliminated for missing values and/or ineligible location. The remaining 320 responses were within the geographic scope and 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 provided an overall response rate of 19%. Applying the sample size estimation formula recommended by Bartlett et al. (2001), this can be shown to be a response rate that will ensure statistical rigor of the data at an alpha level of 0.05 with a 3% margin of error.

The survey elicited the opinion of each respondent about the performance targets achieved and the learning routines and governance mechanisms applied by his/her organization during the completion of a recent or soon to be completed collaborative project with which they had been involved. In the interests of anonymity, respondents were not asked to uniquely identify the projects or organizations they reported on. Therefore, it is probable that the views of some respondents were related to the same projects or organizations. As Australia has seen the delivery of over 500 alliance projects alone (Kelly 2011), it was expected that the sample also covers hundreds of different projects and even larger numbers of organizations that were involved in these projects, given that the respondent group represents all interested stakeholders in the client, contractor and consultant sectors.

One-way between-group analysis of variance (ANOVA) and independent sample t-tests were selected to check for bias, as these methods are universally employed in social science research for this purpose. The tests confirmed there were no significant differences in learning routines, governance and performance due to the variation of any individual organizational or project characteristics, when considered in isolation from the other influencing characteristics. This indicates the data is unlikely to have been biased by multiple responses received in relation to any particular projects or organizations. The analysis confirmed that response bias of this type was minimal (Neuman 2003). Further, t-tests were conducted to check for non-response bias. As is usual, early and late responders were compared to investigate this issue. There were no significant differences found in the mean values of the eight performance indicators. These tests demonstrated non-response error is limited (Lindner et al. 2001).

Table 1 presents selected characteristics of the respondents' organizations and the recently completed projects upon which they reported. All respondents had worked on at least one collaborative project in the past few years. Table one shows that for 89% of the respondents, this was not their first collaborative project, with 17% having worked on 10 or more collaborative projects in their career. Responses were approximately equally distributed between representatives of client, contractor and consultant organizations (34%, 34% and 31%, respectively), while subcontractor and supplier organizations were infrequently represented. Overall, the data in Table 1 indicates the responses were gathered across a broad cross section of participant organizations, collaborative project types, sectors and project values. In line with the previous studies (Manley and Chen 2015; Walker et al. 2015) and industry literature (Morwood et al. 2008; Kelly 2011), the data in Table 1 also suggest that project and program alliances were the primary collaborative contracts adopted by the Australian infrastructure sector at the time of this study. Early contractor involvement as well as design and construct with collaboration are emerging contract types (Love et al. 2014). Other newer contract types include early tender involvement and cost plus incentive fee with collaboration (Kelly 2011; Mignot 2012). The sample structure reflects current market conditions, supporting external validity. Results are reported for collaborative contracts in general. Further details about this survey have been reported in Chen and Manley (2014).

Measures

CLC measurement development methods

The learning routines derived from the literature review for the operationalization of the CLC concept were measured by a 7 point Likert scale (1 = strongly disagree, and 7 = strongly agree) in the survey. As per the survey questions and scale shown in Table 2, the respondents were asked to indicate the extent to which they perceived each learning routine was applied by their respective parent organizations during the collaborative projects they described in the survey. These routines were used to generate the measurement scale for CLC, as discussed further below.

Measures of governance structures (GS) and project performance (PP)

The measurement scales of the GS and PP concepts were developed and verified through structural equation modelling techniques by Chen and Manley (2014). Following that study, the current study identifies two categories of project governance: 1) formal mechanisms; and 2) informal mechanisms. The formal and informal categories are the two first order factors in the structure of the GS measurement scale. The underpinning eight mechanisms become the second order factors in the measurement scale, which themselves are underpinned by 30 action items. Chen and Manley (2014) confirmed 30 action items under eight mechanisms in two categories to operationally define governance structures. The GS measurement scale is defined this way in the current study.

As shown in Table 2, each governance action item is measured in the survey by a 7 point Likert scale (1= Strongly disagree, and 7 = Strongly agree) to enable the respondents to indicate the extent to which the action was applied during the collaborative projects they described. Each first order factor in the measurement scale, and thus the overarching variable of GS, is represented by the mean value of the underlying governance actions.

Following Chen and Manley (2014), the PP measurement scale used in the current survey describes the performance of collaborative infrastructure projects in Australia through eight indicators grouped into three first order factors: (1) time and cost efficiency; (2) innovation, team collaboration, and quality; and (3) environmental and community impact and safety. Survey respondents were asked to indicate the degree to which their respective projects achieved the pre-agreed performance targets across the 8 indicators. As presented in Table 2 a 7 point Likert scale (1= substantially below target; 4 = Target achieved, 7 = substantially above target) was used to facilitate their responses. Each factor in the measurement scale, and thus the overarching variable of PP, is represented by the mean value of the underlying performance indicators.

In the current study, Likert scales were used to provide subjective, self-reported (opinion based) relative measures of project performance and the implementation of learning routines and governance actions. This approach is used ubiquitously in highly regarded studies in the social sciences, including organizational management, and is therefore also considered to be an appropriate approach in the context of this study (e.g. Luo 2007; Hoetker and Mellewigt 2009). In the case of the performance items, Likert scales were used in lieu of access to quantitative project performance data, which is limited due to regulations related to commercial confidentiality associated with infrastructure construction (Department of Treasury and Finance 2009; Eriksson and Westerberg 2011). Subjective measurement scales such as those used here are an acceptable alternative to quantitative scales for organizational performance evaluation (Richard et al. 2009), and have been applied similarly to measure project performance in previous reputable studies on collaborative contracting (Department of Treasury and Finance 2009). Based on the methods suggested by Norman (2010), Bartlett et al. (2001) and Hair et al. (1998), the data measured by Likert Scales in this study was treated as continuous quantitative data, to which quantitative data analysis techniques were applied.

Control variables

In this study, project value and the value of the contract the respondent's organization held in the project were selected as control variables as they have been reported in the Australian collaborative infrastructure literature as being potentially influential in the development of organizational learning capability (Morwood et al. 2008; Kelly 2011). Project value was used to indicate the scope of the project, where reports suggest learning activities are likely to become more intensive when a project is large and complex. The value of the contract was used to indicative the degree of involvement the respondent's organization held in the project they described, where reports suggest a participant organization is likely to conduct more intensive collaborative learning with increasing involvement in the delivery of a project. The measurement scales of the two control variables are present in Table 2.

Analysis

Determining the factorial structure of the CLC measurement scale

EFA was first used to clarify which of the 19 learning routines that were canvassed in the survey were actually implemented sufficiently to contribute significantly to the overall CLC of the Australian infrastructure sector. The EFA also resulted in a preliminary structural analysis of CLC by grouping 'like' learning routines into second order factors. CFA was then conducted to confirm whether the second order factors could be further aggregated into three first order factors representative of the three learning phases of exploratory, transformative and exploitative learning, as proposed in the conceptual model at Fig. 1, based on assertions in the literature. Therefore, the CFA confirmed the factorial structure of the CLC measurement model, thus responding to research objective 2. The CFA was conducted as part of a structural regression (SR) modelling exercise, a type of Structural Equation Modelling (SEM), which concurrently also tested the relationships between the collaborative learning capability (CLC), governance (GS) and project performance concepts (PP). EFA and CFA are commonly employed methods to achieve the purposes outlined above.

Testing the relationship between CLC, GS and PP

The preliminary measurement model of CLC, defined by the second order factors determined in the EFA, was used to conduct an exploratory correlation analysis of the relationship between the three key concepts of CLC, GS and PP. The two control variables of project value and contract value were also included to determine whether they either had a significant relationship with the three key variables, and/or significantly influenced the relationships between the key variables. This gave a preliminary indication of whether there were likely to be significant relationships between the concepts that would warrant more detailed testing. The relationships between the concepts were then confirmed by applying the SR model, thus responding to the hypotheses and research objective 3.

Evaluating the implementation of CLC

The confirmed measurement scale for CLC was used to assess the degree to which CLC and its underlying learning phases and routines were implemented in collaborative projects by the participant construction organizations sampled from the Australian infrastructure sector, thus responding to research objective 4.

Results

Factorial Structure of CLC Measurement Scale

The preliminary measurement scale for CLC that was generated through the EFA analysis was found to be reliable and valid. The statistical significance of the EFA analysis is supported by the following range of indicators. The EFA reported a significant Bartlett test of sphericity. The assessment of the Kaiser-Meyer-Olkin measure of sampling adequacy ($0.91 > 0.60$) 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 EFA to derive a clear separation of the factors. As reported in Table 3, the cumulative percentage of total variance extracted by the factors in the EFA was 74.3%, which is much higher than the 60% minimum threshold of significance proposed by Hair et al. (1998). A Cronbach's alpha (α) value of 0.92 indicates a very good reliability of the scale configuration.

Table 3 presents the results of the EFA. The EFA found 18 of the 19 learning routines that were tested were found to be implemented to a sufficient extent to be confirmed as significant components of the collaborative learning capability that occurs in the Australian infrastructure sector. This is demonstrated by the EFA factor loadings assigned to each learning routine in Table 3, where a factor loading of greater than or equal to 0.50 was considered to be significant at the 0.05 level (α), enabling a power level of 80% with the sample of 320 cases (Hair et al. 1998: 112), also providing evidence of satisfactory convergent validity (Bagozzi and Yi 1988). One exploitative learning routine was removed due to a low factor loading. The 18 confirmed items are shown in Table 3.

Table 3 also shows the final result of the EFA, that the 18 learning routines could be grouped into six second order factors, each capturing three learning routines. The subsequent CFA analysis showed the six second order factors could further be grouped into the three first order factors represented by the three learning phases identified in the literature: exploratory, transformative and exploitative learning. Allocation of the six second order factors to the three first order factors was driven by associations indicated in the literature review, resulting in each first order factor being aligned with two second order factors. This alignment is shown in Table 3. The exploratory learning factors are 'external knowledge exploration' and 'internal knowledge exploration'. The transformative learing factors are 'explict knowledge transformation' and 'tacit knowledge transformation'. The exploitative learning factors are 'knowledge application' and 'knowledge internalisation'.

The CFA generated standardised estimates of factor loadings for each of the six second order factors, demonstrating whether the proposed alignment of first and second order factors was a good fit for the data. The estimates presented in the right hand column of Table 3 were found to be significant at $p < 0.01$, thus confirming the validity of the proposed factorial structure. In this process, a routine that was originally associated with transformative learning was reassigned to an exploitative learning factor to improve the model of "best fit". The factorial loadings produced from the CFA are also shown in the connections between first and second order collaborative learning capability factors in Fig. 2. This confirmation of the factorial structure of CLC constitutes validation of a measurement scale for CLC, fulfilling research objective 2.

Relationship between Learning Capability, Governance and Performance

Exploratory correlation analysis

Correlation analyses were used to explore the relationships between the concepts of CLC, GS and PP, as well as the two control variables. The Pearson correlation coefficient values reported in Table 4 indicate GS is associated with PP, thus reiterating the findings of Chen and Manley (2014). The Pearson values also show CLC is directly associated with GS, as expected based on the literature. This warrants a more detailed confirmatory analysis of this relationship. Both of these associations are significant at $p < 0.01$ level. However, these exploratory results show CLC is not significantly directly associated with PP at the more coarse $p < 0.05$ level. The results of the exploration analysis suggest the influence of the CLC on PP is likely to be mediated by GS.

The results in Table 4 also indicate neither 'project value' nor 'value of the contract the respondent's organization held in the project' are significantly associated with the three key concepts of CLC, GS and PP at the $p < 0.05$ level. The findings suggest the two control variables are unlikely to provide additional explanation of the variance of CLC, GS and PP. This implies the intensity of collaborative learning, the implementation level of collaborative governance and the degree to which pre-agreed performance targets are achieved are not related to project value or the value of the contract held by an organization during a project.

Confirmatory structural regression analysis

A SR model was used to confirm the relationships determined during the correlation analysis. It would have been most statistically robust to use a fully disaggregated SR model, in which each concept in the SR model would have been represented by the full multi-order factorial structure underpinning the measurement model for each concept. However, the sample of 320 cases was not sufficient to meet the required ratio of cases to free parameters (10:1) for a disaggregated model (Kline 2005: 178). Hence, a partially aggregated SR model was used. The principal advantage of a 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). Given that the measurement models for governance and project performance had been validated in prior research (Chen and Manley 2014), only the first order factors of these concepts were included in the SR model. Given the focus of this study on confirming the structure and impact of CLC, both the first and second order factors of CLC were included in the SR model. The components of the SR model are illustrated in Fig. 2.

An initial model was used to test whether there is a direct relationship between CLC and PP (hypothesis 1), as well as between CLC and GS, and between GS and PP simultaneously. A specified (fitted) model was used to test that the relationship between CLC and PP is mediated by GS (hypothesis 2). Fig. 2 shows the two models have very similar structures. The dotted line in Fig. 2 represents the direct connection between CLC and PP which was tested in the initial model, but was removed in the respecified (fitted) model.

The indices in Table 5 indicate both the initial and fitted SR models fit the data well, although the fitted model fits the data slightly better than the initial model. While the ratio of parameter estimate to sample size for both the initial and respecified SR model is slightly lower than the threshold of 1:10 (Kline 2005: 178), the values of Hoelter's critical N (CN) at 0.05 level indicates sufficient sample adequacy for the testing of both models (Byrne 2010). Further, the assessment of the values of normalized estimate of multivariate kurtosis revealed the data were slightly multivariate non-normal in the initial SR model, even though the review of the kurtosis values revealed no variable to be substantially kurtotic (i.e. kurtosis value > 7) (Byrne 2010: 103). 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.

While both models were found to be feasible, the estimation of the initial model identified the path from CLC to PP was not statistically significant ($p = 0.48$). This is consistent with the exploratory correlation analysis that suggested there was no significant direct relationship between CLC and PP. This result of the initial SR model confirms that hypothesis 1 is rejected.

The insignificant link between CLC and PP was removed in the re-specified model. This fitted model confirms the association between CLC and PP is completely mediated by governance, thereby providing support for acceptance of hypothesis 2, in response to research objective 3. The standardized regression weights of the re-specified model based on the original sample are presented in Fig. 2. The 95% bias-corrected confidence intervals computed across 1,000 bootstrap samples indicate both the unstandardized and standardized regression weights in the fitted models are significant at $p < 0.01$. A Sobel test ($p < 0.01$) confirmed GS significantly carries the influence of CLC to PP (Sobel 1982; Soper 2013). Further, the successful fit of the SR model shows the proposed relationship between CLC, governance and performance is supported by the CLC measurement model. Hence, this provides empirical evidence to endorse the nomological validity (Brown et al. 2005) of the CLC measurement scale.

Fig. 2 also shows the squared multiple correlation (SMC) values which indicate proportions of explained variance of endogenous variables in the fitted SR model (Kline 2005: 252). The findings demonstrate the positive influence of collaborative learning is primarily through informal governance mechanisms and the two 'soft' performance factors of (1) innovation, collaboration and quality of work, and (2) environmental and community impact, and safety.

The Extent of Collaborative Learning in the Australian Infrastructure Sector

The CLC measurement scale developed by the study was used to evaluate the extent to which the learning routines of CLC were applied during the projects reported in the survey, thus fulfilling research objective 4. The mean degree of implementation of each learning routine is shown in Table 3, where numbers approaching 7/7 indicate a high degree of implementation, and numbers approaching 1/7 indicate a low degree of implementation. An aggregated mean is also displayed for each of the six factors, and a single aggregated mean value of the overall CLC of the survey respondents. The mean value of CLC overall was 4.54, suggesting collaborative learning in general was conducted by construction organizations in the sample to a 'slight' degree, rather than a 'moderate' or 'high' degree.

There was very little difference in the implementation intensity of the three learning phases, with exploratory and transformative learning having nearly equal mean scores, while exploitative learning was only slightly lower. The last result was driven by the low level of knowledge internalization, mainly attributable to the respondents 'slightly' disagreeing that incentives were used to either (1) encourage use of organizational databases, or (2) encourage information sharing. These two learning routines were embraced the least across the 18 confirmed routines, while at the other end of the spectrum, only one routine was employed more than 'slightly', that being application of new knowledge to projects.

At the level of the six learning factors, the respondents agree five of them are employed in the sector, one of them – knowledge application – slightly more than the others, while the last factor – knowledge internalization – is on average, not employed at all.

Discussion

The study has successfully conceptualized and operationalized the proposed CLC concept. The modelling undertaken resulted in CLC measures of statistical significance and good generalizability. These findings extend the academic frontier in management science by providing, for the first time, insight into the role of collaborative learning in shaping project governance and project performance. The measurement scales are also of great value for project-based businesses in the construction industry to formulate assessable learning strategies.

The fitted SR model shown at Fig. 2 shows significant relationships of varying strengths between the three main concepts (CLC, GS and PP) and measures. The strongest relationships are those associated with the focus of this paper – collaborative learning. The paper makes a very strong theoretical contribution to understanding how collaborative learning can be effectively measured on collaborative infrastructure projects in particular, and on construction projects more generally. The identification of 18 significant, and highly detailed, learning routines provides the backbone for theory building and for enhancement of organizational practice. The strength of their subsequent organization into six second order factors, and finally into the three first order factors illustrates the veracity of the proposed model.

The strength of the relationship between CLC and GS; and between GS and PP; is much less than the strength of relationships between all the factors underpinning the CLC concept. This was expected, given the close association between learning factors, compared to the more distant associations between the CLC, GS and PP concepts (Kline 2005). Even so, it has been demonstrated the three key concepts have a significant impact on each other, as was also expected (Kline 2005: 35). CLC's predictive power on GS ($\beta = 0.39$) was slightly lower than that of GS on PP ($\beta = 0.45$).

The fitted SR model explains the influence of learning on governance and performance of infrastructure projects delivered by collaborative procurement models, such as Alliances, Partnering and Integrated Project Delivery (Eriksson and Nilsson 2008; Asmar et al. 2013). These types of procurement models involve a heavy investment in informal governance (Lahdenperä 2012; Rahman and Kumaraswamy 2012), and demand a high level of learning via collaboration (Love et al. 2015). It is thus not surprising that the model explains a much larger proportion of the variance of informal governance mechanisms (such as communication systems) (SMC=89%), than that of formal governance mechanisms (such as collective cost estimation) (SMC=20%).

Given the newly confirmed role of GS in mediating the relationship between CLC and PP, and the dominance of informal governance mechanisms in explaining variance in GS, it is similarly not surprising that the model explains a very high proportion of variance in the PP factor 'innovation, collaboration and quality of work' (SMC=86%). This is because the measurement items for this PP factor are closely associated with the measurement items for informal governance mechanisms. In the same vein, the model explains a relatively low proportion of variance in the PP factor 'cost and time efficiency' (SMC=21%), reflecting the modest role of formal governance mechanisms in explaining variance in GS. Even so, it is surprising that informal governance mechanisms don't have a bigger impact on cost and time efficiency, given the extent and quality of literature that indicates the existence of a strong relationship (Morwood et al. 2008; Love et al. 2010; Love et al. 2015).

Moving on to consider the impact of specific learning routines on collaborative infrastructure projects in Australia, it must be concluded that survey respondents did not have a high opinion of their organization's learning capability. The mean scores in Table 3 highlight the importance of knowledge application in the sector, yet the value of this activity is undermined by lack of knowledge internalization, with poor incentivization of managers and staff to access databases or otherwise share information.

Table 3 also shows the most embraced routine – application of new knowledge to projects – only resulted in a mean score of 'moderate use'. Yet, this routine is practically a project requirement, in view of the uniqueness of infrastructure projects (Walker et al. 2015). It is thus surprising that respondents didn't use this routine more intensively. A mean score of 'strong' or 'very strong' use might reasonably have been expected.

Conclusions

The study fulfils the four research objectives to clarify the way in which collaborative learning of construction organizations influences project governance and performance. The results support the proposed conceptual model of CLC as an absorptive capacity that is built on learning routines that organizations use to carry out exploratory, transformative and exploitative learning for the delivery of collaborative infrastructure projects.

Theoretical Implications

The study extends the theory building cycle associated with the organizational learning of collaborative infrastructure construction to a deductive phase. For the first time, the governance and performance implications of collaborative learning have been clearly conceptualized from the absorptive capacity perspective and supported via hypothesis testing approaches. The CLC scale acknowledges both external and internal learning should be integrated for measuring an absorptive capacity, as recently asserted by the absorptive capacity literature (Lichtenthaler and Lichtenthaler 2009; Lewin et al. 2011). The findings also reveal that within the infrastructure context, CLC is underpinned by learning routines organized into three factors that (1) explore internal and external knowledge, (2) transform tacit and explicit knowledge, and (3) apply and internalize knowledge. The findings demonstrate the impact of collaborative learning on project performance is indirect, being mediated by its influence on project governance, such that more intensive learning encourages more collaborative governance, which results in higher project performance.

Managerial Implications

The research findings endorse the essential value of collaborative learning for effective governance and maximum performance. Indeed, 18 of the 19 learning routines that were tested were found to be implemented to a sufficient extent to be confirmed as significant components of CLC in the Australian infrastructure sector. Nevertheless the results also show that although learning routines are used, the intensity of their use is sub-optimal. This suggests the importance of organizations understanding the value of learning routines and investing more heavily in them. Further, the learning routines of the CLC measurement scales could be used to develop a survey questionnaire for individual organizations to undertake an internal organization survey.

Descriptive analysis on survey responses can help the organizations to obtain more refined results concerning their particular strengths and weaknesses, in order to identify focal areas and inform strategy improvement.

Research Limitation and Future Studies

The validity and reliability of the research findings can be improved by applying the theory and research process to the infrastructure sectors of other regions/countries. The CLC measurement scales also enable later studies to develop a collaborative learning performance index indicating relative degrees of impact from the learning routines on project governance. It is hoped the index could help to prioritize learning routine deployment. Future study could also adopt a qualitative research approach, e.g. case study, to analyze insightful information within collaborative project contexts. A pattern matching technique (Yin 2007) could be used to validate if learning routines of participant organizations, governance structures, and project performance emerge with patterns which are in line with the relationships identified by this study. Also, sub-contractors and suppliers were poorly represented by the sample of this study, which focused on clients, main contractors and consultants. Future study could reveal the learning behavior of these organizations.

Although this study finds the relationship between collaborative learning, governance and performance is not influenced by project or contractual value, further study could be conducted to identify other project-scope related variables that might influence the relationship. It also seems clear that the links between informal governance of the cost and time efficiency of projects warrant further investigation. Finally, it would be useful for future work to explore how the ideas about dynamic learning presented here could be incorporated into the Lean

Construction concept. The concept currently focuses on efficient production and a stronger focus on dynamic learning may improve its strategic value.

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Supplemental Data

The survey questionnaire is available online in the ASCE Library (www.ascelibrary.org).

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List of Figure Captions

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

Characteristics	n	%
Project Value (m = million)		
< $5m	7	2.3
$5m to < $10m	3	1.0
$10m to < $50m	18	5.9
$50m to < $100m	41	13.5
$100m to < $500m	142	46.9
≥ $500m	92	30.4
Type of contract		
Project alliance	155	51.8
Program alliance	80	26.8
Early contractor involvement	27	9.0
Design and construct with collaboration	16	5.4
Cost plus incentive fee with collaboration	8	2.7
Early tender involvement	8	2.7

Lump sum with collaboration	4	1.3
Other contracts with collaboration	1	0.3
Project Sector		
Road	113	38.0
Water	89	30.0
Rail	52	17.5
Energy	14	4.7
Building	10	3.4
Mining	10	3.4
Oil & gas	4	1.3
Waste management	3	1.0
Defense	2	0.7
Value of the contract held in the project (m = million)[b]		
Contract value < \$500,000	30	9.4
\$500,000 ≤ Contract value < \$2m	25	7.8
\$2m ≤ Contract value < \$5m	15	4.7
\$5m ≤ Contract value < \$10m	13	4.1
\$10m ≤ Contract value < \$50m	61	19.1
\$50m ≤ Contract value < \$100m	45	14.1
\$100m ≤ Contract value < \$500m	82	25.6
Contract value ≥ \$500m	32	10.0
Organization type[b]		
Client	108	34.3
Contractor	106	33.7
Consultant	98	31.1
Supplier	2	0.6
Subcontractor	1	0.3
Number of collaborative projects respondent had previously worked on prior to the reported project[b]		
0	35	10.9
1	38	11.9
2	60	18.8
3	42	13.1
4	28	8.8
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.

[b] The organizations for which respondents worked for when they were on the collaborative projects they addressed in the survey.

Table 2: Structure of survey measurement scales

Variable	**Question statement**[a]	**Scales**
Variables that measure the three key concepts (CLC, GS and PP)		
Learning routines (CLC)	To what extent do these statements on learning apply to your parent organisation during the collaborative project you described earlier?	1 : Strongly disagree; 2 : Moderately disagree; 3 : Disagree slightly; 4 : Neutral; 5 : Agree slightly; 6 : Moderately agree; 7 : Strongly agree.
Governance actions (GS)	Please indicate the extent to which these governance actions apply to the collaborative project you described earlier.	1 : Strongly disagree; 2 : Moderately disagree; 3 : Disagree slightly; 4 : Neutral; 5 : Agree slightly; 6 : Moderately agree; 7 : Strongly agree.
Project performance indicators (PP)	Please indicate the degree to which the collaborative project you described earlier achieved the agreed cost and non-cost performance targets (8 performance indicators considered: time efficiency; cost efficiency; team collaboration; innovation; quality of work; environmental impact; community impact; safety).	1 : Substantially below target; 2 : Moderately below target; 3 : Slightly below target; 4 : Target achieved; 5 : Slightly above target; 6 : Moderately above target; 7 : Substantially above target.
Control variables		
Value of the contract the respondent's organisation held in the project	Value of the contract the respondent's organisation held in the project:	1 : Contract value < $500,000; 2 : $500,000 ≤ Contract value < $2m; 3 : $2m ≤ Contract value < $5m; 4 : $5m ≤ Contract value < $10m; 5 : $10m ≤ Contract value < $50m; 6 : $50m ≤ Contract value < $100m; 7 : $100m ≤ Contract value < $500m; 8 : Contract value ≥ $500m.
Value of the project	Value of the project:	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.

[a] Applied to each of the learning routine or governance actions items, or performance indicators, respectively).

Table 3. Factorial structure of collaborative learning capability measurement scale

Factorial structure of construction organisations' CLC[a]	Mean[c] extent of learning	S.D.	EFA factor loadings ≥0.50 significant at α=0.05	Standardized estimates of the measurement model, significant at $p < 0.01$
Exploratory learning	4.68	1.48		
Factor 1-1 External knowledge exploration	4.88	1.72		0.81
We liaise with external partners to collect information about market developments.	4.89	1.91	0.87	
We liaise with external partners to collect information about technological advancements.	4.95	1.87	0.85	
We liaise with external partners to collect information about staff skill enhancement.	4.81	1.8	0.81	
Factor 1-1 Internal knowledge exploration	4.47	1.61		0.67
We maintain a database of individuals who can help us with collaborative projects.	4.17	1.97	0.75	
We document the development of different types of collaborative governance arrangements.	4.47	1.98	0.72	
We regularly debrief staff on collaborative projects in formal meetings.	4.75	1.88	0.56	
Transformative learning	4.64	1.36		
Factor 2-1 Explicit knowledge transformation	4.58	1.53		0.79
We regularly update guidelines for staff behaviour during collaborative projects.	4.48	1.79	0.77	
We maintain a database of learnings from our collaborative projects.	4.76	1.78	0.71	
Staff regularly use a bench-marking approach in collaborative project review for continuous improvement.	4.50	1.85	0.70	
Factor 2-2 Tacit knowledge transformation	4.70	1.48		0.79
Staff regularly engage in informal information sharing about collaborative projects.	5.00	1.65	0.78	
Staff regularly participate in formal forums, such as meetings, seminars, or retreats, to exchange information about collaborative project implementation.	4.61	1.80	0.76	
Staff with substantial experience in managing collaborative projects are rotated across our key collaborative projects.	4.49	1.86	0.55	
Exploitative learning	4.29	1.16		
Factor 3-1 Knowledge application	5.14	1.35		0.67
In our organisation it is well known who can best exploit new knowledge to collaborative projects.	4.91	1.71	0.84	
We regularly apply new knowledge to collaborative projects.	5.58	1.31	0.78	
We constantly consider how to better exploit the organisation's knowledge base during collaborative projects.	4.95	1.69	0.73	
Factor 3-2 Knowledge internalization	3.45	1.39		0.73
We incentivise managers' use of organisational databases on collaborative project experience.	2.93	1.72	0.72	
Staff incentives are used to encourage information sharing about collaborative projects.[b]	2.85	1.73	0.75	
We use external behavioral coaches to improve staff skills in relation to collaborative project delivery.	4.57	1.95	0.56	
Construction firms' CLC	4.54	1.18		
Reliability				

Total variance explained (rotation sums of squared loadings)	74.30%
Cronbach's Alpha (α)	0.92

a: The item 'Staff regularly attend training programs on collaborative project management' was is deleted by the factor analysis due to low factor loading (< 0.50).

b: The analysis assigned this item to exploitative learning, from its proposed position under transformative learning.

c: The extent to which respondents perceived each learning routine was implemented by their organisation, measured on a scale where 1 = strongly disagree, 4 = neutral, 7 = strongly agree.

Table 4. Exploratory correlation analysis

Parameter	Mean	Std.	Min.	Max.	CLC	GS	PP	Contract Value
1: Collaborative Learning Capability (CLC)	4.54	1.17	1.25	7.00	1			
2: Governance Structures (GS)	5.24	0.86	2.33	6.90	0.285[a]	1		
3: Project Performance (PP)	5.11	1.04	0.78	7.00	0.096	0.364[a]	1	
4: Value of the contract the respondent's organisation held in the project	5.02	2.35	1	8	-0.01	0.091	0.08	1
5: Value of the project	4.80	1.31	1	6	0.10	0.09	-0.02	0.29[a]

a: Correlation is significant at $p < 0.01$ level (2-tailed).

Table 5. Fit indices of the structural regression (SR) models

Parameter	Value representative of a well-fitting model[a]	Initial SR Model	Fitted SR Model
Sample adequacy			
Ratio of parameter estimate to sample size	1:10	1:8	1:9
Hoelter's critical N (CN) at 0.05 level	> 200	358	362
Model fit indices			
Chi-square (χ^2)		48.694	49.203
Normed Chi-square: χ^2/ df (df: degree of freedom)	1.0-3.0	1.249	1.230
p (probability level)	> 0.05	.137	.151
Bollen-Stine bootstrap *p (*computed across 1,000 bootstrap samples)	> 0.05	.283	.308
GFI (goodness-of-fit index)	> 0.90	.974	.974
AGFI (adjusted goodness-of-fit index)	> 0.90	.957	.957
NFI (normed fit index)	> 0.90	.961	.961
CFI (comparative fit index)	close to 0.95	.992	.992
RMSEA (root mean square error of approximation)	< 0.05	.028	.027

[a] Data from Byrne (2010), Hair et al. (1998), and Kline (2005)