

Introducing an innovation promotion model for construction projects

Abstract

Purpose - This research is on investigating and modeling the complex dynamics of innovation enablers in construction projects aiming to develop a framework identifying actions for clients to promote innovation.

Design/methodology/approach – Through a comprehensive literature review, a conceptual model was previously derived to explain the client-driven enablers in promoting innovation. This was tested using the data from 131 Australian construction projects. Statistical analysis was conducted on the data using factor analysis and correlation analysis to test the model, which was validated using the case study approach. The testing and validating aspects are explained in this paper.

Findings – The constructs of the recommended model are idea harnessing; relationship enhancement; incentivization; and project team fitness.

Research limitations/implications - The difficulty of analyzing the complex dynamics happening within projects in relation to innovation has been a barrier to progress research in this area. The introduction of this model would pave the way for researchers to explore this area with ease.

Originality/value – As revealed in the detailed literature review undertaken, this is the first time that a comprehensive study has been conducted to identify client-led innovation enablers for construction projects. The results would benefit industry practitioners to achieve enhanced project outcomes in construction projects through innovation.

Key words construction industry, client, creativity, enablers, incentives, innovation, project level, incentivization, relationship, project manager, project team, organization.

Paper type Research paper

Introduction

There is a significant amount of anecdotal information that suggests innovation is the underpinning driver that leads to enhanced outcomes in different kinds of projects (Duffield & Maghsoudi 2013). Innovation can bring in a number of benefits to construction projects. Summarizing the findings of many researchers, Fernando et al. (2019) produced a list of benefits to construction projects from innovation such as decreased cost, higher quality, health and safety improvements, minimized waste, reduced carbon emissions, additional cost savings in future projects due to gained experience, future collaboration along the supply chain, knowledge transfer to inform future projects, client and end user satisfaction, improved quality of life for local people, increased productivity, competitive advantage, organizational effectiveness, increased organizational commitment, higher organizational motivation, and enhanced corporate image and recognition.

Innovation is turning imagination into practical reality. As there is no limit to human imagination, the benefits from innovation to the construction industry have no limit. Therefore, it is vital to look into how innovation could be used to benefit construction

projects. Unfortunately, the research in this area has not progressed sufficiently to provide necessary guidance to benefit from innovation.

Many researchers have identified this knowledge gap. For example, Brockmann *et al.* (2016) stated that we are lacking knowledge on the details of innovation in construction projects. Ozorhon (2012) commented that much of construction innovation is codeveloped at the project level and most of the literature has focused on investigating innovation at the firm level, and the project level has largely been ignored. This argument was supported by Chen (2014) who added that despite the panoply of studies that use a wide variety of measures to describe innovation outcomes and the input characteristics that affect those outcomes as well as firm performance, most studies focus on firms engaged in innovation and relatively few studies explore projects engaged in innovation.

The situation with regard to innovation research at construction project level can be summed up by the findings of Keegan and Turner (2002), who reported that a review of articles published in the main project management journals (a total of 663 papers) had no mention of innovation as an important topic. Many other researchers supported this claim. For example, Uchitpe *et al.* reported in 2016 of a study conducted to predict the potential research areas that could appear in the foreseeable future of project management research using a quantitative approach. This study utilized different keywords that had been extracted from all publications of a reputed project management journal over a period of five years (i.e. 2009-2013). Innovation was not among the research areas that was found in this study. However, a burst analysis from 2006 to 2012 conducted by Pollack and Adler (2015) to understand more recent developments in project management found that 'Innovation' and 'New Product Development' were among most frequently used keywords when searching for 'Project Management'. They searched keywords of research publications in the ISI and Scopus databases, in response to the search term 'Project Management'. With this finding, they suggested that project management is more recently being viewed as a potential way of driving or managing change and innovation within organizations. However, there was no mention about project level innovation in this research paper either, suggesting that project level innovation in project management area is still not identified as a key focus area.

For the study presented in this paper, over 300 papers (from 1965 to 2019), majority from peer-reviewed journals, were reviewed. The review failed to identify a proper definition for project level innovation, let alone considerable research on the subject area. From the literature review, only 5 papers could be identified as discussing project level innovation directly, indicating that project-level innovation is under-researched. Even these papers concentrated mainly on general factors such as project size and complexity, market conditions, government policies and regulations, most of which are difficult for the clients to manipulate at the project level. There was not a single paper found comprehensively researched client-led enablers that could be implemented to facilitate innovation in construction projects.

This research study was inspired by the importance of innovation within the construction context, the capability of clients to enhance innovative outcomes in construction projects and the motivation to bridge the knowledge gap to progress innovation research at the project level. It envisaged in studying the actions that clients can take to enhance innovative outcomes and simplifying them in order to clearly explain the client-driven innovation process in a construction project. The following were the objectives of the study:

1. To develop a model using identified categories as constructs that encapsulates their relationship with innovative outcomes and their uncovered relationships with each

other, which can be used to describe the complex dynamics related to innovation in construction projects;

2. To empirically-test the model using the data from construction projects; and
3. To validate the developed model through case studies of selected construction projects.

To achieve these objectives, the authors used the previously identified conceptual model and the framework which described innovation enablers applicable to construction projects. They were described in the paper published by Fernando *et al.* (2019). More information including the comprehensive literature review undertaken to derive the model can also be found in Fernando (2019).

The present research was undertaken following the steps outlined below.

1. Developing and conducting a questionnaire survey (primary data collection);
2. Undertaking a statistical analysis on the data to test the model; and
3. Validating the model using the case study approach.

The above steps are discussed in detail in the following sections.

Conceptual framework and the model

This section will discuss how the conceptual framework was developed leading to the derivation of a model. Before proceeding much into this project level research, it is necessary to provide a definition to construction innovation at the project level in order to have clarity and a common understanding of this subject area.

Defining project level innovation

The comprehensive literature review undertaken for the study failed to identify a suitable definition. Therefore, it was considered necessary to develop a new definition for project level innovation. An intensive process was applied for this purpose including the preparation of a list of construction innovation related definitions, identification of attributes considered necessary to describe innovation, proposing a definition and testing with ten industry experts. The following was the accepted definition after undergoing the procedure mentioned above:

“With respect to projects, innovation can be regarded as the application of ideas for new or improved products (including materials, plant and equipment), software, technologies, methods, practices and systems designed to benefit the project”.

As this definition is on projects in general and has nothing to do with construction projects, it was tested with eleven project managers from industries such as mining, mineral processing, oil and gas, information technology, steel manufacturing, and power. All agreed that the definition was applicable to their projects, confirming that the definition can be used to describe project level innovation in general.

Having arrived at a definition to describe project level innovation, the conceptual framework, which was identified using the literature review is explained next.

Conceptual framework

After undertaking a comprehensive literature review and obtaining industry expert input, Fernando *et al.* (2019) identified a simple framework to describe client-led innovation enablers at the project level in the context of construction projects.

The framework developed consisted of the following categories of client-led innovation enablers: (1) idea harnessing (strategies that can be used for the generation of new and beneficial ideas and implementing them) ; (2) relationship enhancement (actions that can be used to improve relationship between parties engaged in the project); (3) incentivization (the types of incentives/ rewards that can be provided to promote innovative activities); and (4) project team fitness (deliberate actions that can be taken to strengthen the project team and improve its capability to focus on innovative activities). They are briefly explained below.

Idea harnessing

Idea harnessing is the group of actions that client can take to generate and implement new and beneficial ideas. It includes the use of idea generation tools (such as brainstorming, scenario planning, risk assessment planning, life cycle costing, value engineering and value management) and techniques (such as engaging suppliers earlier on, following new research in the field of work, using inputs from experienced personnel, key stakeholders, contractors, suppliers and fellow staff and workers, using best practices and using captured project learnings from completed projects).

Relationship enhancement

No innovation could be achieved in an adversarial environment. Relationship enhancement is employing actions to improve relationship within the project team and between parties to the project such as contractors, consultants and suppliers. This includes implementing strategies such as partnering and alliancing.

Incentivization

Research shows that innovative activities in a project could be enhanced by encouraging and providing incentives or rewards. They could also be monetary (such as payments to contractors and to other key suppliers if they undertake innovative activities) or non-monetary (such as giving future contracts to innovative contractors). Incentives could be given to individuals and to teams and they could be from the client's team as well as from parties contributing to the project.

Project team fitness

All the actions mentioned above may not work unless the client's team is capable and focused on enhancing innovation. The actions clients can take to increase the capability of the team are categorized under project team fitness. They include:

1. Creating a capable project team by appointing suitable team members and develop the team to undertake activities to enhance innovation performance.
2. Establishing a strong supportive environment for the project team to undertake innovative activities.

Such strategies help the client's project team to understand the concept of innovation better and how to facilitate the same, to encourage and motivate the team to facilitate innovation and to obtain the support and facilities from the client organization to deal with innovative activities.

The conceptual model

The identification of client-led innovation enabler categories mentioned in the previous section paved the way to derive a conceptual model to describe the innovation process in a

construction project. The categories are represented as constructs in the model, shown in Figure 1.

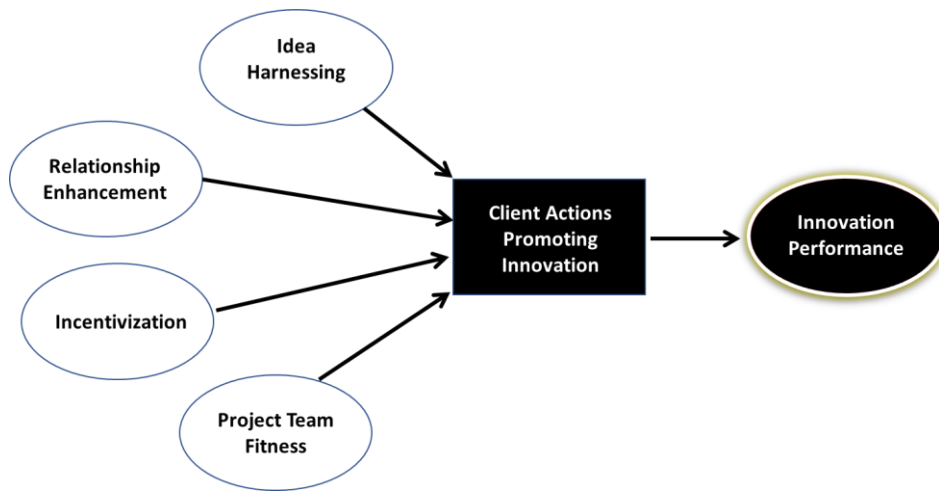


Figure 1. Conceptual model.

The model portrays idea harnessing, relationship enhancement, incentivization and project team fitness as independent constructs, having an influence on innovation performance as the dependent construct. Increased efforts into these independent constructs increase innovation performance. Independent constructs are also interrelated with one another promoting each other. This paper describes the research undertaken to test this model and validate the same.

Model testing

Questionnaire survey

The questionnaire requested participants to provide details of one of their recent construction projects, which they considered innovative. It had the following parts: (1) details of the selected project; (2) performance of client-led enablers with respect to the innovative performance of the project; and (3) background information about the participants and their organizations.

Project information (Part 1) requested information of the project such as the main engineering area, delivery type, cost and the complexity. The questions related to client-led enabler categories requested in Part 2 were under the following categories: idea harnessing (Group A), relationship enhancing (Group B), incentivization (Group C) and project team fitness (Group D). This section also included the participant's perception of the project's innovative performance (Group E).

The last section (Part 3) consisted of questions related to the background of participants and their organisations such as gender, level of education, age group, professional experience, main engineering area of the organisation, occupation and type of the organisation.

The questionnaire was developed using the following:

- Findings from a comprehensive review of literature;
- Questionnaire items used in previous similar research; and
- The suggestions provided by industry experts through interviews.

The questionnaire was distributed to over 300 construction industry practitioners by post and through emails. They were identified through an online search engine and included all engineering statutory bodies at federal, state and local government levels (example: road authorities, city councils), construction companies, other engineering service suppliers such as consultants, designers, and geotechnical service providers. In total, 131 valid responses were received, representing about 44% effective response rate.

The data collected were statistically analysed using factor analysis and correlation analysis, the details of which are given in subsequent sections.

Factor analysis

According to Bhattacharjee (2012), among competing explanations that sufficiently explain the observed evidence, the simplest theory (i.e., one that uses the smallest number of variables or makes the fewest assumptions) is the best and therefore, a theory should be simplified and generalizable explanations of reality. The questionnaire used in this research had 62 variables under the groups of idea harnessing, relationship enhancement, incentivization and project team fitness. It was necessary to reduce the variables to arrive at a simple theory. This was done by subjecting the variables through a factor analysis. As stated by Yong and Pearce (2013), the broad purpose of factor analysis is to summarize data so that relationships and patterns can be easily interpreted and understood. It is normally used to regroup variables into a limited set of clusters based on shared variance.

The data set to be statistically analysed using factor analysis consisted of 5-point Likert scale ("strongly agree", "agree", "neutral", "disagree", "strongly disagree") variables. Before conducting the factor analysis, data were subjected to missing data analysis and the analysis of outliers, which reduced the initial 131 set of data to 115. Initial screening using histograms and Shapiro Wilk tests confirmed that variables generally did not follow a normal distribution.

An analysis of scale reliability was performed to ensure that the set of measurement scales consistently and accurately captured the meaning of the model constructs, which consisted of examining internal consistency and item-total correlations. The internal consistency, measured using Cronbach's Alpha, was 0.952, much above the recommended minimum value of 0.70 (Gennarelli and Goodman, 2013). An item-total correlation test was performed to check if any item in the set of data was inconsistent with the average behaviour of the others, and thus can be discarded. There was one item with a value less than 0.30 as recommended by Field (2013), which was dropped from further analysis.

The other guidelines, which were followed during the analysis, are briefly mentioned below.

- The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was to be above 0.50 and the Bartlett's Test of Sphericity was to be significant ($p < .05$) (Williams *et al.*, 2010).
- The lower level for the test for communalities was taken as 0.2 (Yong and Pearce, 2013).
- Used the Principal Axis Factor for extracting factors (Yong and Pearce, 2013).
- Both Eigenvalues and Scree Plots were used to determine the number of factors to be extracted with Eigenvalues greater than 1 (Field, 2013).
- The factorability in the correlation matrix was limited to 0.3 (Williams *et al.*, 2010).
- Oblique rotational method was used for rotation (Williams *et al.*, 2010) with the rotation technique of Promax (Yong and Pearce, 2013).
- Factor loadings were kept above 0.3 (Hair *et al.*, 2006).

- Minimum number of items per factor was taken as three (Costello and Osborne, 2009).

Taking into consideration of the above, the factor analysis was undertaken using the SPSS Version 23. The analysis was performed separately for independent variables (i.e., those came under idea harnessing, relationship enhancing, incentivization and project team fitness) and dependent variables coming under innovative performance. Several iterations were performed to achieve a set of factors, which could be described in practical terms.

Factor analysis results

Independent variables

Independent variables coming under idea harnessing, relationship enhancing, incentivization and project team fitness, initially had 44 variables. These were reduced to 41 after removing crossloaded variables and variables with factor loadings less than 0.3, under 8 separate factors named as project team attributes, support to the project team, nature of relationship, project team member attributes, internal recognition, client organization, designers and contractors and incentivization. The factors derived for independent variables are given in Table I together with their assigned names and factor loadings.

Factor Name	Variables under factors	Factor loading
Project team attributes	2D4.2 Felt free to talk	0.765
	2D4.1 All were treated equally	0.725
	2D4.4 No difficulty in forming teams	0.716
	2D4.3 Ideas became team ideas	0.715
	2D1.4 PM made quick decisions	0.683
	2D1.5 PM protected the team	0.614
	2D3.2 Project team members motivated	0.500
	2D4.5 No blame game	0.442
	2D1.1 PM sought out, encouraged and promoted new ideas/ technology/ processes	0.423
	2A2.1 We used inputs from experienced personnel	0.349
	2A2.4 We captured project learnings	0.319
	2A2.3 We followed new research	0.297
Support to the project team	2D2.1 Project team was provided with training to improve team skills	0.923
	2D2.2 Project team was provided with training to improve knowledge	0.876
	2D2.4 Project team had opportunities to be exposed to best national and international practices	0.756
	2D2.3 Project team had opportunities to be exposed to others	0.636
	2D2.5 Project team was provided with training to implementers	0.526
Nature of relationship	2B2.2 Had conducive culture within teams	0.937
	2B2.4 Had excellent relationships with other teams	0.861
	2B2.1 Respected each other teams	0.715
	2B2.3 Had good relationships with key stakeholders	0.669
Project team member attributes	2D3.4 Project team members had considerable knowledge and experience	0.881
	2D3.6 Project team members had strong relationships with customers	0.650

	2D3.3 Project team members diverse persons	0.636
	2D3.1 Project team members helpful	0.496
	2D3.5 Project team members had exposure to innovation	0.471
	2D3.7 Project team members considered innovation as a day-to-day duty	0.314
Internal recognition	2C1.2 We recognized idea implementers	0.799
	2C1.1 We recognized idea generators	0.710
	2A2.6 We had implementers to help idea generators	0.422
	2D1.3 PM earned respect	0.413
Client organization	2D5.2 Client organization relaxed technical regulations/ specifications	0.619
	2D5.1 Client organization supported innovative activities	0.612
	2D5.3 Client organization had characteristics of an innovative organization	0.506
Designers and contractors selection	2C1.6 Selecting designers and contractors - used innovation history	0.859
	2C1.5 Selecting designers and contractors - used innovative proposals	0.835
	2C1.7 Selecting designers and contractors - used innovation performance	0.307
Incentivization	2C1.4 Rewarded with personal incentives	0.649
	2C1.3 Rewarded with financial incentives	0.548
	2C1.9 Selected contract types such as alliances	0.500
	2C1.8 Included contract clauses to share savings	0.467

Table I. Factor analysis results for independent variables

Dependent variables

Dependent variables coming under innovative performance, initially had 18 variables. These were reduced to 14, after removing crossloaded variables and variables with less than 0.3 factor loadings, under 3 separate factors named as project outcomes, project recognition and project usage. The factors derived for dependent variables are given in Table II together with assigned names and factor loadings.

Factor Name	Variables under factors	Factor loading
Project outcomes	2E2.3 Project outcome: Sustainable outcomes and reduced waste	0.858
	2E2.1 Project outcome: Operational goals	0.819
	2E2.4 Project outcome: Satisfied project team	0.788
	2E2.2 Project outcome: Satisfied customers	0.732
	2E2.5 Project outcome: Increased productivity and competitive advantage	0.582
	2E2.6 Project outcome: Positive organizational and professional learning	0.471
Project recognition	2E3.3 Highly commended in the media	0.812
	2E3.1 Project personnel received internal recognition	0.807
	2E3.4 External recognition in professional bodies	0.790
	2E3.2 Project received internal recognition	0.788

Project usage	2E1.4 We used improved advanced business or procurement techniques, processes and systems	0.794
	2E1.2 We used improved materials, products, plant, and equipment	0.738
	2E1.3 We used improved computer software/ hardware, models and communication systems	0.650
	2E1.1 We used improved technologies, methods and practices	0.562

Table II. Factor analysis results for dependent variables

Having derived the factors that formed the constructs of the model, it was necessary to find their relationships. Correlation analysis was used to assess the relationship of each construct with innovation performance and the relationship with each other/ which is discussed in the next section.

Correlation Analysis

Associations between variables were analysed using correlation, which is based on covariance. As Field (2013) explained, covariance is a good measurement to assess whether two variables are related to each other. A positive covariance indicates that as one variable deviates from the mean, the other variable deviates in the same direction. On the other hand, a negative covariance indicates that as one variable deviates from the mean, the other variable deviates in the opposite direction. Correlation analysis uses the correlation coefficient to assess the relationship between variables.

Correlation is measured by the correlation coefficient, which represents the strength of the putative linear association between the variables in question. It is a dimensionless quantity that takes a value in the range -1 to +1. A correlation coefficient of zero indicates that no linear relationship exists between two continuous variables, and a correlation coefficient of -1 or +1 indicates a perfect linear relationship (Mukaka, 2012).

There are different correlation coefficients to handle the special characteristics of variables. Most popular correlation coefficients are the Pearson's correlation coefficient, the Spearman's rank correlation coefficient and the Kendall's tau correlation coefficient (Chok, 2010). Pearson's is calculated if the two variables are continuous and at least one is distributed normally. Spearman's rank correlation coefficient would be calculated if neither variable was distributed normally or if one of the variables was discrete (Sedgwick, 2012). The Kendall's tau can be used to assess and test correlations between non-interval scaled ordinal variables. It is considered to be equivalent to the Spearman rank correlation coefficient (Bolboaca and Jäntschi, 2006). Both Spearman's rank correlation coefficient and the Kendall's tau correlation coefficient were used in this analysis as the data were not normally distributed.

When discussing correlation, it is important to discuss partial correlation as well. If the need is in finding whether or to what extent there is a numerical relationship between two variables of interest, using their correlation coefficient will give misleading results if there is another, confounding, variable that is numerically related to both variables of interest. This misleading information can be avoided by computing the partial correlation coefficient. Partial correlation is the correlation of one variable with another, controlling for a third or additional variables (Asuero *et al.*, 2006). In probability theory and statistics, partial

correlation measures the degree of association between two random variables, with the effect of a set of controlling random variables removed.

When interpreting the values of Spearman's correlation coefficient and Kendall's tau obtained in the analysis, the approach taken by Kumar *et al.* (2018) was adopted. In their research in the medical area using the Spearman's correlation coefficient (r), they adopted the convention as given in Table III.

Degree of association	Value of 'r'
Strong	1- 0.7
Moderate	0.7- 0.5
Low	0.5- 0.3

Table III. Spearman's Correlation Coefficient Classification

One of the requirements for using the Spearman's and Kendall's Correlation tests is that the underlying relationship should be monotonic (Chok, N.S., 2010), which was checked through the observation of scatter plots. All the scatter plots showed a linear relationship between each pair of variables.

Correlation analysis results

Spearman's Correlation Coefficient test results are shown in Table IV.

	Project team attributes	Support to the project team	Nature of relationship	Project team member attributes	Internal recognition	Client organisation	Designers & contractors selection	Incentivisation	Innovation performance
Project team attributes	1.000	.335	.467	.513	.495	.425	.437	.322	.593
Support to the project team	.335	1.000	.244	.292	.423	.391	.363	.489	.359
Nature of relationship	.467	.244	1.000	.348	.386	.333	.320	.198	.324
Project team member attributes	.513	.292	.348	1.000	.356	.446	.385	.361	.529
Internal recognition	.495	.423	.386	.356	1.000	.475	.442	.418	.410
Client organisation	.425	.391	.333	.446	.475	1.000	.478	.501	.527
Designers & contractors selection	.437	.363	.320	.385	.442	.478	1.000	.462	.461
Incentivisation	.322	.489	.198	.361	.418	.501	.462	1.000	.429
Innovation performance	.593	.359	.324	.529	.410	.527	.461	.429	1.000
Correlation Coefficient (r) strength									
	moderate (r between 0.7 and 0.5)								
	low (r between 0.5 and 0.3)								
	very low (r up to 0.3)								

Table IV. Spearman's Correlation Coefficient test results

Correlation analysis using the Spearman's Correlation test revealed the following:

1. The significance (p) value of all the correlation coefficients were <0.05 , rejecting the null hypothesis that there was no association between the variables in the underlying population. This means that all the variables were correlated to each other.
2. All the correlation coefficients were positive indicating a positive association between variables.
3. All Bootstrap 95% upper and lower confidence levels were positive, indicating further the associations were in positive territory.

4. Most coefficients can be considered as low (up to 0.5), but there were a few with moderate values (between 0.5 and 0.7).

Kendall's Correlation test results showed the following:

1. The significance (p) value of all the correlation coefficients were <0.05 , rejecting the null hypothesis that there was no association between the variables in the underlying population. This means that all the variables were correlated to each other.
2. All the correlation coefficients were positive indicating a positive association between variables.
3. All Bootstrap 95% upper and lower confidence levels were positive, indicating further the associations are in positive territory.

One notable difference between Spearman's and Kendall's test results was that the correlation coefficients produced in Kendall's test were low in value, none exceeding 0.5.

Partial correlation was analysed using the Spearman's correlation coefficient. As the SPSS software has no readily available procedure to perform partial correlation for nonparametric data, the analysis was done by coding script into the SPSS Syntax Editor.

The results of the partial correlation analysis revealed the following:

- Only project team attributes, project team member attributes and client organization characteristics showed significant partial correlations with innovation performance.
- The project team attributes variable showed the strongest association (correlation coefficient of 0.593).
- The associations of project team member attributes and client organization characteristics were somewhat similar (correlation coefficients of 0.529 and 0.527 respectively).
- All significant associations were positive.

The findings of the factor analysis and the correlation analysis produced an empirical model as shown in Figure 2. The dotted arrows connecting each construct and innovation performance indicate that each construct is correlated to each other and they each are correlated with innovation performance. The black arrows starting from project team attributes, project team member attributes and client organization and ending up with innovation promotion indicate that these three constructs have correlation with innovation promotion irrespective of others (as revealed by partial correlation analysis).

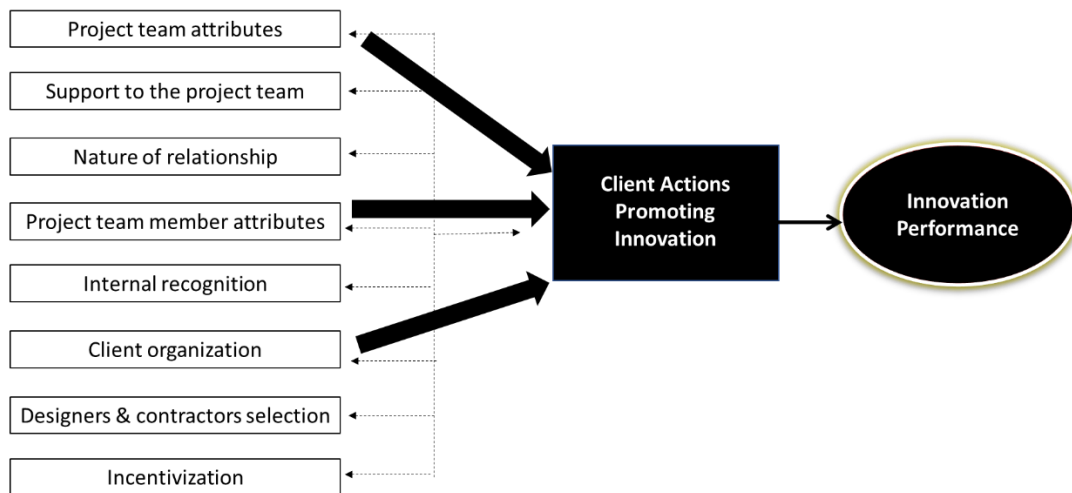


Figure 2. Empirical model

It can be seen that the statistical analysis produced the empirical model that is slightly different from the conceptual model. Instead of four constructs in the conceptual model the empirical model produced 8 constructs, seemingly different in interpretation.

Model validation

The approach selected to validate the conceptual model was the case study method. As explained by Rowley (2002), a case study is an empirical inquiry that investigates a contemporary phenomena within its real life context, especially when the boundaries between phenomenon and context are not clearly evident.

Case studies provided the best research validation method for this study due to the following reasons:

- The research was focussed on how clients could promote innovation in construction projects and why some client actions promote innovation. Case studies is the preferred way of exploring research questions involving 'how' and 'why' or 'who' (Crowe *et al.*, 2011).
- In innovation research, it is difficult to have a practical control of factors and to assess their impact on innovation due to the complex and unique nature of construction projects and the innovation process. As stated by Schell (1992), case study approach is preferred when there is no practical form of control of the events or phenomenon and if there is a high likelihood of focus on contemporary events.
- As noted by Asuero *et al.* (2006), a measure of statistical relationship, such as a correlation coefficient, should never be used to deduce a causal connection and the ideas on causation must come from the practical world, outside statistics. Case studies give the opportunity to test the findings in a real world situation.

The information sources for case studies can be either single or multiple. Single sources of information provide a holistic overview of the phenomena, while multiple sources allow for the use of methodological triangulation (Schell, 1992). The more cases that can be marshalled to establish or refute a theory, the more robust are the research outcomes (Rowley, 2002). The multiple sources approach was used in this research.

Data collection

Semi-structured interviews have the ability to facilitate an in-depth inquiry into the issues (Kulatunga *et al.*, 2011). Therefore, semi-structured interviews were used as the main method of data collection. The interview process used in the research followed the approach used by Kulatunga *et al.* (2011), where the interviews were kept open ended to the maximum possible extent to allow the interviewees to feel free to express their views. The interviews centred on the theme “why those things happened”. However, at the same time, care also was taken not to restrict new themes or concepts from emerging. At least two persons were interviewed for each case. This process enabled to understand issues from at least two distinctive perspectives as well as to triangulate findings to arrive at firm findings. All the interview transcripts were audio tape-recorded and manually transcribed.

Case study selection

Case study selection was done to cover a wide spread of areas such as the following:

- Large and small (cost wise) projects;
- Different delivery types such as traditional, Design and Build, PPP; and
- Different types of clients such as public and private.

All case studies were from Australia. The following were the case studies considered:

1. Construction of a large hospital building. Cost around Aus \$2 Billion. Significant innovations included: being one of the first billion dollar health projects in Australia where Building Information Modelling (BIM) was applied so extensively, including the collaborative use of dRofus (Room database software linked to the 3D model) to its full extent; innovative renewable and energy efficient infrastructure, which used an innovative twin duct system; buildings constructed from non-toxic materials and is considered to be a ‘healthy’ hospital, offering fresh air and natural light.
2. Major rehabilitation of a bridge. Cost around Aus \$30 Million. Significant innovations included: new methods to clean the joints and bearings and a new jacking system used for the first time in the organization. A new material was used for friction plates for the first time in bridges in Australia.
3. Construction of a bikeway. Cost around Aus \$750, 000. Significant innovations included: innovative construction methods to protect the roots of pine hoop trees, making a bridge with fibre composite material, using ground penetrating radar for finding out the root locations of hoop pine trees, all for the first time in the organization.
4. Major intersection upgrade. Cost around Aus \$300 Million. Significant innovations included: an effective way of staging of work, increase of bypass height considered not possible by designers due to terrain posed restrictions.

The level of innovativeness was determined after considering the following factors:

- The novelty of innovations developed;
- The number of innovations developed; and
- The impact from innovations.

These three factors were in line with the 14 variables used in the questionnaire part, which were grouped into project outcomes, project recognition and project usage. The impact from innovations was measured using project outcomes (example, increased productivity and competitive advantage) and project usage (example, use of improved technologies, methods and practices). The novelty of innovations developed was measured using project recognition (example, project receiving internal recognition). As the innovativeness of

projects was assessed (and not the innovativeness of individual innovations) it was necessary to consider the number of innovations developed as well.

For example, the case study on the construction of a large hospital building had the following innovations:

- One of the first billion dollar health projects in Australia where Building Information System (BIM) was applied extensively.
- Included the collaborative use of dRofus (Room database software linked to the 3D model) to its full extent.
- Introduced an innovative renewable and energy efficient infrastructure, which used an innovative twin duct system.
- Buildings were constructed from non-toxic materials and was considered to be a 'healthy' hospital, offering fresh air and natural light.

Some of these were novel innovations and all had positive impacts on productivity and environment and contributed to considerable savings. Therefore, this building construction was considered as highly innovative.

Case study results

Table V shows the performance of each construct of the conceptual model (i.e., idea harnessing, relationship enhancement, incentivization and project team fitness) for each case study.

Project details	Idea harnessing	Relationship enhancement	Incentivization	Project team fitness
<p>1 Construction of a large hospital building.</p> <p>Project cost very high (Aus \$ 2 Billion).</p> <p>This is a PPP project.</p> <p>Highly innovative.</p>	<p>Very strong in idea harnessing. A large number of idea harnessing techniques were used and strategies adopted.</p>	<p>No formal relationship enhancement agreements. However, it is evident that all parties had strong relationships with each other. Most of the client's project team members have worked previously with the contractor's project management team, establishing good relationships. As the client team and the contractor's team represented one organization helped closer bonding of team members.</p>	<p>Past innovation history has been considered when appointing the designer. No personal or financial incentives provided. However, it is evident that there was a strong desire to do best work by each team member. Challenges due to constraints also provided motivation for innovations.</p>	<p>Technically competent, highly experienced project team members drawn from different areas of the organization to represent the contractor's team.</p> <p>Very effective, strong, technically competent project manager who encouraged innovation.</p> <p>Innovative parent organization.</p>
<p>2 Major rehabilitation of a bridge.</p> <p>Project cost low to moderate - around Aus \$30 Million.</p>	<p>Brainstorming and learnings from past projects were heavily used. Operational level staff contributed mostly with novel ideas.</p>	<p>Strong relationship between the client's and contractors' teams was evident. Both teams coming from the same organization would have contributed to the strong relationship.</p>	<p>Challenges due to constraints and the need to show excellence by the contractor provided motivations for innovations.</p>	<p>Technically competent, highly experienced project team of the contractor.</p> <p>Very effective, strong, technically competent project manager who</p>

Cost plus project. Significantly innovative.				encouraged innovation. Moderately innovative parent organization.
3 Construction of a bikeway. Project cost low around Aus \$750, 000. Design and build project. Moderately innovative.	Project team investigated solutions to the constraints imposed on the project. Small project team.	Fairly strong relationship between the client's and contractors' teams was evident. However, the project team consisted of members from two competing state organizations, therefore, were not close enough in relationships due to inter-organizational rivalry.	Challenges due to constraints provided motivations for innovation. No other incentives were provided.	Less experienced project manager with average skills and moderately innovative client organization.
4 Major intersection upgrade. Project cost moderate to high - around Aus \$300 Million. Significantly innovative. Double ECI contract.	Most of idea harnessing techniques and strategies adopted. The nature of Double ECI contract contributed to generating beneficial ideas, especially because the client bought the design of the unsuccessful bidder.	This was a collaborative contract with strong relationship between parties initially. However, when the contract company was bought over by another company, the relationship became poor. All parties working in the same building helped building fairly good relationships.	The motivation to win the contract provided incentive to the bidding parties to look for innovative solutions.	Very effective, strong, technically competent project manager who encouraged innovation. Moderately innovative client organization.

Table V. The performance of conceptual model constructs

From the Table V a trend can be seen that more idea harnessing efforts are contributing to better innovative outcomes. It can be seen that good relations existed in all cases between parties. As all four cases were innovative in varying degrees, it can be argued that good relationships contributed to innovative performance. It is also to be noted that the least innovative case (Case 3) had a low performance in terms of relationship (the project team consisted of members from two competing state organizations, therefore, were not close enough in relationships due to inter-organizational rivalry). It is also apparent that Australian construction clients offer little or no monetary or personal incentives for innovation. The innovations happening in these projects could be attributed mostly to the desire of the project team to overcome challenges and to the self-satisfaction of team members of doing best of their abilities. However, the two most innovative projects had some incentives. In the most innovative project, the past innovation history has been considered when appointing the designer, conveying the message that innovation is important and could be considered when selecting designers for future projects. The next most innovative project used a competitive bidding strategy, which provided incentives to the bidding parties to look for innovative solutions for winning the contract. It can be seen that the project team fitness was very high in the most innovative case (Case 1) and not so high in the least innovative case of Case 3 (lowest performance when compared to others). This indicated that higher project team fitness resulted in higher innovation performance, especially with the increased effectiveness of the project manager.

Therefore, it is apparent that with increased performance of constructs (i.e., idea harnessing, relationship enhancement, incentivization and project team fitness), the innovation performance of the project gets better.

These results validate the conceptual model in promoting innovation in construction projects by clients, where it was shown that the constructs of idea harnessing, relationship enhancement, incentivization and project team fitness contribute to innovation performance. However, this validation technique could not be used to assess the inter-relationship between constructs.

Empirical model related findings

The same case studies were used to assess the innovative performance in relation to the empirical model constructs, namely; project team attributes, support to the project team, nature of relationship, project team member attributes, internal recognition, client organization, designers and contractors selection and incentivization. The findings clearly showed that each construct promoted innovation performance.

Due to space limitation, the details on the validation of the empirical model are not given here. However, they can be found in Fernando (2019).

Discussion

This research was focussed on testing and validating a previously developed conceptual model to describe innovation enablers in construction projects. The analysis of survey data collected from projects in Australia using factor analysis and correlation analysis led to develop an empirical model. The constructs belonging to the empirical model are given in Table 1. The left column gives the name of the construct and the right column gives the list of variables containing under each construct. Each variable has a number containing one of the following letters before the description: A, B, C and D. These letters denote the groups of constructs they belonged to in the conceptual model, i.e. idea harnessing (Group A), relationship enhancing (Group B), incentivization (Group C) and project team fitness (Group D).

By examining the Table 1 it can be seen that 'Project team attributes' has items from Group A (idea harnessing) and D (project team fitness). Other constructs also have variables from the conceptual model. These relationships are shown in Figure 3. 'Relationships between the variables belonging to both models'.

It can be seen that all the constructs of the conceptual model, i.e. idea harnessing, relationship enhancement, incentivization and project team fitness, which were identified during the literature review, were included in the constructs belonging to the empirical model. This shows that although looked different, the empirical model was a manifestation of the conceptual model. It provides evidence that although the conceptual model was developed with world-wide research findings, it is a valid representation of the current Australian construction industry and can be used to represent the actual phenomena prevalent in the practical world.

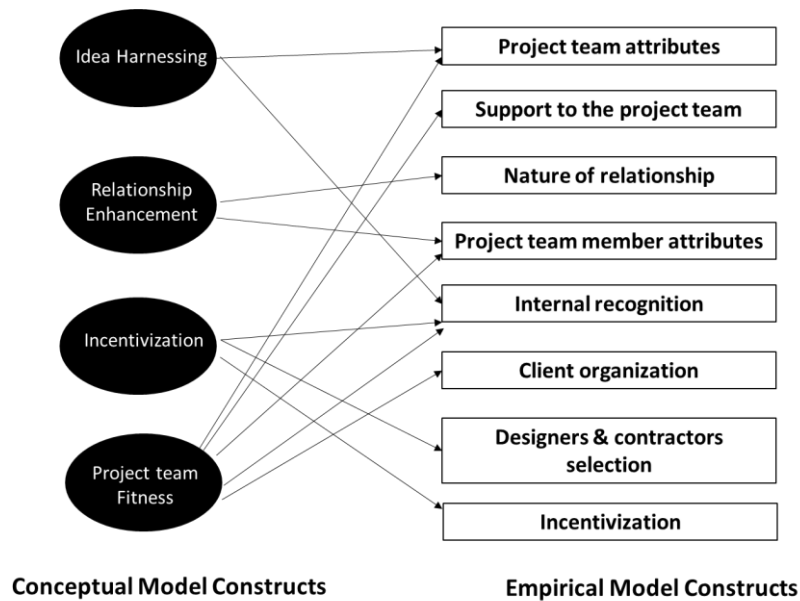


Figure 3. Relationships between the variables belonging to both models

Due to its limitations, the validation method, i.e. the case study approach, could not assess the inter-relationship among constructs for both models. Validating these relationships will help to improve the academic understanding of the innovation process happening at the project level in construction projects. However, it will not be of much use for practical purposes, where the requirement is to find a model to describe innovation enabler categories that promote innovation for the use of clients.

As we have not been able to validate the inter-relationship among constructs, we present the model in Figure 1 as our recommended model.

Conclusions

This research was conducted to fill a significant knowledge gap that existed in the area of construction innovation at the project level. Complexity of factors that contributed to innovation at the project level in construction has been a barrier to progress with comprehensive research in this area. As Ozorhon (2012) pointed out, the project level innovation has largely been ignored due to the difficulties in monitoring the different activities conducted by different parties in each stage of a construction project. The fact that no two projects are identical to each other has exacerbated this difficulty. This study provided theoretical and empirical evidence that help to unravel the complex relationships of client-led factors that contribute to promote innovation in construction projects. For the first time, the research was able to find a simple way of categorizing the complex activities happening in construction projects due to the actions of clients that help promoting innovation and derive a simple model that can be used by clients interested in promoting innovation.

In this research, the client-led innovation enablers were categorized under four major areas, i.e. idea harnessing, relationship enhancement, incentivization and project team fitness. As the model had only these four constructs, which are self-explanatory, the model can be considered as simple, uncomplicated, and easy to understand by clients. In addition, the innovation enablers identified can be implemented by clients themselves without seeking external assistance from the policy makers such as federal, state and local governments or industry players such as professional organizations.

The research findings have the potential to uplift the current knowledge in this area in different ways.

- One of the main findings of the study is that idea harnessing influences innovative outcomes. Although this finding is not new in the broader context of innovation, the authors are of the opinion that this is the first time that its applicability in the construction project level has been proven with empirical evidence. Now it is possible to invest effort to identify idea harnessing techniques and processes at the project level to promote innovation.
- Although not proven in the construction project level context, industry practitioners have been using contractual processes such as partnering and contract types such as alliances to enhance relationship between parties. With this proven validity of the strong association between enhanced relationship within parties to a construction project resulting in higher innovative outcomes, more focus can now be given to find better practices that enhance relationships in the construction world.
- The influence of incentivization on innovative outcomes is another crucial finding with significant ramifications. As revealed in the research, many practitioners in the construction industry in Australia have failed to utilize this valuable approach to promote innovation in construction projects. However, the importance of incentivization to promote innovative performance in projects is highlighted in innovation literature by many scholars including Dulaimi et al. (2002), Eriksson et al. (2007), Ibrahim et al. (2017), Love et al. (2010), Tawiah and Russel (2008) and Winch (1998). The findings in relation to this category of innovation enablers has provided the spotlight on the need to focus more on utilizing incentivization for enhanced innovative outcomes.
- The other finding that project team fitness influences innovation in construction projects is also accepted in the construction industry although not proven previously in the project level context. Many factors contribute to build a capable project team driving innovation in construction projects. The appointment of a technically competent, highly skilled project manager and the parent organization taking actions to be more innovative are two outstanding factors that came out prominently in the research, which future researchers may concentrate their efforts to expand the knowledge further.

If the research findings are used by clients to promote innovation in construction projects, they can achieve significant benefits.

In addition to presenting a model to identify innovation enablers for construction projects, this research also introduced a definition for project level innovation which will help to have clarity and a common understanding of this subject area.

With the use of innovation as a tool in construction projects as introduced here, we strongly believe that the success rate of construction projects will start improving substantially.

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