A MODEL TO ASSESS THE IMPACT OF INNOVATION ACTIVITY ON PROJECT PERFORMANCE IN CONSULTING ENGINEERING FIRMS

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Submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy

Civil Engineering & Built Environment School
Science & Engineering Faculty, Queensland University of Technology
2015

Keywords

Keywords: innovation, project performance, knowledge-based firm, measures consulting engineering firms, innovation activities, impact, Global Financial Crisis (GFC), Delphi study.

Abstract

Innovation in most knowledge-based firms, especially in consulting engineering firms, is used on an adhoc basis by senior managers to leverage competitive edge without understanding the concept and how it is applied to organisations.

Although the body of literature on innovation is extensive, to gain a greater understanding of it in the service sector, more empirical research needs to be undertaken (Oke, 2002). In spite of the availability of 25 years of innovation literature, the service sector, especially consulting engineering firms, have received minimal attention from academics or practitioners. Hayes (2005) also points out that there is a lack of holistic studies on innovation and creativity in the consulting engineering context. Hayes attributes this to engineers being too focussed on design detail and being dull and unimaginative. This has also been identified by a number of researchers in the past. It is also important to mention the research from project-based firms in this context. Keegan and Turner (2002) note that there is scarcity of innovation in project-based firms. They have pointed out the reluctance of managers to develop innovations within business projects. A holistic consideration of innovation and associated activities are still very new to consulting engineering firms, where human resources (full time and part time employees) are of utmost importance as they represent knowledge. These firms use knowledge to gain a competitive edge. Furthermore, most of the researchers (Fagerberg, 2008; Chow, 2007; Davila et al 2006) have concentrated on organisation performance whereas projects are microcosms of an organisation and in most cases seen as contributing significantly to an organisation's performance. The main focus of this research is the interrelationship between innovation activities and project performance. Consult Australia (2014) identifies some of the impacts of the current market downturn which in turn emphasises the need for consulting firms to invest in innovation. In response to the above needs, the aim of this research is to develop a model that uses a structured and systematic approach to assess the impact of innovation activity on project performance for consulting engineering firms.

A comprehensive literature review is carried out beginning with Schumpeter's work on innovation and entrepreneurship and concludes with a review of innovative ideas developed from the current body of literature. Innovation activities that impact project successes were identified from the literature review. It was established that innovation activity is a function of a number of themes each of which in turn comprises a number of sub-activities or independent variables. Project success factors were also identified from the literature. It was identified that project success is a function of subjective and objective measures. This review assisted in exploring, establishing an understanding and answering a number of research questions. The review guided by the questions became the basis of establishing the proposition. A conceptual model interlinking the above variables was developed and mainly based on the rationale provided by the literature review. However, in order to make the model represent the reality it was further augmented by feedback from industry experts directly or indirectly associated with consulting engineering firms. A Delphi study was undertaken to validate the model. The study comprised of three rounds and helped test the proposition. It was established that Innovation activity in consulting engineering firms is a function of R&D activities, staff related activities, communication activities on projects, introducing innovative systems, and client related activities. Each of these are in turn are spilt into sub – activities. It was also shown that these activities have a direct positive impact on project performance. The relative impact was based on the rankings of the prioritised model. A final feedback and workshop was held with the experts to present and discuss the results from the previous Delphi iterations. There was no additional information or contrary opinion forthcoming from this feedback session and the findings from the Delphi process were confirmed.

This research will benefit both industry and academia. The final prioritised decision making innovation model can be used by consulting engineering firms to make an informed decision in investing in appropriate innovation activities that positively impact project performance. This will help in using an informed approach towards investing rather than a 'hit-and-miss' trialling. The application of innovation to consulting engineering is still under researched. The intellectual property produced by this research will also help in it being used as lessons learnt by other researchers to expand the subject matter to other domains. It can be used to inform future research and academic learning and teaching programs. This research will also be an important benchmark extended to Queensland Government departments to inform some of their policy, procurement and delivery models where the focus on prioritisation in innovation is growing.

Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: QUT Verified Signature

Date: October 2015

Acknowledgements

A special thank you to my supervisors Stephen Kajewski and Vaughan Coffey for their constant encouragement, mentorship and giving me the final push to complete this long and hard journey. Their feedback has been important in improving the quality of this thesis.

Also, another special thank you to my wife Laila, son Abdullah and daughter Zarmina. They supported me throughout and gave me the motivation to keep going. Without their support, I would not have been able to complete the thesis.

Finally, I will also like to dedicate this study to my father (late) and mother who have worked hard to raise and educate me which helped me to prosper well in my life. My father would have been proud to see me complete this thesis.

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Chapter 1: Introduction

The 2008 Global Financial Crisis which is still continuing has brought many project cancellations and limited new project opportunities. The impacts of the GFC were felt much later in Australia in 2012 onwards. This impact of the global event was further complicated by recent mining taxes and reduced investment into mining and major infrastructure projects in Australia which was mainly caused by several government changes and re-structures. All of this has significantly impacted large consulting engineering firms who are looking at reducing their overheads to make them more competitive in this tight market. Most of the larger infrastructure projects especially mining and oil and gas projects are at the tail end of their completion and there is a lack of planning and resources to identify a stronger and more sustainable pipeline of projects going forward. A recent report by Consult Australia (2013) which was based on a survey undertaken on the services industry identifies the impact of the downturn on consulting engineering firms:

- Over 60% of consulting engineering firms which were surveyed at that time have reduced in size by an average of 30% in the last 12 months. This included smaller and bigger consulting practices.
- There has been 1,000 staff made redundant in the past 12 months and there are more expected in the coming months. This number has increased since then. Some of the organisations who have a global presence have sent people away on long term and short term assignments to deliver projects elsewhere in their offices across the world.
- 70% of staff reductions are directly attributable to redundancies with the remainder made up by natural attrition, and interstate and overseas transfers.

Baark (1999) notes that usually engineering consultancies face a market that is volatile and tends to fluctuate with cycles of growth and stagnation. It is also driven by the extent of public capital spending on infrastructure such as large infrastructure, resources, transportation projects or environmental facilities. The market is characterized by fee competition even though the industry is intellectual and technology based. One way to overcome this fee driven market is to develop innovative solutions that provide better value for money option for clients. To minimise the impact of market fluctuations on consulting engineering firms, there is a recent and growing need for introducing sustainable, holistic, structured and integrated decision making tools that can inform consulting engineering firms to invest in innovation activities that best suit their business and will have a most positive impact on their project performance. The lingering financial downturn puts a growing impetus on consulting engineering firms to expedite the development and implementation of such tools. This is also consistent with suggestions from Chakrabarti et al (2007) who note that 'Economic shocks are valuable contexts for research, serving as natural experiments for testing the boundary conditions of various associations'.

Huse et al. (2005) suggests that innovation appears to be the only way for an organisation to convert change into opportunities and success. This is also in line with the requirements of the Australian federal government recommendations made after reviewing the national innovation system. Cutler (2008) who carried out the review proposed that the government should assist firms in developing metrics, performance indicators and mechanisms for collecting and sharing data. The report from this review recommends advancement in innovation in areas such as strengthening people skills, business, excellence in national research information and market design. The report concludes that innovation activities either project or organisational specific are a measure of innovativeness.

The economic down turn has also resulted in a client driven market. Clients are dictating terms and consulting engineering firms are being forced to reduce their profit margins. Procurement for public and private projects is only cost driven and very little consideration is being given to a quality based criteria to select designers. It is a 'loose-loose' situation for all relevant players as it impacts clients, consulting firms and their staff. Clients are not getting the quality product they expect. Employees of the consulting firms are losing their jobs. Consulting engineering firms are losing the intellectual property retained by their staff. Some of them are moving towards redundancies to reduce their overheads. (Consult Australia, 2013). The need is therefore to develop and implement a structured, holistic, integrated and rigorous framework that can help organisations efficiently and effectively deal with external and internal changes. This research project is being undertaken to service this need specifically for consulting engineering firms. This will allow consulting engineering firms to focus and prioritise their investment into high potential innovation opportunities rather than wasting time and effort on non-viable pursuits.

1.1 RESEARCH AIMS AND OBJECTIVES

The proposed research is expected to generate new knowledge specifically relevant to consulting engineering firms. There has been a lot of work done on innovation activity and its impact on organisational performance in the manufacturing sector (Dess at al, 2003, Zahra 1993, Cutler 2008). The current financial crunch has resulted in an urgent need to develop a systematic structured assessment model that can be implemented consistently throughout an organisation (Cutler's, 2008). For consulting engineering firms, the main hubs of revenue are their projects so it is important that these assessment models are extended to projects. In some consulting firms there are existing tools but senior managers are not educated and informed to use them appropriately. In other organisations the emphasis is only one or selective aspects of innovation used on an 'adhoc' basis. To deal with the current constraints associated with slowing down of the market, there is an urgent need to assist consulting engineering firms through the use of innovative, consistent and decision making tools that have been developed through a rigorous research process. The aspiration is to have this model consider risks while identifying areas of opportunity and improvement that can be used as guidance by organisations into investing into lucrative innovation activities. (Consult Australia, 2013).

Recapping the main objective of this research, it is to develop a model that identifies and assesses the impact of innovation activity on project performance. The conceptual model will also assist the decision makers in an organisation to select and implement only those innovation activities that have a more positive impact on project performance. It will also help them dig deeper into looking at the individual innovation activities and give them an opportunity to benchmark it to their competitors. The lessons learnt from the benchmarking can be used to feedback into improving innovation activities that directly impact project performance. Some of the underlying objectives of this research study are to understand:

- Consulting engineering firms and their differences or similarities with knowledge-based firms.
- Innovation and innovation activities in the context of knowledge-based firms in general and consulting engineering in particular.

1.2 SIGNIFICANCE OF THIS RESEARCH

It is envisaged that the outcomes of this research will assist in improving project performance through the implementation of appropriate and relevant innovation activities in consulting engineering firms. There will be an opportunity to re-invest the savings and associated benefits due to improved project performance. Thus the model acts as a continuous improvement cycle to re-invest the benefits realised from its implementation. It is anticipated that this concept will be comparatively more useful to developing engineering firms where innovation activities and their implementation are still in the infancy stages. But it equally useful for established consultants who can use the model to benchmark their innovation activities. The model will not only be useful to reform the internal organisational policies and systems but also available to be offered to client as a commercial consulting service. Organisations benefiting from the implementing of this model will have more levy and available funding to invest into their in-house executive education or training models and research partnerships with high profile tertiary institutions. This will give them profile and opportunities to further develop areas of research that are tailored to and enhance their core business activity.

Some of the other expected benefits from the implementation of the innovation model are:

- The model considers a more holistic view of innovation and captures the innovation related activities associated with stakeholder involved in a project environment i.e. clients, internal organisational team members and project team members. It also encapsulates innovation activities associated with technology, use of process and tools and research and development. This is a major shift from the work of previous researchers on innovation which only considered innovation as a cost cutting activity.

- The people related innovation activities such as investment into staff development that have a positive impact on project performance will assist in increasing employee commitment and in turn influences staff turnover.
- Client focussed innovation activities will help in identifying market and client sector focussed strategies which in turn will help in generating new business and also improve the probability of repeat business and project opportunities.
- Improving systems and processes and technical excellence will drive efficiency in delivery projects and also pursuing clients.
- Improving communication strategy across multiple external stakeholders and design team members will positively impact all the above outcomes. The need is to also implement communication channels that support the weaving of innovation through the fabric of the organisation.

Due to the paucity of research specifically relevant to consulting engineering firms, future researchers can build on the outcomes of this research and explore the following areas:

- This research focusses on the impact of innovation on project performance for consulting engineering firms only. There might be interest from clients, and contractors to extend the model to their organisations and understand the similarities and differences.
- The model might also have variations if it is extended to a program or portfolio of projects. This will be particularly interest Queensland Government who have multiple and complex programs and portfolio and might want to understand the innovation activities that can be put in place across multiple programs and portfolio of projects.
- To further explore the impact of external contingency factors such as changing governments (political uncertainty), and financial market conditions.

A detailed discussion on future research and activities is presented in Section 5.4.

1.3 RESEARCH PROBLEM

A growing number of researchers have found innovation and entrepreneurship as important driving factors for firm survival and performance (Dess et al, 2003, Zahra 1993, Kanter 1988, Drucker 1985, Miller, 1983). Other researchers (Chow 2007, Fagerberg 2008, Domb 2003, Huse 2005) list innovation activity as one of the main initiatives through which organisations can achieve a competitive edge. These researchers have linked innovation activities to organisational performance. However, most of their studies and findings focussed pre-dominantly on the manufacturing sector. Some researchers have made efforts towards extending innovation activity concept to Knowledge-based Firms (KBFs) (Lucke and Katz 2003, Bratton and Gold 2003). KBF's key source of value is knowledge and employees embody this knowledge (Grant 1996). However, the literature relevant to innovation activity in consulting engineering firms is still scarce and there is a growing need for empirical research on assessing the impact of innovation activity on project performance in these firms. It is important to mention the literature on project-based firms. Keegan and Turner (2002) note that there is scarcity of innovation in project-based firms. This is mainly due to the overall culture of consulting engineering firms which are a type of knowledge-based firms but don't support innovation activities that impact the day-to-day project activity mainly due to internal commercial pressures and external economic environment. There has been some work done in project-based firms but that is more focussed on the impediments to innovation rather than focussing on innovation activities that bring about a positive impact on project performance which is the topic area.

Innovation in the context of this research was based on the pioneering work of Schumpeter's (1934) who broadly defines it as:

- The introduction of a new good in a market.
- The introduction of a new method of production.
- The opening of a new market.
- The conquest of a new source of supply of raw materials or half-manufactured goods.
- The carrying out of the new organization of any industry, like the creation of a monopoly position or the breaking up of a monopoly position.

Although the above definition is drawn from the manufacturing sector, this research establishes that there exist similarities between consulting engineering firms and other services or manufacturing firms. The research establishes and works on the assumption that due to the similarities it is possible to generalise and extend the innovation concept from manufacturing to consulting engineering firms. A review of literature also reveals that researchers have tried to establish linkages between innovation activity and organisational performance. There is credible research that establishes that projects are an integrated part of an organisation. This can be viewed from a systems approach where a system is an organised unitary which for the purpose of this research is the organisation. The uniform entity is composed of two or more interdependent parts which are the projects, HR, administration, operations and marketing departments that form the organisation. These scientists draw a close link between project and organisational success as they perceive that project success can help organisations achieve a competitive edge due to the revenue produced by these projects (Bourne 2004, Turner 1999, Drucker 1959, Woodridge 1995). Bourne (2004) identifies projects as organisations in microcosm, of human scale. Turner (1999) calls a project a subsidiary of the parent organisation. Hence, it is clear from the above inter-linkages that projects are important for organisations to achieve a competitive advantage. The above interrelationships deduce that organisations will achieve better than their competitors when the innovation activity has a positive impact on project performance which indirectly improves organisational performance. However this perception needs to be tested and forms the central enquiry of this study.

Our main proposition to answer the research questions and address the research problem is that innovation activity in consulting engineering firms has a positive impact on project performance. The aim of this research is to develop an assessment model which helps us identify and quantify relative positively impact on project performance. This is mainly to fill the gap created by having a lack of holistic approach towards innovation where only some aspects that are beneficial to only one or multiple stakeholder related to project delivery (Hayes 2005, & Barrett & Sexton 2006). Furthermore, current literature suggests that there has been a scarcity of having adequate and relevant assessment models and measures to gauge the performance of organisations (Cutler 2008, Pinto and Slevin, 1998). This further justifies the need of developing an assessment model. Based on the above gaps and interdependencies, the following research questions which form the core of the research problem and need to be answered to address the problem are as follows:

- What are innovation activities that can be used to develop a model to assess the impact of innovation activities specifically in the context of consulting engineering firms?

  To answer the above question it is important to answer some of the underlying questions which are:

  - Is innovation required for knowledge-based firms and consulting engineering firms to succeed?
  - What is innovation in the context of manufacturing and can this be easily applied to knowledge-based firms?
  - What are consulting engineering firms? What are the similarities with knowledge-based firms?
  - What innovation activities can be applied to consulting engineering firms?

- Does innovation activity has a positive impact on project performance?

  To answer the above question it is important to answer some of the underlying questions which are:

  - How is project performance measured for consulting engineering firms?

Based on the answers to the above question, the objective of this research is to develop a model that can be used to asses the impact of innovation activity on project performance particularly in the context of consulting engineering firms.

The research questions would be used to establish the propositions. A comprehensive literature review using credible Australian and international journal and conference papers, industry reports, peer reviews and unpublished thesis was undertaken to find answers to the above research questions. The findings from the literature culminated into and provide the justification for establishing the proposition which was the basis of developing the theoretical model. A Delphi study was undertaken to test the proposition and validate this model. The validated model is utilised to assess the impact of innovation activities on project performance. The gaps in and recommendations from this research were used to develop suggestions for future research.

1.4 RELATIONSHIP TO OTHER PROJECTS

This project is being undertaken as part of a PhD thesis undertaken by Daniyal Mian. It is being undertaken on an individual basis and has no relationship with another project across QUT or industry. It does take into reference the lessons learnt from previous projects and relevant research papers. The research review was undertaken while using consulting engineering firms as key search criteria. Some of the previous research papers published by the researcher are also used to set the scene of the research and also validate the innovation model. Work from this research has also been published and presented at high profile conferences.

1.5 RESEARCH APPROACH

This research and associated thesis is mainly divided into the following five main sections namely Introduction, Literature Review, Research Methodology, Model Validation and Conclusions & Recommendations for Future Research.

The content across the five chapters is as outlined below in Table 1.1

Table 1.1 *Research Approaches*

Chapters	**Content & Focus**
Chapter 1 Introduction	This section starts with a brief outline of the background of the thesis, followed by the purpose of the research, its significance and the research questions which will be addressed as part of this project.
Chapter 2 Literature Review	This section includes an in-depth review of accredited, industry and academic resources on the topics of innovation, innovation activity, project performance and contingency factors. All of these, as much as possible, are

	relevant to knowledge-based firms particularly consulting engineering firms. The outcomes from the literature review will be used to develop the research model.
Chapter 3 Methodology	Outlines the research plan or process that will be undertaken to achieve the objectives set in section 1.2.
Chapter 4 Model Validation	A Delphi Study with select experts who have direct or indirect association with consulting engineering firms was used to validate the conceptual model. An approach based on a health check model is the basis of using the validated model to assess the impact of innovation activities on project performance.
Chapter 5 Conclusions and Recommendations	Conclusions drawn from the analysis of data from the Delphi study was used to provide a framework for future research that can be extended to industry and academia. The gaps in this study will also feed into the recommendations for future research.

1.6 LIMITATIONS

The study is subject to the following limitations:

- This study uses 8 experts which can be seen by some critics of Delphi as a very small group to undertake a credible and meaningful statistical analysis. However, in the past most previous researchers (Habibi et al., 2015; Outhred, 2001, Skulmoski, 2007) have used 7 or more experts to successfully undertake a Delphi study. However, the impact of the smaller group can be offset by drawing conclusions from the relative results across the rounds rather than using the individual data or numerical set to validate the model. Also, a number of complementary statistical techniques were undertaken to ratify the conclusions drawn from the individual statistical methods. Also, the study was only terminated when a high convergence was achieved.

- The Delphi study helped in tailoring the model to consulting engineering firms. The innovation activities identified through the literature review were further validated through a Delphi study due to the lack of this type of data in the context of knowledge-based firms and particularly consulting engineering firms. It was established that there exists a lot of credible data on project performance measures which form part of the model. The model along with project performance was presented to the Delphi experts. However, the experts were asked to focus on the innovation activities and not specifically asked to rank the performance measures. It might be as part of future research to establish the relative importance of the project performance to determine the overall changes on the model. However, the conclusions drawn from the Delphi study hints that the experts are most inclined to introduce innovation activities that can improve long term project financial performance. This may be a good start for future research.
- A robust set of criteria was developed to select an expert panel. This was based on a rigorous review of Delphi studies undertaken by previous researchers to understand the type of criteria they had used to run successful Delphi studies. The criteria were used as a basis to shortlist experts for this study. This helped in selecting experts who have sufficient experience in dealing with similar complex situations through their significant industry and academic leadership and who are also committed to complete the study. A detailed selection criteria to shortlist relevant Delphi experts is discussed in the following chapters. But even with good banding on expertise and a robust selection criteria there will always be some divergent ideas during the start of the study due to which multiple rounds of Delphi are run until a healthy convergence can be achieved.

Chapter 2: Literature Review

The literature review begins with a search of relevant literature on innovation from credible Australian and international scientists and researchers. The review also extends to relevant industry surveys, government policy papers, reports by professional forums and relevant papers posted through social media. Next, the review dives into contemplating research on measures of innovation activities that effect project performance. The search starts broadly into multiple market sectors and then narrows down to innovation measures and issues specifically related to consulting knowledge-based firms. Using the broader learnings from the review, the researcher then delves down into the innovation focused research using the context of consulting engineering firms. A review and analysis of project success measures is then undertaken. The findings from the review are used to develop and contemplate the research questions and associated proposition. A stepwise review and analysis helps in developing a conceptual model for consulting engineering firms which links the performance measures (success measures) to innovation activities. The main purpose of the literature review is to answer the main questions identified in section 1.3. However, to answer the main questions it is important to first focus on the broader underlying questions.

2.1 INNOVATION - A CHANGING DEBATE AND CHANGING SOLUTIONS

In the current fast changing world and associated fast changing needs, innovation is more important today than it was a few years back. More and more organisations are realising the importance of this concept and there is growing seriousness towards integrating it into their businesses. In this changing economic climate, knowledge-based firms and particularly consulting engineering firms have started looking at their capability to innovate and use this as their competitive edge. It has become a hot topic of discussion at various levels of government and politicians are trying to understand it better to leverage it for political gains. A large literature has emerged in recent years on various aspects of innovation and many research units including centres, institutes and departments are focussing on innovation in particular. A web search in July 2007 identified 136 units worldwide that operate in the innovation area and 80% of them are located in universities (Fagerberg, 2009). This search was mainly done using all major search engines at once using a search engine called 'Dogpile' which returns results from the leading search engines which are used on a daily basis.

The European Federation of Engineering Consultancy Associations (EFCA) in 2008 published a white paper that identifies that although the development and implementation of innovation has always been at the heart of engineering consultancies, CEO's of major multinational consulting engineering firms have a realisation that innovation in the industry is not sufficient to face up to the major economic and environmental challenges. The Lisbon Strategy underlined the strategic importance of innovation in a "knowledge-based society" faced with worldwide competition. The paper highlights that engineering consultancies design, study and create works, equipment or industrial products and for this reason, they are constantly innovating. Thus, to transform a project into reality, from an idea to an execution drawing, then to a completed work, it is not enough to apply purely pre-existing solutions. In fact each project is unique and requires new and specific technical, financial, legal and organisational solutions. It is thus necessary, starting from existing concepts, to invent a new innovating configuration to suit each individual project.

As I was going through the literature on innovation from the modern researchers, it became evident that their work was mostly drawn from the theories of Schumpeter. Hence, I came to conclusion that to understand the term 'innovation' better it is important that its emergence be explored. The work on this field of study was started by a social scientist Joseph Schumpeter who focussed in particular on innovation and the factors influencing it. According to Schumpeter there was a source of energy called innovation within the economic system which would of itself disrupt any equilibrium that might be attained (Schumpeter, 1937). His major theoretical treatise on the subject, 'The theory of economic development' focussed on the interaction between innovative individuals who he called 'entrepreneurs'. According to him entrepreneurs are by definition neither inventors, capitalists nor a social class. Although all three can be combined in one person, this combination is unnecessary (Hagedoorn, 1996). Schumpeter (1934) broad definition of innovation and the work that followed from it helps us understand the four underlying questions linked to the first research question i.e.

- Is innovation required for knowledge-based firms and consulting engineering firms to succeed?
- What is innovation in the context of manufacturing and can this be easily applied to knowledge-based firms?
- What are consulting engineering firms? What are the similarities with knowledge-based firms?
- What innovation activities can be applied to consulting engineering firms?

According to him, innovation is:

- The introduction of a new good in a market
- The introduction of a new method of production
- The opening of a new market
- The conquest of a new source of supply of raw materials or half-manufactured goods
- The carrying out of a new organization of any industry, like the creation of a monopoly position or the breaking up of a monopoly position

He is also well known for suggesting that large firms and monopolists are in a better position to be innovative due to their capacity to invest in large R&D projects. Corte, V., Zamperalli, G. and Micera, R (2013) through an in-depth review of literature points out that the Schumpeterian concept of "innovation" is different from "invention." The latter is a discovery of an outside opportunity while innovation is the ability to exploit that opportunity. Also, Kenneth Arrow another 20th century influential economist presented a competing logic by which competition rather than monopoly promotes innovation (Baker, 2007). Arrow explained that an organisation which is already leading a market may not find it important to further make an investment in innovation. This shortfall of the monopolist to innovate was later termed as the 'Arrow effect'. Schumpeter's lifelong of advocacy of innovation as a driving force behind economic growth seemed almost a lost cause at the time of his death in 1950. But mostly due to his work and the work of his contemporaries the interest in innovation steadily increased from 1960 onwards with rapid growth since the early 1990s. One of the most important scientific entrepreneurs who believed in Schumpeter's ideology and the influence of innovation on long term economic development was Christopher Freeman. He headed the Science Policy Research Unit in Sussex which was the only institution outside of US where significant growth in the science on innovation was realised. To complement Schumpeter ideology of innovation and its influence on long term economic development, Freeman introduced the concept of National System of Innovation (NIS). He defined this as a set of institutions whose interactions determine the innovative performance and the associated economic performance of national firms. (Nelson, 1993). Some of Schumpeter's work was also further developed by Nelson and Winter (1982). They developed a model of economic growth which was contingent on a number of organisational factors more specifically the different ways organisational knowledge was managed which influenced later research in a number of different areas.

More recently, Palangkaraya et al. (2010) defines 'Innovation' as the introduction of new forms of processes and products into the organisation. The degree of innovation can range from minor improvement which falls into incremental innovation to completely new which is breakthrough innovation (Garcia et al, 2002) We further explore innovation in the context of knowledge-based firms in general and consulting engineering firms.

2.2 INNOVATION IN KNOWLEDGE-BASED & CONSULTING ENGINEERING FIRMS

Most of the innovation literature explicitly or implicitly comes from manufacturing or other technology firms (Montoya-Weiss and Calantone, 1994). Mian (2009) notes there is over 20 years of innovation literature. However, to date the service sector has received minimal attention from academics. Australian innovation surveys from 2001 to 2005 have identified that manufacturing businesses are more innovative than other businesses. (Palangkaraya et al, 2010). Palangkaraya et al. (2010) also identifies that among SME's manufacturing firms have the highest probability to engage in innovation activities. Overall manufacturing firms have the highest contribution and share to investment into innovation. In some cases researchers in the past have been adopting manufacturing innovation indicators for the service industry (Steiner et al 2001, Sirilli, 1998, Mesch 2000, Fagerberg, 2008).

However there were reservations with the successful implementation of these indicators and that in most cases they were not serving the intended benefit. For example, generally, the algorithm in software is not patentable. Hence, there is a need to identify robust innovation activity indicators which better suit the knowledge-based service industry. Mian (2009) notes that there have been attempts in the manufacturing industry to harness the innovative potential of the business and apprehend its use as a point of difference to improve monetary and non-monetary outcomes. However, further work is required to innovatively extrapolate the lessons learnt from manufacturing and achieve an incremental and/or radical innovation in knowledge-based firms (KBFs) especially consulting engineering firms. Creativity is the prerequisite for innovation especially when moving from incremental to radical innovation. However, to get a complete view of a firm's innovation activity one has to look not only at the innovation input but the success of the product and process innovation (Steiner, 2006). A number of researchers (Tidd & Bessant, 2011 and Iddris et al, 2014) note that in recent times knowledge-based firms are attaching much importance to capability to innovate. As a result research interest in this phenomenon has increased over the past few years. Gann and Salter (2000) note that project-based firms including consulting engineering firms contribute considerably to the gross national product of most western economies.

Literature also identifies the two main differences between the manufacturing and knowledge-based service industriessy. First, the KBFs have seen to be investing more in software and existing technology. Second expenditure in research and development is comparatively insignificant. Knowledge-based firms also have relatively higher expenditure cost in adapting and implementing technologies solutions that have been sourced off the shelf. As compared to manufacturing, innovation activity in KBFs is realised through the use of new technologies and that are externally acquired (Wieland, 1993).

Since the early 1980s and more recently the literature on innovation especially in manufacturing industry has grown very voluminous and to summarise it in a few pages is quite risky. However it would be unfair not to mention the work of some of the entrepreneurs from last century and the work of some of the present day innovative leaders. Worth mentioning is Vedin's (1980) research on innovation within large Swedish companies which identified three different factors as determinants of a company's innovative performance namely environment, corporate structure and management orientation.

As Chow (2007) posits, innovation represents the single largest opportunities for companies to differentiate their businesses. Manley and McFallan (2008) emphasise that innovation is an important contributor to economic growth. Over the past few years many organisations have based their growth strategies on innovation. In 2006 McKinsey Quarterly conducted a worldwide survey of more than 3400 CEOs and found out that 25% identified innovations in products, services and business models as the single most important factor in contributing to the acceleration of change in global business. Other sources reveal that the idea of innovation is only attractive to firms if the introduction of a new service or a product increases value for their clients i.e. if the change brings a positive change: increased business, wealth for shareholders, prosperity and continuity of service for the staff. Most of all, if it becomes a firm's point of difference helping secure a suite of projects which can help in improving the overall financial bottom line, client satisfaction and staff retention.

Nonaka and Takeuchi (1995) identify that knowledge and skills can help an organisation gain competitive knowledge. This is mainly because by gaining knowledge and acquiring skill these organisations would be able to innovate new processes and products that will bring value to the external stakeholders. This applies to consulting engineering firms where knowledge workers are the main source of competitive advantage who can offer improved processes on project to improve their performance.

Bratton and Gold (2003) defines innovation in knowledge-based firm as the development of what is known or introduction of something new by valuing the collection, dissemination and utilisation of new knowledge. A convenient definition of innovation from a KBF perspective is given by Luecke and Katz (2003), who wrote, 'Innovation is generally understood as the successful introduction of a new thing or method. Innovation is the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services which gives an organisation a competitive edge.'

From an Australian perspective, The Business Council of Australia (1993) defines innovation as something new or significantly improved that can create value for a firm or indirectly for its clients. Similarly, Phillip (1997, p4) concludes that an organisation is considered to be technologically innovative if it at least introduces one new or improved product or process every three years. Covin and Miles (1994) call innovation as the introduction of a new technique, resource, systems or capability to the firm or its market.

More recently this work has been extended to the services sector. In 2005 services were responsible for 50% of the GNP in UK while manufacturing sector contributed to 14.9% of the GNP (Bark, 2001). Australian R&D expenditure is still lower than UK and Europe (Palangkaraya et al. (2010)). Innovations in services have led to the greatest level of growth and dynamism over the past few years in terms of economic activity (de Bretani, 2001). However, there is a gap between consulting engineering firms and other service firms. A number of researchers (Seaden & Manseau, 2001; Winch, 1998) note that it is difficult to measure innovation in construction industry where consulting engineering firms get majority of their work as traditional measurements like R&D activities and patents have been used to gauge innovation. This is contrary to what consulting firms focus on that is projects, organizational processes, contracting arrangements and assembly methods. (Seaden & Manseau, 2001). In recent academic comparisons of innovation activity across different sectors of the industry, construction sector in particular underperforms significantly compared to manufacturing (Reichstein, Salter & Gann 2005). One of the main reasons of this gap is mainly because consulting engineers do not get the time to innovate as they are mainly rewarded for client related billable hours. This leaves very little opportunity to get involved in activities associated with innovation. The billability targets constraints the amount of time that senior leadership or delivery & design managers can commit to innovation. The other issue is the difficulty to distinguish between operational routines and innovative routines (Baark, 2000). For engineers the problem of separating innovation activities is quite complex. They understand that their everyday engineering design work includes innovation and creativity but this is deeply imbedded in this work and although it can be categorised as incremental innovation, it is very difficult to identify specific radical changes. Engineers Australia (2006, p3) pin points some of the reasons for lack of innovation activities across organisations:

- Lack of availability of technology, resources and strategic alliances/partners.
- Corporate culture is not supportive: Consulting engineers have to change their conservative risk management approach. An innovative approach needs to come from the top leadership. There needs to be a corporate culture that seeks continuous improvement, offers support for new ideas and provides assistance in development of new products and services.
- Not enough investment into R&D: Due to the current financial downturn most of the consulting engineering firms have slashed their training budgets and there is very little investment going into people or product development. The investment into partnership with tertiary institutions or in-house R&D also been reduced. Wood (2004) believes that there is a high correlation between the wealth of nations and R&D intensity and the investment into R&D has to increase if there has to be a significant growth in the future.
- Informed clients are a vital factor in supporting and accepting innovative solutions. Customers who support status-quo and are unable to pay a little extra to integrate innovation into technical design and excellence are a major impediment to a company's will to innovate.
- Financial issues especially the recent GFC (2008-2015). The GFC has hit hard in Queensland in 2014 and 15 due to winding down of some of the major infrastructure, mining and oil and gas projects.
- Education and skills: Australia is currently producing twice as many scientists as engineers, which is in contrast to countries such as Singapore and Taiwan. To increase the number of engineering students, children must be given an opportunity to develop an interest in engineering. Primary school units should include units that explore how engineering and science can solve Australia's most pressing social and environmental problems. Secondary schools must provide students an ambition to undertake an engineering degree. Also, part of the education funding

should be invested in training school staff to make them capable for teaching engineering. The submission from Engineers Australia (2006) identifies ‘that scientific advances represent enormous potential, but commercialisation is constrained by a disproportionately limited engineering skills base. As a result, Australia is losing its ability to compete successfully in the rapidly growing knowledge-based economy’.

- Government incentive programs can be in the form of R&D grants, repayable grants, loans and interest rate subsidies. There is published research on manufacturing firms which acknowledge that they would not have been able to get their R&D base off the ground without some government assistance and tax break schemes.

It is important to make mention of the literature on project-based firms. Keegan and Turner (2002) define project-based firms as those where the majority of services and products are tailored to customer needs which is very similar to consulting engineering firms. According to Gann and Salter (2000) firms in construction, engineering and film industry are project-based. As consulting engineering firms depend upon their projects and the revenue generated from them, for their success, they are also project-based firms. However, architectural, project management and management consulting firms are also project-based firms. Keegan and Turner (2002) note that there is scarcity of innovation in project-based firms. They have pointed out the reluctance of managers to develop innovations within business projects. They note that the traditional and modern project management literature largely ignores innovation. It is quite evident from the literature on project-based firms, there is more emphasis on the impediments to innovation rather than focus on innovation activities within these organisations. There is little literature which specifically identifies innovation activities for project-based firms. Through the case study analysis of project-based firms, Keegan and Turner found out that when it comes to planning and project controls they are failing to provide a supporting platform for innovation. In some cases the management might see it as risky, costly and dangerous. Similarly, Taylor and Levitt (2004, p-1) support the view that although innovation in traditional, hierarchical organizational structures, little research to date explores the issues associated with innovation in the project-based organizations that populate the swollen middle.

Gann and Salter (2000) note that project-based firms are not given sufficient coverage in the innovation literature. The lack of resources due to recession in construction markets, traditional approaches in some specialist areas limited the ability to innovate.

Floortje Blindenbach-Drissen et al. (2006) undertook a case study of four project-based firms and no explicit criteria or prioritisation model was used for project selection or prioritising. The selection was mainly based on the intuition of senior management.

Keegan and Turner (2002) conclude that project-based firms that includes consulting engineering firms still see as slack resources that can be specifically allocated to advance innovation activity, as enemy to their day to day project activity. Only when significant challenges or direct requirements to deal with a client specific issue, there are loosening of resources to be allocated to spent time on innovation. Gassmann et al (2010) & Chesbrough (2007) identify that to maximise the benefits from investing into innovation activity, firms need to breakdown their institutional boundaries. The outcome from their research study highlights that consultants who use external specialist resources and sub consultants rather than doing everything in-house enjoy more advantages. They are able to develop a more sustainable model that helps them in securing ongoing project work. This is becoming more and more obvious with the ongoing Global Financial Crisis where there is a high mobility of knowledge workers and some of the consulting engineering firms are benefiting from poaching highly skilled workers to enhance their ability to commercialise and implement new products. The use of an extended network of specialist resources and an effective collaboration and communication strategy has helped some consultant to move into new markets.

Also, according to Hayes (2005), there is a lack of holistic studies on innovation and creativity mainly in the context of consulting engineering firms. Hayes attributes this to the engineers being purely focussed on design detail. In some cases people have developed a perception that engineers are dull and unimaginative which has been identified by a number of researchers in the past. It all seems that there are opportunities for consulting engineering to innovate but they are not fully utilising them to create a holistic innovative framework (Bessiere et al., 2008).Similarly, Barrett and Sexton (2006) note smaller project-based construction firms may only consider the introduction and use of new ideas or systems as innovation which is not a holistic approach while considering innovation as it does not reflect the interest of all the stakeholders.

Gann and Salter (2000) emphasises the need of project-based firms to be able to manage innovation and technology across the organisational boundaries while considering the expectations of external parties or joint venture partners including suppliers, customers and regulatory bodies. Similarly, for consulting engineering firms, Toivonen (2004) notes that innovation stems from their extended and versatile contacts with multiple and varying stakeholders.

Keegan and Turner (2002) note that the same principles that make project-based firms such as consulting engineering firms successful i.e. delivery projects within the parameters of time, cost, quality and safety; may limit the tendency or capacity to innovate. Traditional methods of evaluating projects are limiting innovation. In most cases innovative ideas are generated by individuals are not implemented to see the real benefits.

In some cases innovation can also be seen to have a negative or disruptive effect as in most cases there are risks associated with introducing a change. The staff reluctance to change which may be introduced due to adopting innovation can also have an impeding impact on staff morale. (Cutter consortium, 2005). Some of the negative impacts of introducing innovation include: Lack of ownership of introducing and implementing innovation; risk aversion to change; significant increase in training requirements; and lack of client stewardship and support. A survey of project success and failure factors for software development projects shows that approximately 50% of failures are due to scheduling while 27% fail due to customer dissatisfaction (Cutter consortium, 2005). Given these odds for traditional project, innovation activities and associated risks introduce a greater uncertainty and increase the probability of failure. Letens et al (2005) notes that, it is critical for organisations to identify risks associated with introducing innovation. Early planning and mitigation will assist in avoiding major threads or significant missed opportunities

Wong (2012) notes that engineering is a knowledge-based consultancy service and profession. Hence, engineering consultancy is a business based on the provision of knowledge-based professional engineering services. Before innovation is further explored, it is important to define the main function of a consulting engineering firm which is the context topic of this research. Lowendahl (2000) identifies the following features of consulting engineering firms:

- Their value creation centres on the delivery of highly knowledge-intensive services, delivered by highly educated employees, and frequently closely linked with research and scientific development within the area. The knowledge of the employees is frequently (though not always) certified by a professional organization and (or) or internal accreditation specialists.
- The services are highly customized to specific client needs.
- Delivery involves a high degree of discretion and personal judgment by the experts involved. In many professional service firms project directors, principals, company partners and joint venture partners are personally held legally responsible for liability claims.
- Delivery typically involves a high degree of interaction with the client representatives, throughout the diagnosis, planning and delivery phases.

However, researchers in the past have argued over this as some think that the term 'knowledge-based firm' sounds very prestigious and some organisation without having the demonstrated capability adopt it. Grant (1996) even goes a step further and suggests that it is very hard to define what knowledge is but instead of concentrating too much on the definition, it is important to focus on its role among firms which engage in production, mainly because this is the important and complex means of value creation.

Alam (2003) suggests that consulting engineering firms undertake a variety of activities including project management, designing plans for constructions of bridges, shopping centres, and sports complexes, town planning, environmental science research, waste and water management. They plan a key role in injecting innovation in several industries. This is by virtue of their positions in the marketplace as they are much closer to the real problems of customers. To stay competitive they have to focus on developing successful innovations and constantly respond to customer needs and expectations. The current marked downturn puts an additional onerous on them as the clients are being very clear and prescriptive in asking for an effective and inexpensive solution. Alam (2003) concludes that given that pioneering innovation currently is attracting significant attention in the extant literature, managers need to involve consulting engineers as they may suggest ideas for pioneering innovations.

EFCA (2008, p15) notes that consulting engineering firms design, study and bring about, in whole or in part, works, equipment or industrial products. '*They play the part of messenger between the theoretical knowledge developed by scientists and its practical applications: using this new knowledge, they make a client's project feasible.'*

Their services can include designing a motorway, hospital, factory, bridge or dam (responsible for design, calculations and detailed drawings), then offering contract management in some cases. It may also involve designing a product, for example a vehicle lighting system for a car manufacturer, a section of the Airbus A380, or tram equipment. The delivery of the above complex projects requires research planning, design and development of holistic and sustainable solutions to successfully develop sustainable infrastructure, build communities and support the environment. It is quite evident from the definition that consulting engineering firms need to have knowledge, intellectual property and experience that can be put to use to produce holistic, sustainable and integrated solutions for their clients, the government and members of the community that are directly impacted from it. Researchers (Alvesson, 2000, 2001, Swart et al, 2003 and Bontis, 1998) categorise a consulting engineering firm as a Knowledge-based Firm (KBF) because most of its work is of intellectual nature and reliance on human capital as opposed to physical capital. Innovation differs in every sector and patterns of innovation in manufacturing differ from those in services (DTI, 2007). Organisational change often drives innovation in services (NESTA, 2008). Alveson (2002) considers a KBF to be one where knowledge is related to individuals/employees rather than the organisation, machines and technologies and where the majority of workforce has a high educational background. The knowledge base is considered and used as a key business differentiator. Grant (1996) goes a step further and defines KBFs as those where vital input in production and the key source of value is knowledge, where employees embody this knowledge. The human resource is of utmost importance as it epitomises knowledge which is the point of different for the organisation (Herling et al, 2000). Typical examples of other KBFs are law and accounting firms, management, computer consultancies, advertising agencies, research & development units and high tech companies. Alvesson (2000) states that Architecture or consulting engineering are also knowledge-based firms mainly due to the similarity of their attributes. Some of the commonly documented attributes identified in this research are:

- They have a problem solving capability and may in some cases work in the non-standardised production area
- Employees are highly creative
- The central assets for delivering value are not the tangible assets but instead the employees, client networks, customer relationship, tacit and explicit knowledge
- Strongly dependent on key employees and vulnerable if retention cannot be generated.
- Employees in most cases are highly educated. It is not uncommon in consulting engineering firms to have a significant pool of engineering and drafting staff and senior managers having a doctorate in a specialised area which they are also leading across the firm.
- The knowledge of the employees is frequently (though not always) certified by a professional organization and internal certification processes.
- The services are highly customized to each client's needs.
- Delivery involves a high degree of discretion and personal judgment by the experts involved, and as a result senior leadership, principals and partners are personally held legally responsible for liability claims.
- Delivery typically involves a high degree of interaction with the client representatives across the diagnosis, planning and the delivery phases.
- Unlike other industries, the central assets for delivering value to consulting engineering firms are not the tangible assets e.g. materials, buildings etc. Instead, the employees, client networks, customer relationship, tacit and explicit knowledge are the core assets. Some of

examples of types of knowledge across consulting engineering firms based on the work of Amidharmo (2014) are as in the Table 2..

Table 2.1 *Types of Knowledge relevant to a Consulting Engineering Firm*

Business Division	**Explicit Knowledge**	**Tacit Knowledge**
Engineering	Technical engineering design principles Understanding and familiarization with accepted engineering standards and building codes Flair with the use of analysis/design software packages	Site experience Specialist technical expertise Preliminary design: selecting the appropriate structural framing solution for a given architecture and market conditions
Drafting	Use of CAD or REVIT drafting software packages	Shortcuts/tips and tricks for efficient drafting.
Project Management	Project financial status Project Timeline Construction market trends	Client management and relations Risk Management

Most of these attributes apply to architecture or consulting engineering firms which rely on a high degree of inputs from their staff who are the knowledge-workers, a term coined by Peter Drucker (1959). Drucker defined a knowledge worker as one who primarily works with information to develop and use knowledge in the workplace. Woodridge (1995) describes the knowledge worker as a person who does not add value through labour as such but because of what they know and how it is refined. Investing in knowledge workers can help firms perform better than their competitors. However, human resources are complex and intangible assets due to their cultural and technical dimensions and cannot be managed like other assets. However to ensure a sustainable competitive advantage the resources need to be valuable, rare, non-inimitable and non-substitutable (Barney, 1988). There has been a massive growth of knowledge workers in Australia since the 1980s. The focus by the federal government in the last 10 years to open the doors for skilled migrants has helped in increase knowledge workers. This direction and initiative is a clear recognition of the growing knowledge economy especially where it caused growth in the labour market in the service sector (Yigintcanlar et al, 2008).

The above literature helps in responding to the underlying research questions i.e. all firms whether manufacturing or knowledge-based need innovation as a point of difference to better then their competition. The above literature clearly provides a theoretical justification to answer our underlying third research question that architecture or consulting engineering firms are types of knowledge-based firms mainly due to the similarity of their attributes. The knowledge workers (engineering and drafting resources) are the main contributors to providing a competitive advantage when it comes to consulting engineering firms. Based on the precedence set by previous researchers, the innovation activities from manufacturing can be extended to services firms and consulting engineering firms but they will need to be validated and tailored to the particular industry requirements.

Reverting back to innovation studies, Butlin and Carnegie (2001) add another dimension to innovation, the organisational development e.g. new forms of employment. Similarly Leber et al (2004) suggests that innovation in knowledge-based firms is also a function of development of corporate services and structures.

Buchen (2003) argues that Knowledge-based Firms have to make both innovation and learning an integral part of mission. The commitment should extend deep into the organisation and staff should be committed to embracing this change. The commitment should be measured through the staff appraisal and performance evaluation process. In short, organisations that make innovation part of their mission are holistically proactive in generating innovations which are designed, in large part, by and for the future. Customer service and the level of customer satisfaction are regarded to be significant in building trustworthy relationships with customers and retaining the competitive advantage (Stefanous and Sarmaniotis, 2003).

Similarly Brazeal (1993) developed a model that focuses on the relationship between innovative-minded individuals and organisational factors. He defines innovation as the ability to create something new which has a direct impact on the economic performance of the organisation and is bolstered by creating an environment which offers reward and appreciation for whoever manifests this ability. Braezal emphasised that to promote innovation among its employees, careful attention must be given to melding individual attitudes, values and behavioural orientations with organisational factors offering structure and reward.

Davila et al (2006), emphasises that, innovation, like many business functions, is a management process that requires specific tools, rules, discipline and management support. Innovation starts from individuals within an organisations or teams working on a specific project mainly through the generation of creative ideas. However, these ideas need to make a positive change in a product or service for the innovation cycle to be completed. Furthermore, none of this can happen without the support of senior staff responsible for making decisions about financial and resource commitment.

Fagerberg (2004) makes an important distinction between invention and innovation. Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice.

Before concluding, it is also important to critique the gaps in the overall literature on innovation. The term 'Innovation' was mainly coined from the work of Schumpeter. Over the last decade, this work has been applied to the manufacturing and process sector. However, some of the concepts have also been extended to knowledge-based firms. Consulting engineering firms are a type of knowledge-based firms and there are more similarities than differences across them. Innovation in consulting engineering firms is still in infancy stage and this research will use some of the insights gained and apply and test it in a consulting engineering environment.

Overall, it can be concluded from the review of the literature that most of the existing body of knowledge comes from the manufacturing sector or is not industry specific. Although there is literature on innovation specifically associated with other types of knowledge-based firms and other project-based firms. But it would not be an overstatement to say that literature associated with consulting engineering or project-based firms especially on innovation activities is quite scarce. Some researchers state that the focus on innovation is negligible within the consultancy engineering firms (Leiponen, 2000; Swan et al, 1999). The focus on innovation in consultancy firms is on an 'ad-hoc basis' and knowledge sharing which is one of the main attributes of innovation is described by Leiponen (2006) as a paradox; in fact there is lack of attention to knowledge sharing activities. Most of the literature (Keegan and Turner, 2002, Gassmann et al, 2010) & Chesbrough, 2007) that is available in project-based firms focusses on impediments to innovation rather than focussing on what innovation activities have they got in place particularly to improve project performance. Gann and Slater (2000) note that there is little research available from a knowledge-based view on innovation in project-based firms. While considering innovation in project-based firms there is lack of consideration of cooperating partners who were involved in the development of those systems. (Gann and Salter 2000). There is also lack of prioritisation models that can help into investing in innovation. Other researchers (Letens et al, 2005 and Cutter consortium, 2005) have only focussed on the disruptive aspects of innovation.

Researchers in the past have extended the use of innovation activities from manufacturing firms to knowledge-based firms. However, due to some of the similarities with other services and manufacturing sectors it might be possible to generalise some of the activities (and associated indicators) and extend them to consulting engineering firms. In some cases researchers in the past have been adopting manufacturing innovation indicators for the service industry (Steiner et al 2001, Sirilli, 1998, Mesch 2000, Fagerberg, 2008). However there were reservations with the successful implementation of these indicators and that in most cases they were not serving the intended benefit. For example, the algorithm in software is not patentable. Hence, there is a need to identify robust innovation activity indicators which better suit the knowledge-based service industry. However, before this can be achieved it is proposed that there is a need to look at tailoring the innovation activities to a consulting engineering firm. An approach to achieve this which will be adopted for this research is to get the innovation activities further validated by subject matter experts.

The overall leadership culture, internal commercial targets and external market pressures in most of the consulting engineering firms prevents them from investing into innovation. The above are perceived gaps and this research will attempt to fill it.

Before we develop a concrete view on innovation, it is important to do a more detailed review of activities associated with innovation.

2.3 INNOVATION ACTIVITIES

Investment in innovation is crucial in the existing financial environment. Huse et al (2005) suggests that innovation appears the only way that an organisation can convert change into opportunities and succeed spectacularly. Chesbrough (2007) and Gassmann et al. (2010) suggest that by investing into innovation, firms can produce radically new products. A study was commissioned by the Australian Business Foundation Ltd in 1999. It undertook a survey of a number of businesses across Australia and highlighted a trend of poor investment into business innovation and research and development activities. The expenditure when compared to the OECD averages was very little and the situation worsened as very little emphasis was given by the Australian government to improve these figures. However, in 2008 the Australian Federal Government, after reviewing the National Innovation System, recommended some significant changes to the way organisations shared knowledge. Cutler (2008) who carried out the review proposed that the government should assist firms in developing metrics, performance indicators and mechanisms for collecting and sharing data. The report recommended advancement in innovation in areas such as strengthening people skills, improving business and operational performance, excellence in national research information and enhancing market design. It was also noted that innovation activities either project or organisational specific are a measure of innovativeness.

Moreover, it is becoming evident from the literature review that it is difficult to measure innovation due to the broad nature of innovative activities being undertaken in organisations. Rogers (1998) splits innovation measurement into inputs and outputs activities. Some of the output activities noted by Roger (1998) are:

- Introduction of new processes

- Intellectual property statistics
- Firm performance (econometric techniques).
- Some of the input activities are:
- Research and Development (R&D) investment
- Acquisition of new initiatives and technology options to facilitate business of new initiatives and technology options to facilitate business
- Marketing & organisation change.

Some scientists talk about organisations acquiring specific technology such as Knowledge Management System. Davenport and Prusak (1998) define Knowledge Management as the set of organised and disciplined actions that a firm takes to fully utilise the available knowledge. By knowledge they refer to both the experience of the staff, lessons learnt which is mainly gained through acquiring experience and the standard documentation or artefacts. The systems and managerial initiatives used to manage knowledge are called Knowledge Management Systems (Marwick, 2001). Whitley (2006) notes that for project-based firms investment into knowledge sharing and management systems and associated codifying, combining, and distribution of knowledge that enables the organisation to develop distinct core competencies is an important requirement and supportive condition for innovation.

The OECD Oslo Manual from 1995 suggests standard guidelines on measuring technological product, people skills and process innovation. The new Oslo manual from 2005 takes a wider perspective to innovation and includes activities such as marketing, business development and organisational innovation. Wang et al (2007) measures technological innovation capability in terms of R&D research capabilities, innovation decision capabilities, marketing capabilities, manufacturing capabilities and capital capabilities. Each of these is then assessed by three or more indicators associated with each measure. It is important to note that individual firms may differ in their innovation abilities (Tseng et al, 2008). Other examples of innovation measurement can be seen at the US department of Defence where specific innovation strategies are used to measure innovations and call this concept ‘balanced innovation management’. The measures (or modes) include: R&D, alliancing, joint venturing, Acquisition of new initiatives and technology options to facilitate business of other businesses and offering services through a licensing arrangement (King, 2006). Some of the more project specific examples include measures such as setting up an innovation centre of excellence, developing personnel, venturing, investing into gathering competitive intelligence and undertaking product experiments. Gann and Salter (2009) note that R&D in project-based firms is confined to R&D units, senior management and engineering staff. Project teams are involved in a lot of practitioner research and they develop the expertise during the course of delivering project activities/deliverables (Groak and Krimgold, 1989)

In most cases innovation activity may be determined by the organisational and procedural capability. Firms may be specialised in particular technologies or related expertise leading them to pursue different activities (Francis and Bessant, 2005).

Kaplan et al (2007) notes that across the Fortune 1000, that do possess innovation indicators, for example, the most prevalent innovation activities include:

- Annual R&D budget as a percentage of annual sales
- Number of patents filed in the past year
- Total R&D headcount or budget as a percentage of sales
- Number of active projects
- Number of ideas submitted by employees
- Percentage of sales from products introduced in the past year

The literature on innovation also broadly groups innovation into incremental and breakthrough. Cheng & Chen (2013) identifies some of the incremental innovation activities such as; minor changes in technology, simple product improvements or initiatives that improve project performance. Cheng points out that some of the breakthrough innovation activities include; introduction of completely new technology or systems and focussing on achieving more customer benefits.

Close collaboration with customers is essential for development of incremental projects (Brown and Eisenhardt, 1995). Firms that know their customers well will be able to deliver their project needs better (Floortje Blindenbach-Drissen et al., 2006)

In some cases the researchers tried to link the selection of innovation measures to the purpose of innovation and the deliverables expected from this change process. Goffin and Pfeiffer (1999) argue that innovation management in firms can only be successful if they perform well in developing innovation strategies, creativity & ideas management, selection and portfolio management, implementation management and Human Resources (HR) management. Goffin and Pfeiffer also mention that it is important to manage well the integration aspects of the above areas. Oke (2002) suggests that the first step in formulating an innovation strategy is to look at the drivers of innovation needs. Oke emphasises that top management needs to develop its strategy and drive performance improvement through the use of appropriate performance indicators. Budgets, staff ownership and timelines may constrain the implementation of some of these innovation activities.

The above literature on innovation activity explains that the understanding of innovation is primarily based on the lessons learnt from generic and manufacturing-specific literature on innovation. Nevertheless, work by other researchers has started on expanding innovation activities to Knowledge-based Service Firms (Steiner al, 2001).

It is evident from the review of literature associated with the manufacturing industry that the use of tangible indicators such investment in R&D activities or patents is common, mainly because there are dedicated R&D departments in the manufacturing firms. In comparison, consulting engineering firms use indicators such as resources numbers and their qualification, investment on tangible assets and their influence on organisational and project performance. Innovation activities in firms which rely on their staff to deliver the end product often include small adjustments of procedures and thus are incremental and rarely radical (Sundbo, 1998). Clients have also played an important role in guiding the focus of innovation in knowledge-based and consulting engineering firms e.g. for some knowledge intensive business services the innovation evolves due to the firm devising a solution for a specific client problem. For example IT support firms, management consultancies and engineering firms come across client's requests which can be quite complex and a breeding grounds for introducing innovation. In some instances the benefits of these innovations can spill over to have a broader benefit for the society and may end up exciting the economy (Mesch, 2000). There also exists a strong link between innovation development and strong leadership. Barsh, Capozzi and Davidson (2008) identify that one of the most important factors that has a positive impact on project performance is strong leadership support and sponsorship. It is important that the leadership support is not seen as a lip service. On the contrary, top executives spend their time actively supporting innovation and driving it.

Johansson and Loof (2006) note that in Europe there is growing group of studies that employ information from the Community Innovation Survey (CIS-data) for individual countries, identifying individual firm innovation attributes such as R&D, patents, collaboration on innovation, physical capital, human capital, firm size and sales.

Some other examples (Brown et al, 2005 and Morris, 2008) which say less about the company's capacity to innovate over time but more about how well the innovation process is running include:

- The number of ideas put forward by individuals to team leaders
- Resources made available for continuous innovation
- The average time from idea evaluation to full implementation
- Saving achieved through successful operational efficiency ideas
- Revenue generated through ideas resulting in new products or services.

While some of these can be valuable for driving investment in innovation and evaluating results, they do not provide a holistic view of innovation.

Based on the Austrian National Innovation Survey which was carried by the National Institute of Economic Research (1999), 56.6% of the service sector firms have introduced a new or improved product or process during 1994 to 1996 which is 9% less than the manufacturing sector. The survey was targeted at the architectural, engineering, telecommunications, transport and financial sectors. The focus was on the innovating firm and not on the individual innovations. One of the commonly used measures of innovation activity was the 'innovation expenditures by turnover' which amounts to 2% in the service sector as compared to 4% in the manufacturing industry. The investment was broken down into different categories: Research and development, training, machinery and equipment, software or systems and preparation for introduction & implementation of innovation.

More recently, Tang et al (2008) grouped 68 innovation activities identified through literature and a questionnaire and interview process mainly for the services industries:

- Frequency of launch of new products
- Creation of new ideas
- Employees training including knowledge sharing
- Incentive mechanisms to help development of new abilities
- Introduction of new technology and equipment
- Cooperation between individuals.

It is important to note that some of the above innovation activities are generic in nature and based on a high level view of what they entail e.g. Cooperation between individuals or team members is a high level description of this activity. It is important to note that it has been intentional to capture some of these as they were identified from the literature review. This will provide an opportunity for the organisation that embarks on a journey to implement this model to dig deeper and consider innovative solutions or enablers to implement the innovation activity (e.g. what are the effective enablers of improving communication between individuals).

After contemplating the above research studies in innovation and innovation activity and exploring, it is quite clear that there are some common threads of activities across knowledge-based firms. It also identifies that consulting engineering firms are also categorised as a knowledge-based firm. However, current research lacks a holistic approach towards innovation. Hence, the common themes of innovation activities can also be extended to consulting engineering firms. Most of the researchers only focus on single aspects of innovation activities that might be beneficial for a single stakeholder. The expansive research helps us in developing a more holistic view of innovation which as noted by previous researchers (Shapiro, 2001 and Potter, 2001) was in the past dominated by a cost spiral. There are still some clients who see innovation as a value engineering exercise to cut costs. Macfazdean et al. (2005) confirms through a detailed examination of the innovation literature that there are varying views on what actually constitutes innovative activity, and most of the literature deflects the attention from the core components of innovation. Hence, there is an urgent need to have a holistic and tailored innovation model for consulting engineering firms. The matrix in Table 2..2 matches the innovation activities to the work done by the relevant researchers. Based on the focus of these activities, it is not hard to group them into overlapping themes. The four relevant themes for these activities are: R&D innovation activities, activities related to communication on projects, innovation activities associated with introducing systems and client related activities. The above literature clearly provides a theoretical justification to answer our second research question that architecture or consulting engineering firms are types of knowledge-based firms mainly due to the similarity of their attributes. The above literature helps answer the fourth question and the findings from overall literature review clearly provides a theoretical justification to answer our first main question and helps us understand the innovation activities that can be used to develop a model to assess the impact of innovation activities specifically in the context of consulting engineering firms. Due to the precedence set by previous researchers some of the innovation activities from manufacturing will also be extended to consulting engineering firms but their application and relevance will be further tested using expert solicitation.

The review of literature to answer the main and underlying questions helps us put forward the first proposition for this research that is;

Innovation activity in consulting engineering firms is a function of R&D activities, communication activities on projects, introducing innovative systems and client related activities. Each of these are in turn are spilt into sub – activities.

Table 2.2 *Matrix maps out the commonly identified innovation activities against the key researchers (only select list included)*

Innovation Activities	**References**											
	Fagerberg (2008)/ Luecke and Katz	**Bratton & Gold (2003) Tidd &**	**Kaplan et al(2007)/Prusak**	**Tang et al (2008)/Roger (1998)**	**Morris 2008)/Brown et al (2005)**	**Cheng (2013)/King**	**Wang (2007)**	**Gassmann et al (2010)/ Chesbrough**	**Ilke (2002)**	**Johansson & Loof (2006) NIER (1999)**	**Brazeal (1993)**	**Cowen & Miles (1994)**
R&D activities												
Improving annual R& D budget			√	√						√		
No of patents registered in the past year			√									
No of active R& D projects			√									
Total R& D budget as percentage of turnover			√			√						
Partnerships with R&D organisations and tertiary institutions		√				√						
Acquisition of new initiatives and technology options to facilitate business				√		√						
Communication activities on projects												
Increasing the number of idea put forward by team members to leaders	√		√	√	√			√			√	
Reducing the average time from idea evolution to full implementation					√			√			√	
Resources made available for continuous innovation					√						√	

Increasing cooperation between individuals				√								
Using more opportunities to discuss innovation and reward smart ideas and reward smart ideas					√							
Introducing systems												
Improving the percentage of sales from products introduced in the past 1 year				√						√		
Improving IP and opportunities for commercialising & offering services on licencing arrangements				√		√						
Improving mechanisms for sharing and collecting data/product				√								
Introducing a Knowledge Management System	√	√	√	√						√		√
Using innovative decision making tools	√			√						√		√
Introducing particular technologies for training staff	√			√		√				√		
Client related activities												
Increased and focussed marketing activities				√								√
Effective use of market intelligence to achieve a competitive edge				√								
Optimising the savings achieved through successful operation/innovative ideas					√	√						
Introduction of client management tool				√		√				√		√
Broadening of client portfolio/diversification				√								√

Extending the model further in line with the observations of Bourne (2004) who notes that projects must also by their nature, and the nature of single task to be performed , work within the tradition of a clear focus on performance measures such as cost, time and quality. This leads us to exploring the nature of these measures in relevance to KBFs.

2.4 PERFORMANCE MEASURES

Project performance which is mainly gauged by project success or failure means different things to different people. Mian (2005, p 2) notes that each project stakeholder considers a different definition of success or failure, which is consistent with his or her perception and interests in relation to the project outcome. In order to develop common measures that broadly represent the interests of all stakeholders, the subject of project success or failure has been one of the main areas of focus for a number of researchers over the last decade.

Rubin and Seeling (1967) are considered the pioneers in this area first introduced the concept of project performance. Their research was based on investigating the impact of a project manager's experience on project's success or failure. The ideas was then taken up by Avots (1967) who extended it by conducting a theoretical study. The findings from the study concluded that the choice of the wrong project manager, lack of senior leadership support and untimely project termination were considered the main reasons of a poorly performing project. In the past most researchers have considered time, cost and quality as measures of project performance (Freeman et al, 1992, Rubin and Seeling, 1967). Concurrent research carried out by Belassi et al (1996) identifies that time, cost and quality are the basic criteria of project success. They are also discussed in articles on project success such as that of Skitmore (1997) and Shenhar & Levy (1997). Atkinson (1999) and Westerveld (2002) called these measures as the 'golden triangle'. However, the issues of project success turned out to be far more subtle than this. The approach to focus on these measures was considered mundane and can be quite deceiving as there have been projects which were provided an innovative design but were behind on cost and time. Conversely, as outlined by above researchers, there are examples of projects that were a technical failure but were very profitable and finished on time. This also shows that project performance or success is based on human perception and can be quite subjective. Researchers started realising that perceiving project success simply as the compliance with time, cost and quality can be qualified as a more narrow view in this respect. This approach has evolved over the last half century and now there is a clear agreement between researchers and practitioners that project success is much more complex than meeting cost, time and quality requirements and also includes other variables which are discussed later.

Russell & Jaselskis (1992), Abidali & Harris (1995) and Kanagari (1988) used prediction models to explain failure factors at the project level. These models were easy to understand and used financial indicators and ratios. These were derived by statistical analysis and research and evolved from a number of relevant and plausible financial indicators. More recently, Arditi (2000) reasoned that the use of financial ratio's to measure project failures may not be very reliable as they can only highlight symptoms. It is also very common to have the top management create data that can make themselves look good. Project success indicators based on this flawed data does not reflect the actual success of the organisation and can be an embracement for the associated stakeholders.

As the research on project success evolved researchers such as Pinto and Slevin (1987) and Morris and Hough (1987) found out that soft or subjective measures such as communication, environment events, community involvement, team member conflict, lack of negotiation and arbitration, legal disputes, management inability to understand site people, and stakeholders value were likely candidates for measuring project success or failures and warranted the need of including them along hard objective measures such as Cost, Time, Quality and Safety. Mian (2004, p 3-5) found the most commonly identified cost overrun issues in the literature in the last ten years included poor estimating, inclement weather, fee overrun and lack of positive cash flow. Less common issues included lack of contractor project type experience and contractor's lack of familiarity with local regulations. Issues such as complexity of project and inflation were found occasionally. Similarly, time overrun measures most commonly encountered included communication gap between project parties, inaccurate prediction of production output, inclement weather, design changes, safety issues, industrial action and skill shortages. Issues reviewed less frequently included lack of supply of plant, equipment & materials and site storage problems. Issues that were occasionally covered included locational project restrictions (site access) and production of design drawings. The information was based on interviews of different stakeholders on eight projects in Queensland. Some of the measures identified were only applicable to knowledge-based firms including the architect, consulting engineering team and their sub-consultants.

Sidwell (1982) carried out a study of 32 UK projects and concluded that client experience, form of building procurement and project and project organisational structure are elements of a complex model of project time performance. The success measures are both objective and subjective and include associated indicators. It was noted client satisfaction on cost and time, overrun on cost and time as a percentage of the planned cost and time were relevant to the design team. Ireland (1983) engaged in a similar work as Sidwell (1982) whose work focussed on projects in Australia. He discovered that the building cost was found to increase due to: increasing variations to the contract, poor architectural quality and the capability of the sub-contractors. Ireland used both objective and subjective measures to assess the success of a project. The measures relevant to the design team included engineering and design quality, actual program and project cost.

Mian (2004 p 2, 2005, p 3 & 2006) also found out that during this time period the most commonly found quality measures were reluctance to adopt quality systems, inadequate quality assurance and control systems, lack of product identification and traceability, lack of internal and external audits, infrequent inspections and insufficient training. Less commonly found factors included lack of control of inspection and testing equipment, lack of control of non-conforming product and poor data control. Quality measures least commonly found in the literature included lack of employee conscientiousness and lack of encouraging specialization in construction work. This indicated that the majority of clients and stakeholders now took the issue of quality conformance more seriously and believed that the issue of resuscitating failing projects due to poor quality of documentation or workmanship is vitally important to a vibrant, healthy industry. The old adversarial attitudes, which were, ingrained as part of poor project outcomes for at least some of the key participants were seen as being passé.

Van Aken (1996) defined project success or failure as the satisfaction or dissatisfaction of all stakeholders.

Rowlinson (1988) carried out a study of 27 industrial buildings in UK. The main objective was to identify variables which led to systematic improvement in the performance of these industrial building projects. Rowlinson (1988) used three type of measures:

- Objective, absolute measures
- Objective, predictability measures
- Subjective measures which mainly focussed on client satisfaction.

Davies (2002) noted that a group of 15 European private companies developed a best practice network mainly focussing on developing and shared credible data on project performance measures. One of the key learnings being shared by the network with the industry in general is the use of holistic and relevant performance measures on projects. Since then the network number has increased to almost ten and the membership to nearly a hundred organisations in Australasia, USA and Europe. Their main focus was client satisfaction and its impact on design fees.

A review of the above research indicates that further research on project performance should incorporate both subjective and objective success factors. The objective measures that need further contemplation are: cost performance, budget overrun, overrun on cost and time as a percentage of planned cost and time. The commonly used subjective measures to explore are client's satisfaction with quality, client's satisfaction with cost and time and relationship with other stakeholders. In some cases the measures are not applicable to a specific stakeholder but they do influence most of them in one way or the other.

However, not all of the above measures apply to consulting engineering firms which are the proposed focus and context of this study. Saqib et al (2008) notes that concept of project performance changes from one participant to another depending on their own interests, scope of services, technological implications, expectations and a range of other factors.

Due to its relevance to consulting engineering firms, it might be appropriate to review that work of Mian (2005 p 4-5) on project success which draws some parallels between construction project health and human physical health:

- State of health influences performance

- Health often has associated symptoms
- Symptoms can be used as a starting point to quickly assess health
- Symptoms of poor health are not always present or obvious
- State of health can be assessed by measuring key areas and comparing these values to established norms
- Health changes temporally
- Remedies can often be prescribed to return good health
- Correct, accurate and timely diagnosis of poor health can avoid small problems becoming large

Here project health is synonymous with project performance, if a project or any particular aspect of a project is not performing as expected by the stakeholders it would be perceived as unhealthy or failing. On the other hand if it is fulfilling the expectation of the stakeholders it would be perceived as healthy or successful. The requirement for rapid, accurate diagnosis lead to the concept of an initial broad health checking mechanism which could guide a further more detailed investigation designed to identify the factors contributing to poor health. The use of performance indicators to assess the state of the contributing factors allows remedies to be prescribed, based on the condition of the contributing factors investigated.

A model presented in **Figure 2.1** is derived from Deming's (1986) continuous improvement management cycle. This was developed to adapt the medical health model to a construction project scenario. This model is based on a four stage process beginning with broad and rapid assessment of current health, followed by a more thorough analysis of the areas identified as unhealthy, which allows prescription of a remedy and finally the last stage is the continued monitoring of the health condition.

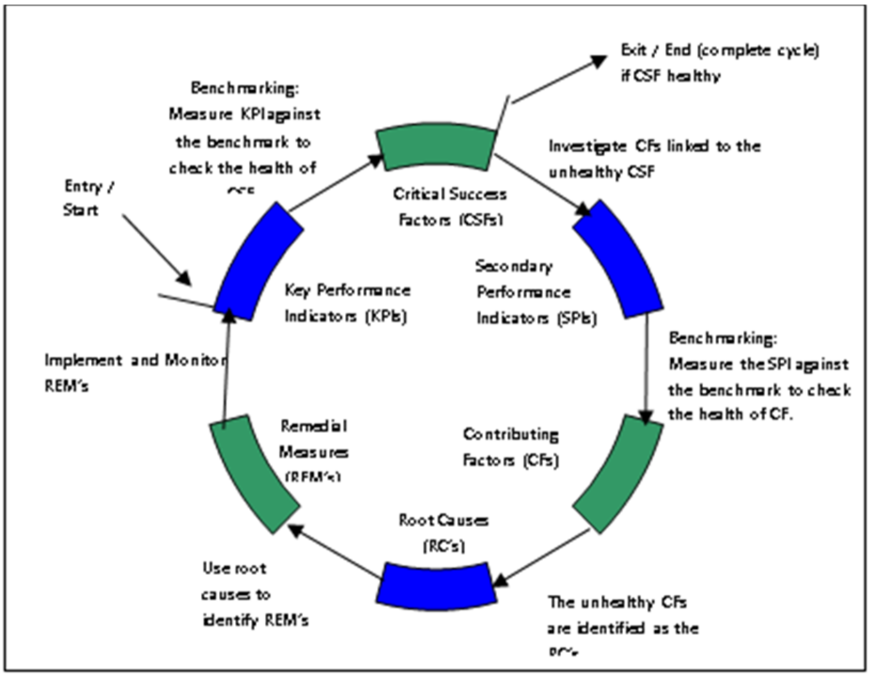

Figure 2.1. Project Health Check Model.

Returning to the research topic, architects and consulting engineers which established on the basis of research elsewhere falls in the knowledge-based category play an important role in the completion of a project. Kumaraswamy (1999) identifies that success factors for these firms include subjective factors such as team experience, project design complexity and mistakes in producing design documentation. Saqib et al (2008) notes that meeting design fee/profit goal, meeting project schedule and budget are subjective measures important from a designer point of view. He suggests that client satisfaction, professional staff fulfillment, minimal construction problems, and well defined scope of work are equally important.

Reviewing the above it is not difficult to ascertain that there are commonalities between the success measures set out by different project participants. However it may be defined in a way which is more akin to the role and expectation of a specific stakeholder. For example the owner wants the project to be completed on time and budget and the consultant want to achieve design fee and program goals. At the same time the builder wants to complete the project on time but have a lot of emphasis on safety which may not be important for the other stakeholders. The performance measures on projects relevant to consulting engineering firms for designers that may also have an influence on other stakeholders are outlined below:

2.4.1 Subjective Measures

- Client satisfaction with time
- Client satisfaction with design quality
- Client satisfaction with meeting the project budget
- Design team satisfaction.

2.4.2 Objective Measures

- Meeting design fee
- Construction time influenced due to design work/project program
- Meeting project budget.

The above answers the underlying question for the second research question. By adopting a global approach similar to the work of Chan (1996), in assessing projects success, it is quite easy to ascertain that project performance can be measured through soft and subjective measures such as client satisfaction, design team satisfaction with quality, design team satisfaction with fee and tangible & objective measures such as meeting design fee, construction time, and meeting project budget.

To summarise, the topic of project performance is very well researched and articulated. There is a constant stream of public reports, and commentary, about projects, which fail to meet pre-determined objectives. Many of these are high profile publicly funded projects that attract much adverse publicity. As the existing body of knowledge is quite extensive and based on credible collective knowledge of experienced project management academics and practitioners, the measures from the literature review will be carried over from the conceptual model without any further validation. However, as outlined in the methodology chapter, a group of experts will be asked to validate the relevance and relative priority of the innovation activities that impact project performance without further contemplating the types of measures used to gauge project performance.

2.5 RATIONAL FOR DEVELOPING A MODEL

To progress any further, it is important to justify and substantiate the need for a model to assess the impact of innovation activity on project performance.

Knowledge intensive firms have been seen as highly innovative, exhibiting a high proportion of R&D expenditure (Sundbo, 1998). Engineering consultancies demonstrate a contradictory case with comparatively lesser investment in R&D and other in-house innovation activities. The sparse investment into R&D has limited the opportunity to understand innovation in consulting engineering firms. Also, industry practitioners and outside observers appear to agree that the routine work that engineers employee may have innovation imbedded into it, but it does not present radically different solutions or require substantial changes in production processes (Baark, 2001 & 2002).In order to distinguish between mundane operational routines in engineering consultancies, Baark (2001 & 2002) identifies three major categories of innovations; new processes, new delivery methods and new producers. EFCA (2008) identifies the following two key reasons for reluctance of consulting engineering firms to develop and implement innovation models:

- Requirements, usually formulated in terms of deliverables and deadlines, leave little or no time to innovate. Due to the tight timeframe and fixed project completion dates, the search for innovation appears as an overload of work.
- Due to the current financial constraints it is difficult to absorb the innovation budget into the total project cost and often proves a prohibitive obstacle.

This clearly necessitates the need for developing an innovation model which impacts project performance. It seems from the literature review on innovation that there is very little work done by tertiary institutions in this space. Fagerberg, (2008), Tidd (1997) and Wolfe (1994) note that despite the popularity of innovation as a concept, it is still not recognised as a scientific discipline by universities at the postgraduate or undergraduate level. To bridge this gap between academia and industry, it is important to develop a research model which links innovation activity on project performance and provides an opportunity for entrepreneurs and research leaders to work closely with and learn from each other.

Furthermore, most of the researchers have linked organisational performance to innovation activity. Cohn (2013) notes that there a number of innovation models that help firms manage their innovation activities with proper measurement techniques and tools e.g. the Linear Model, the Innovation model focussed on teams, the Innovation Value Chain and other similar models . But there is insufficient evidence of links between innovation activities in firms in general and specifically in consulting engineering firms and project performance. Hobday (2000) notes that consulting engineering firms which are project-based, the projects are more important than the functional organisation. Turner et al. (2000) undertook a study across 19 project-based companies from 8 countries and 3 continents and interviewed 44 people across these firms. Some of the common themes of quotes that come out of the interviews were:

"Projects are the key factor for [our company] ... the company and its success depends on all projects, not just one.

Projects are the centre of gravity ... the value added for [our company] is in managing projects.

Increasingly, it is also more than that. It is managing projects so that clients get quicker completion, more creative processes, better managed projects."

Domb (2003) proposes that there is a need to extend the innovation concept to projects. He outlines that project managers in the past have avoided creativity in a belief that it creates uncertainty and is difficult to manage. He then acknowledges that innovation can be managed and focussed. He also notes that it is a reason why a project succeeds. The intent of this research is to fill this gap and draw a link between innovation and project performance.

To facilitate this I further explore the links of innovation to projects. Researchers have found that there also exists a link between project management and innovation (PMI- PMBOK, 2000). A project is about something new and unique and the produce of every project is unique in some distinguishing way. In line with the PMI definition, it is widely accepted that project management is used to bring a new idea or project from its conceptual stage through development to full implementation.

Moreover, one way to draw up a relationship is to go back to the definition of project performance. Project Management Institute (PMI), which was set-up in US in 1959, defines project management as 'application of knowledge, skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and performance expectations from the project' (White paper on MSF and PMBOK, 2001). Through the use of appropriate tools and techniques, projects are to be planned in a way that the expected outcomes relevant to program, quality and cost are achieved. Project teams directly interact with the client and their manager must ensure that appropriate trade-offs are made between cost, time and performance requirements of the project (Gray, 2000). It can be conveniently inferred that the concept of project management is associated with effective use of tools and techniques, introducing people skills improvement strategies/techniques and effective client management. Going back to Schumpeter and Freeman and some of the modern entrepreneurs (Davita 2006, Bratton and Gold 2003) innovation activity is defined as:

'The introduction of a new good, method or technique'

By looking at the commonalities in the above both the definitions it is not hard to envision that there exists a link between innovation activity characterised by the introduction of improved tools, techniques and people skilling strategies and project management which controls/manages the successful implementation of these activities on projects to ensure that they are completed on time, on budget, on quality and within the required client satisfaction levels. Thus we conclude that there exists a perceived positive relationship between innovation activity and project performance and this needs to be further tested.

The above linkage is also supported by research undertaken by Blayse and Manley (2004). According to them, engineering and construction firms need to innovate to win projects and to improve the financial performance of these projects. They must innovate to compete. Development and effective use of new technology can provide important competitive advantages for engineering and construction firms.

To further substantiate the link we consider one example of innovation activity e.g. knowledge management as its importance as a business enabler for consulting engineering firms has been established in this literature review. The link between knowledge management and project has been recognised as essential by a number of researchers (Brookes et al. 2006 and Linder & Wald (2011). Studies of knowledge management in projects environments have emphasised the difficulties from within projects and across projects (DeFillippi, 2001). To tackle these difficulties, more and more consulting firms are setting up shared knowledge management systems, repositories of tools and lessons learnt that can be used by their project organisation. DeFillippi (2001) notes some of the examples of readily available knowledge for project directors, project managers, engineers and project teams include:

- The project brief/plans
- Technical specifications
- Contractual documentation
- Business documentation related to the client organisation that directly impacts the project
- Project mobilisation reviews
- Post project reviews.

Fedida (2014) acknowledges a similar knowledge share for IBM projects and identifies that these are very useful in finding history (problems and decisions) and also identify who worked on the project. Consulting firms in Australia are more and more using these effectively to share lessons leanings and good practice rather than re-inventing the wheel each time a problem arises. The introduction of skilled networks and incubation groups are becoming more and more common to use the knowledge established from previous projects.

Before we go any further let's explore the linkages between innovation and measures which are used to gauge the performance of a project a bit further. Kanter (1998) showed that successful innovative projects were those empowered with an abundance of financial, structural and personal resources. Other studies have linked innovation to slack resources (Aitkin et al, 1971), lack of skilled people (Chakrabarti and Rubeinstein, 1957) and the perception of available resources (Ancona et al, 1992). There have also been studies conducted by small groups who have reported linkages between innovation and improvement in problem solving behaviour (Benbasat, 1993) and technology transfer due to adequate resources on projects.

With the growing pressures on organisations in the existing financial environment it is important that organisations innovate and use innovation activity as a competitive edge. There is more than sufficient evidence supporting this argument (Baker 2007, Brazeal 1993, Faberberg 2004 and Chow 2007). Furthermore, projects are very important for consulting engineering firms as the associated knowledge workers (Drucker 1959, Woodrigde 1995) produce revenue for the organisation by working on projects.

Furthermore, Bourne (2004) suggests that projects should be considered as organisations in microcosm, of human scale. The structure of both organisations and projects are similar as like organisations, projects also have teams, authority, culture and a goal. The major difference is that projects are temporary organisations and their structures may be different from the parent organisation they are operating in. The main reason is that projects are run by people who may belong to different organisations and may have different cultures (Theilen, 1999). Turner (1999) suggests projects are a subsidiary of the parent organisation. He identifies that project is undertaken to introduce a change because the organisation recognises that it cannot achieve its objectives by routine work. Although researchers identify other subsets of an organisation such as HR, Administration, Operations and Business Development but most of these operate due to the revenue generated from projects. Conversely, most of these subsets contribute heavily to project success. But organisations need better project performance to be able to perform better than their competition. In other words projects are the building blocks of an organisation. It is not unreasonable to infer that this will in turn have a direct impact on the organisational performance.

The above provides the answer to the second research question that innovation activity have a positive impact on project performance. Hence based on it we put forward our second proposition that:

Innovation activity positively impacts project performance for consulting engineering firms.

Finally, one of the other reasons of specifically concentrating on projects and projects success is because it complements my previous work on Project Diagnostics which was done under the umbrella of CRC for Construction Innovation and lead by Arup, a multinational consulting engineering firm. Depending upon the findings of the Delphi study, there might be an opportunity to link some of the work to the findings of Project Diagnostics, which are in public domain. The project in this case refers to the projects associated with the specific organisation being considered and not a multi organisational project.

Now, that the core theme of this study has been established, it is important to explore some of the other reasons for pursuing this specific topic of research. One of the drivers of developing a more holistic model of innovation is to expand the tunnel vision thinking of some of the previous researchers who have always considered innovation only as an enabler of cost cutting on projects. The model from this research will help in building up on the work by Shapiro (2001) and Porter (2000) and look at other innovation related activities that are identified in the preceding sections. It is envisaged that the lessons learnt from this research can also be useful to improving procurement process in the Queensland Government where work has in the past been awarded to the lowest bidder which has caused huge issues within the engineering design because of the under cutting of fees. (McLeish, 2004). This is important to break this trend which still continues in 2015 across some of the agencies embedded within the Queensland Government. The urgency for investment into a holistic innovation model is compounded by the current global financial crisis is which is hitting hard on some of the consulting practices in Queensland. A recent survey undertaken by Consult Australia (2014 p 1-2) across some of the major consulting firms identified the following impacts due to the downturn of the industry:

- There ere has been a decrease in the size of firms by between 9 and 16%. Ninety percent of the firms are those that employ more than 100 people. This is on top of a 30% reduction in firm size two years ago.
- Firms continue to make planned redundancies and shift staff to interstate offices.
- On average, firms had only 3-6 months of secured work for less than half their workforce and less than 1-3 months of secured work for more than 80% of their workforce.
- Firms are expecting declines in both profit and revenue in the next 12 months.
- Business remains pessimistic about the growth of Queensland industries within the next 12 months with all sectors expected to slightly decline except for transport and defence.

- Overheads for business have increased with inexperienced procurement personnel singled out as the largest contributing factor increasing the cost of tendering for firms doing business with government.
- Government agencies and departments are viewed as the most expensive to tender for and also the poorest in their ability to procure well.
- The importance of having assessment models has also been highlighted by Cutler's (2008) review of innovation activity in Australia. Cutler suggested that presently there is not enough being done to assess the innovation capability of organisations. He strongly recommends that the government should do more to facilitate the implementation of indicators to measure performance. This view is also shared by Pinto and Slevin (1987) who suggest that there is an increasing need for tools for monitoring and feedback that enables a positive response to troubled areas.

Furthermore, there is a widely held view that innovation in academia is still under developed and highly fragmented (Wolfe 1994, Tidd 1997) so innovation models similar to this research will help in filling this vacuum. Fagerberg et al (2008) notes that despite the popularity of innovation as a concept, it is still not recognised as a scientific discipline at universities at the postgraduate or undergraduate level. In order to widely introduce research and executive education model which are relevant to this scientific study it is important to identify entrepreneurs and research leaders. The leaders should be trained to work closely with the industry to explore tools or assessments models that can help organisations assess the benefits of their innovation activity and provide the justification for investment into similar initiatives. This is an imperative in the current financial market when organisations are struggling to retain their staff due to reduced project activity. Finally, Fagerberg (2008) also points out that very little has been written on innovation studies although there is significant literature on the emergence of a new scientific field which can be used to inspire readers.

Combining the two propositions which are based on the findings from the literature review provides the basis for *developing a conceptual model for assessing the impact of innovation activity on project performance of consulting engineering firms.*

2.6 DEVELOPMENT OF A CONCEPTUAL MODEL

A robust literature review was undertaken to develop the conceptual model. The review started with researching academic and credible resources for exploring innovation, innovation activities and its relevance to consulting engineering firms. This review assisted in exploring, establishing an understanding and answering the following research questions:

- What are innovation activities that can be used to develop a model to assess the impact of innovation activities specifically in the context of consulting engineering firms?

  To answer the above question it is important to answer some of the underlying questions which are:

  - Is innovation required for knowledge based firms and consulting engineering firms to succeed?
  - What is innovation in the context of manufacturing and can this be easily applied to knowledge-based firms?
  - What are consulting engineering firms? What are the similarities with knowledge-based firms?
  - What innovation activities can be applied to consulting engineering firm?

- Does innovation activity has a positive impact on project performance?

  To answer the above question it is important to answer some of the underlying questions which are:

  - How is project performance measured for consulting engineering firms?

A matrix to map out the literature against the innovation activities was used to establish the innovation activities forming part of the model. This resulted in proposition # 1:

Innovation activity in consulting engineering firms is a function of R&D activities, communication activities on projects, introducing innovative systems, and client related activities. Each of these are in turn spilt into sub – activities.

A further review of literature on project performance measures and their proposed linkage to innovation activity lead to proposition #2:

Innovation activity positively impacts project performance for consulting engineering firms.

Combining the above provides some justification of a conceptual model to mutually assess the impact of innovation on project performance. By combining the two propositions, the overall proposition for this research study is:

Innovation activity in consulting engineering firms is a function of R&D activities, communication activities on projects, introducing innovative systems, and client related activities. Each of these are in turn are spilt into sub – activities. And that these activities have a direct positive impact on project performance. Project performance is measured using the following:

- *Client satisfaction with time, design quality and budget.*
- *Design team satisfaction.*
- *Meeting design fee/project budget & program.*

The proposition is the basis of the innovation management conceptual model. The technique of using models to represent or explain phenomena and relationships in the real world has developed from their use in the formal sciences and is now being used more and more by the social sciences (Sidwell, 1985). Sidwell who has done credible work in this area further suggests that a model needs to be a representation of what actually happens in reality. Walden (1990) argues that the very essence of a model is to simplify the real world into a scale smaller than 1:1. A good example of a model is a CPM chart which represents real activities of a construction project. Similarly in the engineering design world, Wind Tunnel Testing is used to test the models of bridges may be in high speed simulation wind tunnels. Sidwell (1985) also identifies that models may be descriptive, predictive, explorative, physical, conceptual or mathematical. Echenique (1970) did a lot of work on the applications of these models.

This aim of this research is to develop a conceptual model based on literature review which is explains the linkages between innovation activities and project performance of consulting engineering firms which is shown in Figure 2.2 and in further detail with sub innovation activities in Figure 2.3. Some of the above measures might not be very relevant to consulting engineering firms as they have been extrapolated from knowledge-based firms and other industry sectors. It is important to get the view of experts in the industry on the relevance, applicability and relative importance. Delphi is an attempt to elicit expert opinion in a systematic manner for useful results. It usually involves iterative questionnaires administered to individual experts in a manner protecting the anonymity of their responses. Feedback of the results i.e. importance rating is included in each questionnaire iteration, which continues until convergence of opinion, or a point of diminishing returns is reached. The end product is the consensus of experts, including their commentary, on each of the questionnaire items, usually organised as a written report by the Delphi investigator. (Sackman, 1975). The Delphi technique is a rigorously developed method for using experts in the process of research (Outhred, 2001). The main aim of using Delphi is to add further credibility to the research process and validate the measures identified from the literature review. The aim of the validation is to test the proposition and to get confirmation of the model through:

- Validation of the list of innovation activities that have a positive impact on project performance.
- Also, get the experts to prioritise and rank these activities in terms of their impact on project performance.
- Recapping the benefits of this research, it is envisaged that the outcomes of this research will assist in improving project performance through the implementation of appropriate and relevant innovation activities in consulting engineering firms. There will be an opportunity to re-invest the benefits from improved performance into ongoing advances and innovation requirements. Some of the anticipated benefits are:
- The model will be used to identify relevant innovation activities that can benefit consulting engineering organisations rather than investing into a whole host of generic innovation ideas.
- The model considers a more holistic view of innovation and captures the innovation related activities associated with 'stakeholders' involved in a project environment i.e. clients, internal organisational team members and

project team members. It also encapsulates innovation activities associated with technology, use of process and tools and research and development. This is a major shift from the work of previous researchers on innovation which only considered innovation as a cost cutting activity.

In current times when the market conditions are tough, consulting organisations will only invest in prioritised innovation activities which will help them re-assign the surplus income to other activities. It will also reduce the risk of poorly performing projects provided the appropriate innovation activities are implemented at the right times.

This concept will be comparatively more useful to engineering firms where innovation activities and their implementation are still in the infancy stages. The model will not only be useful to reform the internal organisational policies and systems but also may be offered to client as a stand-alone commercial service. It is anticipated that the benefits and savings realised from the implementation of this research will motivate consulting engineering firms to enhance their cash or in-kind investment into executive education models and research program specifically related to this field. It is important to emphasise that the existing body of knowledge on project performance is quite extensive and credible so the innovation model is being developed on the assumption that the measures of project performance from the literature review will be carried over 'as is' from the conceptual model without any further validation. Also, to avoid introducing any ambiguity for the Delphi experts, they will be asked to validate the relevance and relative priority of the innovation activities based on the following performance measures.

- Client satisfaction with time, design quality and budget.
- Design team satisfaction.
- Meeting design fee/project budget & program.

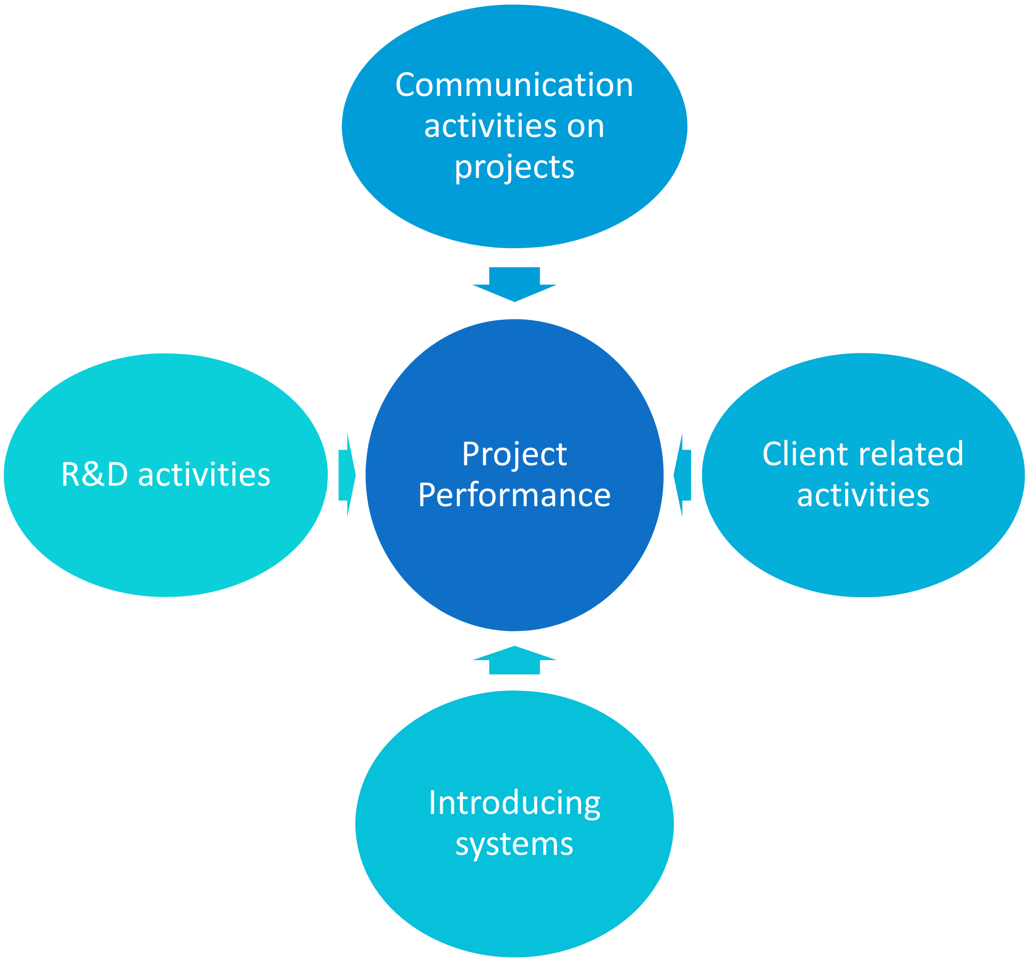

Figure 2.2. Innovation management conceptual model

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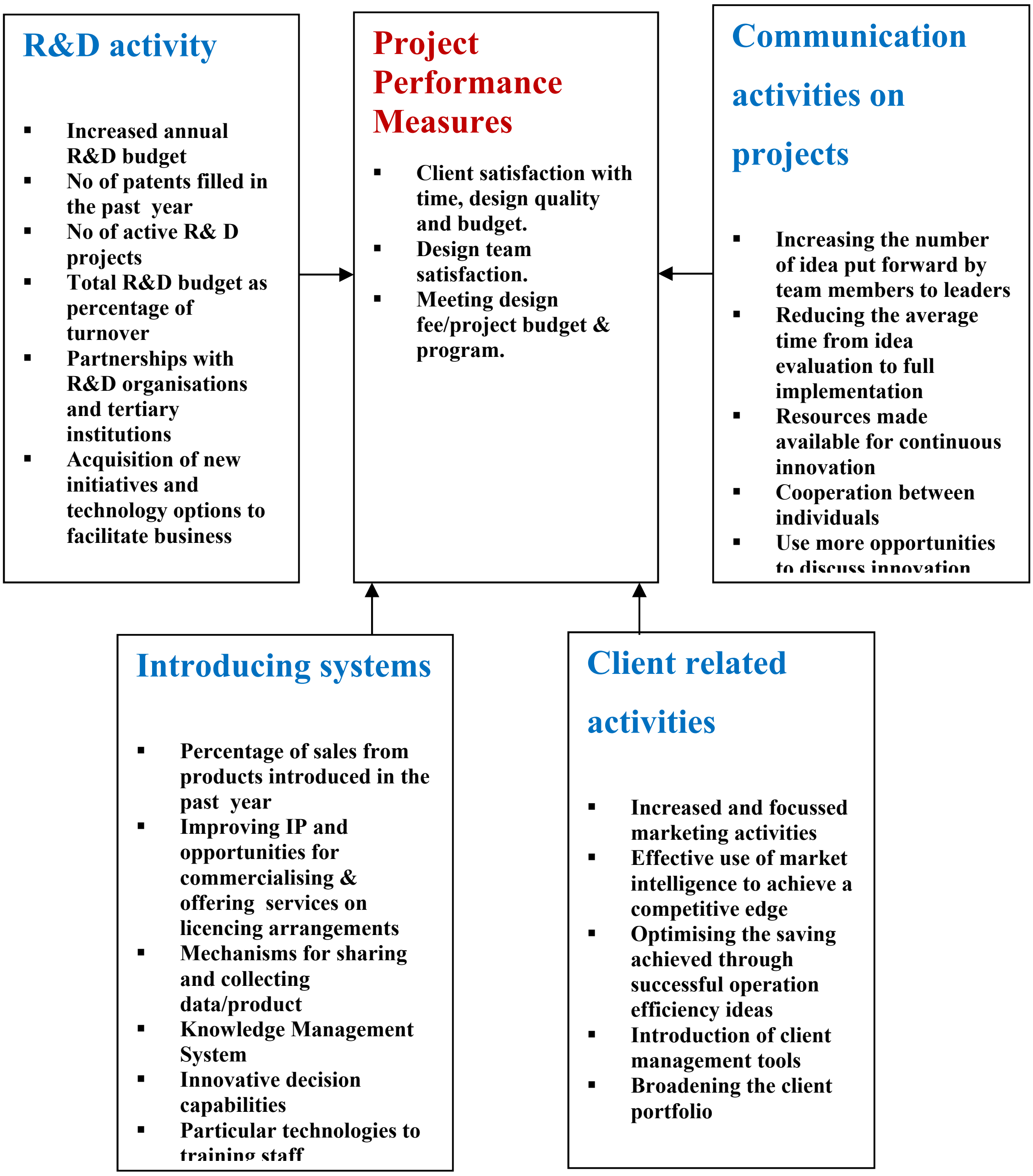


Figure 2.3. Conceptual model that shows each of the main activities broken down into associated sub-activities

Chapter 3: Research Methodology

"Research Methodology can be seen as a way of thinking about and studying social reality" (Strauss & Corbin, 1998). Methodology determines how the researcher goes about investigating what is to be known (Guba & Lincoln 1994 and Zikmund et al, 2010). The Literature Review reveals that some researchers used quantitative methods and others developed Case Study models (Sidwell 1982, Chan 1996, Fagerberg 2008, Brazeal 2003). They collected qualitative as well as quantitative data through qualitative methods. Generally, we refer to data as quantitative when it is statistically analysed and expressed, presented or measured in numbers. Furthermore, data which cannot be statistically analysed and is difficult to measure in numbers is often called qualitative: for example, strong, weak, easy or difficult (Ghauri, 1995).

In the quest to identify a robust set of innovation measures, literature reveals that scientists employed various data collection instrument ranging from unstructured interviews that asked the respondents to list a number of measures (important to gauge innovation on projects) to structured interviews that required the respondent to rank a list of measures that affect organisational or project innovation strategies.

3.1 MIXED METHODS

(Casebeer & Verhoef 1997) note that the quantitative and qualitative paradigms are at each end of the quantitative – qualitative continuum of research. A research can make use of both approaches of qualitative and quantitative approaches in one research or, one approach is dominant with the other supporting it (Johnson & Onwuegbuzie 2004, Johnson, Onwuegbuzie & Turner 2007). Silverman (1998) asserted that 'it is inaccurate to assume that quantitative and qualitative research are polar opposites.' There are no principled grounds to adopt either a quantitative or a qualitative approach. It all depends on the objectives driving the research and the choice of the researcher if they can substantiate the relevance and a good fit towards the topic being researched. Each research have to select a method based on their due diligence and review of relevant research material. For this research, Delphi analysis was used to validate the model which was developed from the literature review which is in line of what researchers have done in the past. (Outhred, 2001; Linstone, & Turoff , 2011).

3.2 BRIEF REVIEW OF METHODOLOGIES

A number of methodologies were considered before the above proposed methodologies were selected.

3.2.1 Surveys

A survey is sometimes the only way to get a picture of the current state of a community, a project, an organisation, an electorate or a profession (James, 1999). In fact the use of surveys to undertake investigations into a particular population is quite common. Czaja and Blair (2005) noted that this method is being commonly used not only across scientific and research activities but also business, marketing, media and a number of other areas. The fundamental of this methodology is to secure required information from a population or area under research by securing information from a smaller and accessible group that represents the larger population. The information can be gathered by face-to-face interviews, telephone contacts, electronic contacts and mail-outs. Babbie (2001) notes that some of the benefits of the surrey methodology, include:

- its ability to describe the characteristics of a large population.
- since being self-administered, they make large samples feasible.
- they are quite flexible in structure.

However, the research topic under observation is quite complex as it includes a number of interrelated and holistic measures which would be quite difficult to explain through telephone or mail-outs. Also, as the topic is specifically related to consulting engineering firms, it is conjectured that only feedback from experts directly or indirectly associated with this specialist sector will add value to the research. Furthermore, due to the number of surveys received by the average person these days and declining response rates (Berk et al, 2007), it is important that the survey is sent to a targeted group of relevant people so that the results can produce interpretable and useful information.

More recently, people in the industry have been bombarded by generic and lengthy surveys which in most cases are directly being sent to them by research students or marketing companies. In the current environment, most of the consulting firms in particular have had a number of redundancies and they are using a restricted number of employees to run projects and day-to-day operations which put a huge time pressure on these employees. Due to these commitments and issues, undertaking an expansive and generic survey will not yield the same quality and enriching content as expected from an engagement with a focussed group of specialists who are known in some way to the researcher and sympathetic to help them achieve their deadlines for the completion of this thesis.

3.2.2 Grounded Theory (GT)

Researchers in the past have defined 'Grounded theory'(GT) as one of the qualitative research approaches suited to the purpose of theory development (Strauss & Cobin, 1990, Glaser 1995, Charmaz 2000 and Parse 2001). In this case theory comes from the data and at no stage does the investigator attempt to link a specific theory from another study onto the data (Stern, 1985). This means that the data determines:

- What to be explored in this research
- The literature searched
- The research question
- The number of participants

This means that theory is 'grounded' in verified data which is to be gathered through questionnaires, interviews, focus groups and similar instruments. From this data, attempts are made to identify common threads or key words whilst ensuring that research does not close off other possibilities/later observations. The use of GT was attractive for this complex, integrated and holistic research problem because of its ability to deal with a number of complex issues concurrently. However, Davidson (2002) has noted a number of issues with it, notably lack of precision and lack of clarity in how data sets are to be identified and analysed. Furthermore, after undertaking a detailed review of literature, no research relevant to consulting engineering firms is currently being undertaken that specifically uses the GT model. There has also been little work done in the knowledge-based firms using GT.

Many research projects, particularly those exploring the relationship between a small number of definitive variables, will continue to be well served by one of the methods identified above. In the exploration of more diverse domains, however, some reconsideration of research frameworks to be used would appear opportune to ensure relevance and practicality of outcomes.

Hefferan and Mian (2006) note that research projects in the property, development and asset management domains provide a good example of these challenges. These areas have been the subject of dramatic change over the last decade, with significant shifts in demographics, technology and business structures influencing both product and use.

There are a number of innovative research methodologies now used widely across many research activities and disciplines. However, there are only a limited number of cases where these have been used for research in development, construction and property asset sectors. This is despite the fact that, on the face of it, some would seem well suited to research in these areas. Delphi analysis methodology offers an innovative research framework that addresses the need to widely canvas diverse opinions and information sources in forming aggregate conclusions. We discuss Delphi and its viability for this research next.

3.2.3 Delphi Study

Delphi originated from the Rand Corporation in 1948 and has been extensively used by organisations, research institutions and government. Linstone & Turoff, (2011; 1975) define Delphi as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. Fowles (1978) asserts that the word Delphi refers to the hallowed site of the most revered oracle in ancient Greece. Forecasts and advices from gods were sought through intermediaries at this oracle. However Dalkey (1968) states that the name "Delphi" was never a term with which either Helmer or Dalkey (the founders of the method) were particularly happy. Dalkey (1968) acknowledged that it was rather unfortunate that the set of procedures developed at the RAND Corporation, and designed to improve methods of forecasting, came to be known as "Delphi". He argued that the term implies "something oracular, something smacking a little of the occult", whereas, as a matter of fact, precisely the opposite is involved;

it is primarily concerned with making the best you can of a less than perfect kind of information.

One of the very first applications of the Delphi method carried out at the RAND Corporation is illustrated in the publication by Gordon and Helmer (1968). Its aim was to assess the direction of long-range trends, with special emphasis on science and technology, and their probable effects on society. The study covered six topics: scientific breakthroughs; population control; automation; space progress; war prevention; weapon systems (Gordon and Hayword, 1968). The first Delphi applications were in the area of technological forecasting and aimed to forecast likely inventions, new technologies and the social and economic impact of technological change (Adler and Ziglio, 1996). In a reference to technology forecasting, Levary and Han (1995) note that one of the objectives of the Delphi method is to combine expert opinions pertaining to the likelihood of realizing the proposed technology and the expert opinions concerning the expected development time into a single position. When the Delphi method was first applied to long-range forecasting, potential future events were considered one at a time as though they were to take place in isolation from one another. Later on, the notion of cross impacts was introduced to overcome the shortcomings of this simplistic approach (Helmer, 1977).

The method emphasises on structuring group communication processes in a systematic manner in order to achieve a reasonable convergence of opinion from a group of experts (Linstone & Turoff, 2011). Outhred (2001) makes suggestion on the characteristics of an appropriate team of expert. He emphasises that the experts should not be solely academics but include stakeholders, experts and facilitators. Ojala et al. (2013) had a differing view and undertook a Delphi study to understand the future of transport and logistics in the Baltic Sea Region. He used a select group of academics for his Delphi group. Ojala noted that the benefit of limiting the sampling frame in this way is that academics are less likely to have political interests that would distort the results. The downside was that it might not cover the issues faced by the broader business community. Ojala’s study was based on the assumption that since the academics belonged to a well-educated segment of the society they should have the capability to make well-informed projections of the future. There are no strict guidelines on the number of experts but previous researchers (Linstone and Tutoff, 1975: Outhred, 2001: Skulmoski et al, 2007) have used 4 to 11. The larger the group, the more convincingly the results can be said to be verified. However, a smaller sample might be used, with results verification conducted with follow-up research (Skulmoski et al, 2007). In some case researchers have used a final workshop to further validate the research outcomes from Delphi which is used as an extension to it and involves the same Delphi experts. Researchers (Nambisan et al, 1999; Wynekoop and Walz, 2000) recommend that, results should be cautiously interpreted, if the sample size is small or if the participant expertise is under question. For this study, Delphi is being used to confirm the innovation activities that have a positive impact on project performance. The conceptual model for this research was developed from a review of the literature.

Patari and Sinkkonen (2013) build upon the work of previous proponents of using Delphi process. Patari and Sinkkonen note that the Delphi method is probably the best-known forecasting mechanism carrying its own name. It is a qualitative research method that is applied widely to a variety of problems in different domains. Patari reiterates some of the key features of a Delphi procedure i.e. iteration, anonymity, controlled feedback and a group statistical response

Schmidt (1997) notes that that the number of rounds of questions will vary from case to case and the researcher must know when, in effect, to stop polling. Too many rounds, or too many items for consideration for ranking, may cloud consensus. He observes that the good use of statistical techniques should bring consensus out from the optimum number of rounds – whatever that number may be for the specific project. In this regard, Loo (2002) considered that provided that the initial research leading up to the Delphi process was sound, and the process well organized and executed, then three or four rounds should be sufficient to secure the required level of convergence and consensus. This appears likely for this research project but will be dependent on achieving a healthy convergence.

Kerstin Cuhls (2001, p 98) from the Fraunhofer, Germany, Institute of Systems and Innovation suggest that before starting a Delphi study, the following questions should be considered:

- What are the objectives of the study under review?
- Do we have the right resources?
- Is Delphi the right choice? Have we undertaken an in-depth analysis?

- What are the questions in reference to the particular study?

Delphi analysis methodology offers an innovative research framework that addresses the need to widely canvas diverse opinions and information sources in forming aggregate conclusions. Substantial research work exists (Gupta and Clarke 1996, Okoli and Pawlowski 2004, Ono and Wedemeyer 1994, Rowe and Wright 1999) that confirms that Delphi analysis is relevant and robust in many contemporary research areas. The work by Senaji et al (2014) uses Delphi to understand and validate an African perspective on leadership culture and motivation. (Okoli and Pawlowski, 2004) note that Delphi can be used to identify/prioritize issues; as well as to develop concepts/frameworks.

These researchers also identify that like any other research methodologies, there are certain structural and operational components that need to be carefully managed to ensure sound process and outcomes. Schmidt (1997) recognised the risk that Delphi analysis, poorly applied, can be less than definitive or certain. He noted, therefore, the importance of close management of the process and of statistical support for conclusions through the various phases. It was seen as important to keep the time for responses and the timing between rounds relatively short. This would assist in maintaining levels of interest and momentum.

Gupta and Clarke (1996), in an extensive search, identify over 460 pieces of published research where Delphi has been substantially used in areas as diverse as education, agriculture, medicine, engineering and medical services, environmental studies, finance and economics, tourism and management. Some of the areas of its application identified by Linstone and Turoff (1975) are:

- Gathering new and historical data
- Budget allocations
- Identifying and Exploring urban and regional planning options
- Planning university curriculum development
- Developing an educational model
- Exploring priorities of personal values and social goals.

Outhred (2001) successfully used the process in a thesis pertaining to the assessment of environmental impacts of pre-fabricated residential building systems in Australia. Delphi study was used to validate the model developed by literature review and is explained in more detail in the next chapter.

3.3 RESEARCH PLAN

Leber et al (2004) suggests that it has proved effective to split an innovation process or project into a stepwise research plan. The steps typically used by previous research studies are:

- Developing a plan- literature review and proposition development
- Filter ideas- Analyse literature review for identifying trends and themes. This stage can also be used to map out research questions. Other proposed methods frequently used as part of this stage include; Pilot studies, Development of individual frameworks etc.
- Develop the realisation plan- research development into methods, models or analytical frameworks.
- Refinement of ideas- Validation- Using Delphi study supported two or more statistical analysis to refine and validate ideas.

This process is further extended to include the well-known approach by Deming (1967) which identifies an additional phase of ‘lessons learnt’ mainly designed to improve the process and provide direction for future research. A research plan for this study is shown in Figure 3.1.

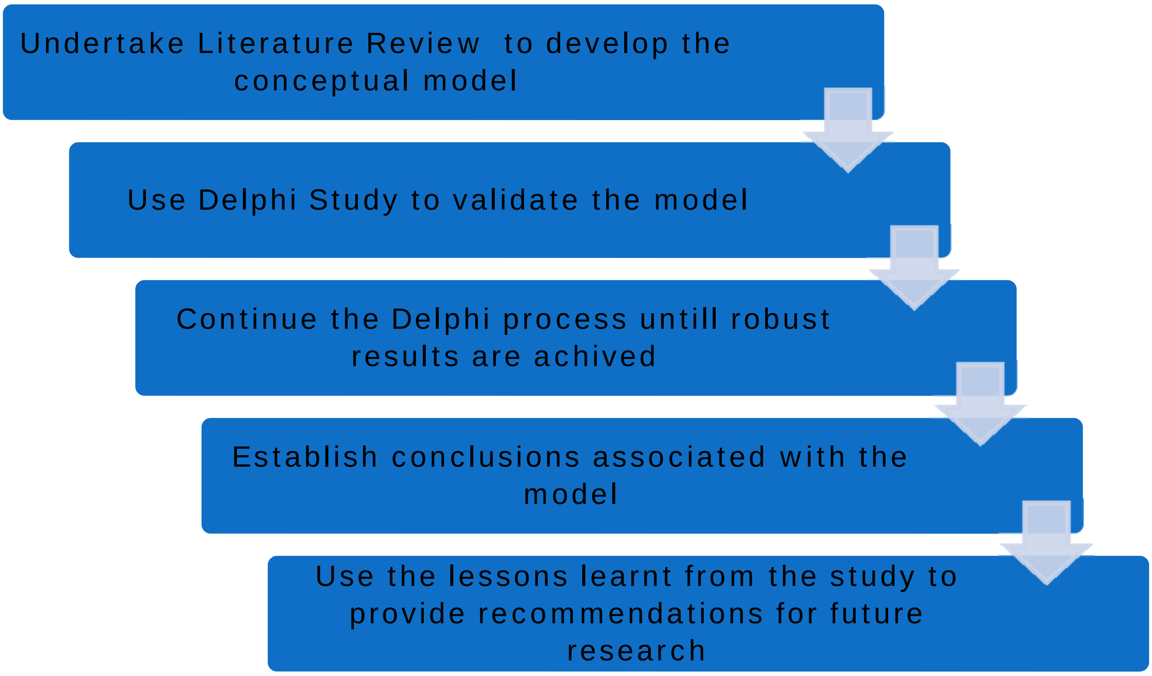


Figure 3.1. Research Plan

3.3.1 Literature Review-Developing the research model

An in-depth literature review in Chapter 2 was undertaken to specifically explore innovation and innovation activity in the context of consulting engineering knowledge-based firms. It was established that there are some common threads of variables that influence project performance. The four relevant themes for these activities are: R&D activities, communication activities on projects, introducing systems, staff related activities and client related activities. It was further established through a robust analysis of the literature review that innovation activity positively impact project performance. Combining the two propositions becomes the basis of developing the model for assessing the impact of innovation activity on project performance in the context of consulting engineering firm. The research model is shown in Figure 1b in Chapter 2.

3.3.2 Validation of the Model using a Delphi process

The Delphi study which is a well-established research technique was used to validate the conceptual model. As part of this study, expert opinion was solicited on:

- The relevance of innovation activities that have a direct positive impact on project performance

- Relative weighting or strength of innovation activities that will form part of the prioritised model that help us establish how some of the innovation activities have a more positive impact on project performance as compared to others.
- A prioritised model will then be presented to the experts through a workshop and feedback process to get their feedback on the rank and if they would want any additional criteria to be included into the model.

3.3.3 Check the Robustness of the Results

As the Delphi rounds progresses relevant data will be added and deleted based on the findings of the Standard Deviation (S.D) reinforced by Kendall's coefficient of Concordance which is also complemented by Chi-Square. An alternate way to determine convergence using box plots will also be used. Box plots can be used to determine if the interquartile range (where 50% responses lie) and associate average assigns a criteria a high or low score. ANOVA is a more sophisticated technique which may be used to measure the variation in the responses from the experts. The Delphi rounds will be repeated until a healthy convergence is achieved and there are no further gains from continuing with the study. Importance index may be used to develop a prioritised innovation model.

3.3.4 Conclusions/Recommendations for Further Research

For the sake of simplicity Step 4 and 5 of the research plan are being merged. In the past few years there has been a growing emphasis on the use of innovative tools, strategies and policies with a view to gain a competitive edge. After learning the lessons from the manufacturing sector, consulting engineering firms have also changed their focus and they are more supportive of investing into innovation activity. Some of the consulting engineering firms have undertaken some initial steps towards 'adhocly' integrating some aspects of innovation to suit their's and clients business needs. There is still a long way to fully embrace innovation in a holistic manner and this model provides a road-map to help them prioritise and make relevant their investment into innovation.

Before embarking on this research, I undertook some informal discussions with some senior managers from some of the leading consulting engineering firms in Brisbane, Australia. Through the discussions, it was easy to establish that there is a need of similar structured, innovative and holistic tools that adopt a systematic approach to measuring innovative activities. Their view was that this can help the strategic managers to prioritise and invest in initiatives that will have a direct impact on the firm's performance and prove to be a benefactor especially in the current tight financial market. To respond to these growing needs it is proposed to develop a model that assesses the impact of innovation activities on project performance specifically to service Knowledge-based Firms. The main emphasis is to:

- Identify the innovation activity that impacts project success
- Identify the measures of assessing project performance relevant to consulting engineering firms
- Develop a model that explains the inter-links between them.

Although the intent for the time being is to only target consulting engineering firms, it would be useful to extend this concept to other stakeholders such as contractors and clients. Although due to the specific focus of their research, researchers have not considered considering contingency factors such as project stages and procurement types, it would be good to develop a tool that broadly applies to different project stages and uses different procurement methods. It is also recommended if possible to change the dependent variable which is the project performance to organisational performance. This will enable the inclusion of other organisational facets such as HR, Operations, Admin and Business Development and Marketing.

A detailed analysis of numerical data from Delphi is undertaken to draw down the conclusions. Some of these provide a clear direction for future research and improvements that can be tuned into the innovation model development being developed as part of this research. This will further expand its relevance and application.

3.4 COMPARISONS OF STRENGTHS AND WEAKNESSES OF DELPHI

Delphi has been successfully used by organisations, research institutions and government for more than 60 years. The brief review of Delphi in section 3.2.3 provides some justification for me to use Delphi as the proposed methodology for this research. However, a more detailed review is undertaken into strengths and weaknesses to substantiate that my decision is based on sound reasoning and credible research.

There have been several studies (Amment, 1970; Wissema, 1982; Helmer, 1983) focussing on the strengths of Delphi. In fact, the Delphi technique was considered by Uhl (1983), Dalkey (1969) and Helmer (1966) to be the best tool available for consensus building. The anonymity ensured by Delphi process is its main strength. It promotes a meaningful dialogue where people are not scared to share radical views without having inhibitions about changing them due to the opinion of the other expert panelists. Delphi is particularly powerful in acquiring reliable consensus of a group of experts' opinions by a series of intensive questionnaires together with controlled feedback (Dalkey and Helmer, 1963).

Another key strength is its powerful use as a forecasting tool. A study conducted by Milkovich et al. (1972) reports the use of the Delphi method in manpower forecasting. The results of the comparison indicated high agreement between the Delphi estimate and the actual number hired and less agreement between quantitative forecasts and the number hired. Another study by Basu and Schroeder (1977) reports similar results in a general forecasting problem. They compared Delphi forecasts of five-year sales with both unstructured, subjective forecasts and quantitative forecasts that used regression analyses and exponential smoothing. The Delphi forecasting consisted of three rounds using 23 key organization members. When compared against actual sales for the first two years, errors of 3-4% were reported for Delphi, 10-15% for the quantitative methods, and of approximately 20% for the previously used unstructured, subjective forecasts.

Also, Delphi is quite flexible and can easily be tailored to individual project needs without giving away its power. Its strength lies in generating and filtering intuitive ideas that can be critiqued by experts. Delbecq et al (1975) note that Delphi allows open minded questions, it tolerates flexibility in the means used to make sense of the data and it permits flexibility in the selection of the staff as the panel selection is not constrained by geography, time or cost. Okoli and Pawlowski (2004, p-19) note that research studies in the past have shown where expert opinion is required the average of individual responses is inferior to the averages produced by group decision and consensus.

Lastly, the Delphi process promotes social change. Experts both shape and are shaped by the ideas generated by the panel. Mitchell (1991, p 333) wrote "the Delphi method is really effective in constructing new realities and encouraging participants to forecast where they seem their role in the future" and that "the method is an educational tool for the participants themselves assisting to clarify individual opinion and understanding of a particular topic and also to develop skills in future thinking".

Delphi is still one of the best methods for building a consensus about future trends. However, to improve its effectiveness, the researcher should give due consideration to the instructional quality, clarity, presentation and length of each questionnaire iteration. In line with Borg and Gall's (1983) recommendations, it is important to explain why participation of each expert is important and sharing the range of expertise represented on the panel as a way of affirming the significance of their contribution. The Delphi method is based completely on the judgment of the panel of experts and is not reliant on previous historical data. It is therefore suggested that the method is typically intended to provide a trend of judgements (from the expert panel) on a specific subject area, rather than producing a quantifiable measure or result (McLeod & Childs, 2007). This method can therefore be used in new and exploratory areas of research that are highly unpredictable and not easy to quantify.

Like any of the other research methodologies, the Delphi method has criticism as well as support. The most extensive critique of the Delphi method was made by Sackman (1974) who criticizes the method as being unscientific and Armstrong (1978) who has written critically of its accuracy. Martino (1983; 1978) underlines the fact that Delphi is a method of last resort in dealing with extremely complex problems for which there are no adequate models. Helmer (1977) states that sometimes reliance on intuitive judgement is not just a temporary expedient but in fact a mandatory requirement. Makridakis and Wheelright (1978) summarize the general complaints against the Delphi method in terms of

- A low level reliability of judgements among experts and therefore dependency of forecasts on the particular judges selected.
- The sensitivity of results to ambiguity in the questionnaire that is used for data collection in each round.

- The difficulty in assessing the degree of expertise incorporated into the forecast.

The complaints can be summarised in Martino (1983) lists of concerns and is outlined below:

- **Illusory expertise:** some of the experts may be poor forecasters. The expert tends to be a specialist and thus views the forecast in a setting which is not the most appropriate one.
- **Sloppy execution:** there are many ways to do a poor job. Execution of the Delphi process may result in experts losing the required attention easily.
- **Format bias:** it should be recognized that the format of the questionnaire may be unsuitable to some potential societal participants.

However, Goldschmidt (1975) attributes the above shortcomings due to poorly conducted Delphi studies. He warns that it is a fundamental mistake to equate the applications of the Delphi method with the Delphi method itself, as too many critics do. There is, in fact, an important conceptual distinction between evaluating a technique and evaluating an application of a technique. Schmidt (1997) recognised the risk that Delphi analysis, poorly applied, can be less than definitive or certain. He noted, therefore, the importance of close management of the process and of statistical support for conclusions through the various phases. Equally important is to keep the time for responses and the timing between rounds relatively short. This would assist in maintaining levels of interest and momentum.

It is also important to note that some of the above concerns are from early and late 70s and the Delphi research has come a long way since then. In line with the strategy adopted by above researchers (Senaji et al, (2014); (Okoli and Pawlowski, 2004), this research also looks at tailored mitigation measures to deal with some of the above concerns. Table **3.1** below lists some proposed mitigation measures to deal with the above issues. Some of the mitigation measures to deal with the overall limitations of this research study are also mentioned in Section 1.6.

Table 3.1 *Mitigation Measures to Deal with Delphi Limitations*

Concerns with Delphi Studies	**Proposed Mitigation Measures for this Research**
Illusory expertise	A robust set of selection criteria was developed to shortlist experts who had relevant experience in the subject matter and had in the past been involved in forecasting activities or tasks.
Sloppy execution	Regular engagement was undertaken with the experts and they were kept interested by communicating the results from the previous studies to them.
Format bias	A pilot study was run with selected researchers to refine the format and structure of the data collection instrument before sending it to the Delphi experts.

3.5 WHY USE DELPHI FOR THIS STUDY?

Now that a detailed analysis of the strengths and weaknesses of Delphi has been undertaken, it is important to do a comparison of the Delphi methods to some of the other similar techniques.

Chan et al. (2001) suggested that Delphi can be utilised to structure the group communication process, to ensure that the process is effective in facilitating a group of individuals as a whole to address complex issues. The Delphi method is generally conducted by several rounds of questionnaires intertwined with group opinion and information feedback in the form of statistical data and trends (Lee & King, 2008). The method therefore collates and analyses the opinions of experts through several rounds of questionnaires.

While looking at the appropriateness of using Delphi, it is important to further contemplate thoroughly the context within which the method is to be applied

(Delbecq et al. 1975). A number of questions need to be asked before making the decision of selecting or ruling out the Delphi technique (Adler and Ziglio, 1996):

- What kind of group communication process is desirable in order to explore the problem at hand?
- Who are the people best suited and with expertise relevant to the problem and where are they located?
- Consideration of alternative techniques available- what are they and what results can reasonably be expected from their application?

Only when the above questions are answered can one decide whether the Delphi method is appropriate to the context in which it will be applied. Adler and Ziglio (1996) further claim that failure to address the above questions may lead to inappropriate applications of Delphi and discredit the whole creative effort.

The outcome of a Delphi sequence is nothing but opinions. The results of the sequence are only as valid as the opinions of the experts who made up the panel (Martino, 1978). The panel viewpoint is summarized statistically rather than in terms of a majority vote. There are other methods that can be used as an alternate to Delphi. Sackman (1975) has drawn parallels between Delphi technique and problem solving, He thinks that both the methods have the same framework, i.e.:

- Establishing the aims and objectives of the study
- Exploring and formulating the problem
- Analysis and solution testing
- Writing up and disseminating results

Sackman (1975) further elaborates on these parallels:

"The payoff of a Delphi is typically a presentation of observed expert concurrence in a given application area where none existed previously. This assumes that participating panelists are experts in the subject area and that the reported consensus was obtained through reliable and valid procedures."

There are other methods that can be used in a similar situation. A survey is sometimes the only way to get a picture of the current state of a community, a project, an organisation, an electorate or a profession (James, 1999). In fact the use of surveys to undertake investigations into a particular population is quite common. Czaja and Blair (2005) noted that this method is being commonly used not only across scientific and research activities but also business, marketing, media and a number of other areas. The fundamental of this methodology is to secure required information from a population or area under research by securing information from a smaller and accessible group that represents the larger population. The information can be gathered by face to face interviews, telephone contacts, electronic contacts and mail-outs. Babbie (2001) notes that some of the benefits of the surrey methodology, include:

- its ability to describe the characteristics of a large population which depends on the study at hand.
- they are in most cases self-administered, they make large samples feasible.
- they are quite flexible in structure to apply to a number of applications.

However, the research topic under observation is quite complex as it includes a number of interrelated measures which would be quite difficult to explain through telephone or mail-outs. Also, as the topic is specifically related to knowledge-based firms, it is conjectured that only feedback from this specialist sector will add value to the research.

Furthermore, due to the number of surveys received by the average person these days and declining response rates (Berk et al, 2007), it is important that the survey is sent to a targeted group of relevant people so that the results can produce interpretable and useful information.

A Case Study approach was also contemplated to see if it can be used to validating the research model. However, it was decided not to pursue this approach due to the following short comings (Hodkinson et al, 2001 and Flyvbjerg, 2011):

- It requires too much data and in most cases researchers can be swamped with data which is not relevant to the study. This requires much more effort and time commitment.
- It can be expensive if attempted on a large scale.

- It is hard to simply represent the outcomes which may be based on a complex research question.
- They do not lend themselves to numerical representation.
- They can be easily dismissed by those who are not supportive of them.
- They can’t answer a large number of relevant research questions.
- Case study is more appropriate for generating a proposition rather than testing or validating it.
- One cannot generalise on the basis of one case.

However, Flyvbjerg (2011) provides justification for clarifying some of the above perceptions.

From some of the options presented above, Delphi analysis methodology offers an innovative research framework that addresses the need to widely canvas diverse opinions and information sources in forming aggregate conclusions. Substantial research work exists (Gupta and Clarke 1996, Okoli and Pawlowski 2004, Ono and Wedemeyer 1994, Rowe and Wright 1999) that confirms that Delphi analysis is relevant and robust in many contemporary research areas. These researchers also identify that like any other research methodologies, there are certain structural and operational components that need to be carefully managed to ensure sound process and outcomes. Gupta and Clarke (1996), in an extensive search, identify over 460 pieces of published research where Delphi has been substantially used in areas as diverse as education, agriculture, medicine and medical services, environmental studies, finance and economics, tourism and management. Some of the areas of its application identified by (Linstone and Turoff, 1975) are:

- Gathering current and historical data
- Evaluation of possible budget allocations
- Exploring urban and regional planning options
- Planning university curriculum development
- Putting together an educational model
- Exploring priorities of personal values and social goals

Outhred (2001) successfully used the process in a thesis pertaining to the assessment of environmental impacts of pre-fabricated residential building systems in Australia.

Other contemporary means of data collection, such as the use of focus groups, have potentially serious group dynamic issues which can prejudice outcomes. These can include shortage of time, non-representative membership, and the dominance or otherwise of individuals within the group which may lead to superficial agreement, but less than valid consensus (Outhred, 2001).

Delphi provides quite different parameters to a number of other survey techniques (Okoli and Pawlowski 2004). Hefferan and Mian (2006, p 4)) note some of the strengths of the Delphi over techniques which include:

- Rather than using a random sample of the general population, this approach involves the overt selection of experts.
- It is a multi-stage process of progressive refinement and feedback at every stage. It helps in providing a progressive tightening and refinement.
- It is very effective in maintaining an anonymous communication line between the individuals with the group, but avoiding potentially negative impacts of group dynamics on outcomes (i.e. the use of a Nominated Group Technique [NGT] rather than an Interactive Group Method [IGM]).
- It is a broadly used, tested and successful technique. It is now accepted and widely used across multiple discipline areas which makes it firm in its structure but adaptable to various situations and research tasks.
- Experts in the industry area aware of Delphi and keen to contribute to it. Normally strong involvement by nominated experts and little incidence of non-responsiveness that is notable in other survey types.
- Due to the iterative nature of Delphi, it allows for data enrichment through interaction, the opportunity to add further information and for respondents to be aware of how the research is evolving and to react

and respond to that. This keeps the respondents interested and keen to input robust ideas.

- As pointed out by previous researchers (Outhred, 2011 and Linstone & Turoff, 2011), Delphi attempts to address a range of these issues and to establish a methodology that is relatively quick, inexpensive, and justifiable and that leads, in a structured and predictable way, to sound outcomes.

In light of the above analysis where the benefits of the Delphi overweigh its shortcomings, it was decided that Delphi will be used to facilitate the involvement and communication of multiple, knowledgeable participants in order to validate the innovation model developed through the literature review.

3.6 ADMINISTER THE DELPHI PROCESS

Previous researchers (Brooks 1979, Rowe et al 1999 and Loo, 2002) note that the Delphi process usually involves the following steps:

- Develop, based on prior research of the subject, a series of appropriate questions pertaining to the key elements of the research area being examined. Refining the questions and then presenting it to the experts, in isolation, to the individual experts.
- Opportunity exists for the experts to propose additional items not previously identified. The main focus of the questions is to get the experts to prioritise issues which have emerged from that prior research as probably important.
- Selection of a team of experts (known to have particular relevant knowledge of the subject area) to participate in the exercise. This is mainly based on identifying a criteria based on the work of the previous researchers and also tweaked to align to the requirements of the study at hand.
- The identity of each of these experts and their individual response is kept confidential from the other experts.

- The results of this first round are analysed to identify the measures of relative importance. The summarised results are also presented to the experts.
- Second and subsequent rounds of questions are developed from the results of the first round (and can include those additional matters of input and observation provided by those experts in the previous round).
- These rounds of formal questioning continue until a point of stability, convergence or diminishing gains is secured.
- The final results are outcomes and results are communicated to the experts.

It is important to re-emphasise the observations of Kerstin Cuhls from the Fraunhofer, Germany, Institute of Systems and Innovation in 2001 who suggests that before starting a Delphi study, the following questions should be considered:

- What is the objective of the Delphi Study?
- Do we have the relevant resources to run it?
- Is Delphi the right choice for the area being researched?
- What are my questions?

Figure 3.2 shows the different stages of a Delphi study that were adopted for this research.

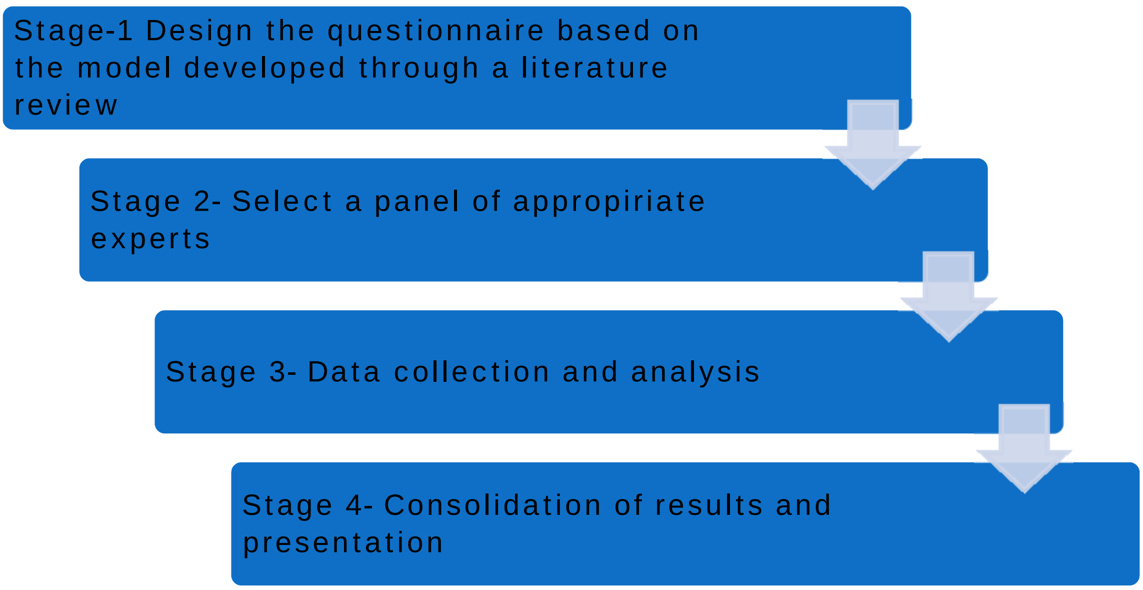


Figure 3.2. Delphi methodology to validate the research model

Chapter 4: Validation of the Model

Delphi originated from the Rand Corporation in 1948 and has been extensively used by organisations, research institutions and government. Linstone & Turoff (1975) define Delphi as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. According to Borg and Fall (1983), a Delphi Study can be used to identify problems, define needs, establish priorities, and identify and evaluate solutions. In the context of this research project, the Delphi study is being used to validate the model which was developed through the literature review process. A stepwise analysis of undertaking the Delphi process to validate the conceptual innovation model is outlined as follows.

For the Delphi study associated with research, it will be conducted by distributing relevant and concise questionnaires to the panel of experts. Subsequently, responses will then be analysed and used to develop feedback to the panel of experts in the next round of questionnaires (this step can be repeated in order to conduct a series of questionnaires). In addition experts on the panel will not communicate directly with each other rather they exclusively provide responses to the Delphi administrator.

The process will include:

- Individual contribution from experts where they generate ideas based on their knowledge and expertise.
- Assessment of a subjective group view or judgement.
- Opportunity for panelists to assess their responses and revise their views.

- They will also provide feedback on the views of other experts from diverse backgrounds.
- Experts don't feel under pressure from the impact of group dynamics. They are able to expresses radical or widely divergent views in a non-threatening context.

In summary, the Delphi method is a research technique that collects and analyses the knowledge of experts to develop understanding of complex situations. (Okoli and Pawlowski, 2004) note that Delphi can be used to identify, prioritize issues; as well as to develop concepts/frameworks. This approach was adopted for this research.

4.1 STAGE 1- QUESTIONNAIRE DESIGN

A conceptual research model and associated proposition based on the findings of the literature review, has been developed. However, due to the paucity of literature in consulting engineering firms (Leiponen, 2006; Swan et al, 1999) especially when considering the relation to project performance, a Delphi study is proposed to further validate the measures identified from the literature review.

4.1.1 Pilot Study to Develop Questionnaires

In line with the Neuman (2006) suggestions the questionnaire for each round for the Delphi study was tested before it was sent out to the expert panelists. A Pilot approach was adopted. The questionnaire was sent to my colleagues in the consulting industry and also fellow researchers and informally asked to undertake a sanity check based on the following criteria:

- The questionnaires includes proper wording. They reviewers were asked to point out any associated ambiguities and vagueness that needs be eliminated.
- A clear methodology that helps the panelists to complete the survey.
- Clear linkages between the successive rounds of questionnaires.
- A clear statement on the analysis from subsequent rounds is included to facilitate the understanding for completing the next round.
- A clear confidentiality statement.

Sample questionnaires for Round 1 to Round 3 are attached in Appendices A, B and C.

4.2 STAGE 2- PANEL SIZE AND SELECTION

Outhred (2001) makes suggestion on the characteristics of an appropriate team of expert. He emphasises that the experts should not be solely academics but include stakeholders, experts and facilitators. Habibi et al. (2015) emphasises that the validity of a Delphi study and its result depends on panel members' competence and knowledge. While there are some disagreements about the composition and panel size of the Delphi technique, a dominant pattern can be recognized. It is better to use a combination of individuals with multiple specialties (Powell, 2003; Somerville, 2008; van Zolingen and Klaassen, 2003; Hsu and Sandford, 2007).

There are no strict guidelines on the number of experts but previous researchers (Linstone and Tutoff, 1975: Outhred, 2001: Skulmoski et al, 2007) have used 4 to 11. Researchers (Nambisan et al, 1999; Wynekoop and Walz, 2000) recommend that, results should be cautiously interpreted, if the sample size is small or if the participant expertise is under question. Habibi (2015) identifies that that between six and twelve members are ideal for Delphi technique. If a mixture of experts with different specialties is used, between five and ten members are sufficient (Somerville, 2008). Okoli and Pawlowski (2004, p-19) reemphasise that the Delphi group size does not depend on statistical power, but rather on group dynamics for arriving at consensus among experts. There were two studies specifically run to investigate the impacts of size of a Delphi panel and there was no consistent relationship found between the size of the panel and its effectiveness. (Rowe and Wright, 1999). In other literature on aggregating group opinions, groups of 6 to 12 members were determined to be optimum (Hogarth, 1978; Mitchell, 1991).Hsu (2007) notes that some of the drawbacks of having a large sample size are low response rates and potentially the larger blocks of time that the researcher and the experts have to allocate to the study which usually results in expert dropouts. Previous researchers have adopted Delphi on a common understanding. They researchers emphasise that unlike the traditional surveys with Delphi the objective is not to select a representative sample of a population. The whole argument justifying the use of Delphi is that the panel members should be experts in the area to yield results that are more accurate and robust. Hence the selection of the right panel members more than their size is an important consideration.

Wissema (1982) underlines the importance of the Delphi Method as a mono variable exploration technique for technology forecasting. He further states that the Delphi method has been developed in order to make discussion between experts possible without permitting a certain social interactive behaviour as happens during a normal group discussion and hampers opinion forming. Baldwin (1982) asserts that lacking full scientific knowledge, decision-makers have to rely on their own intuition or on expert opinion. The Delphi method has been widely used to generate forecasts in technology, education, and other fields (Cornish, 1977).

Woudenberg (1991) recognised the value of the structured expert panel approach that Delphi offers, provided that a balance between human judgment and prediction and information based on fact could be established. He notes that the anonymous nature of the data collection helps manage some of the negative effects of group dynamics that can emerge in focus groups and other forums.

Cabaniss (2002) presents an interesting definition of an expert. He thinks that an expert is someone who has the special skills or knowledge evident through his or her leadership in professional organisations. They can also be someone holding office in a professional organisation, a presenter at national conventions or who has published in recognised journals. Alder & Ziglio (1996) suggest that the experts should have four areas of expertise; knowledge and expertise relevant to the issues under investigation, capacity to participate, effective communication skills and sufficient time to participate in the study. Sakal (2005) points out that without any doubt the selection of the right participant is critical to the overall success of any project. To corroborate this view the selection of candidates for this study was based on a slight variation of the well-known method used in selecting alliance partners for the National Museum Project. The philosophy adopted for selected the experts for this study was based on the research by Hutchinson & Kinsley (1999) and Hauck et al (2004). Ross (2003) suggests that selection criteria can be adjusted to suit the particular requirement and circumstance of a project.

It was decided to use the following criteria for selecting the experts:

- Profile in the industry and previous work with consulting engineering firms. To assess against this, a brief review of their CV, LinkedIn profile or past publications was undertaken.
- Relevant experience related to the subject matter of innovation and innovation activities. This assessment was again made based on using some of the above resources. Further discussions were held with colleagues of the Delphi experts who I know through my professional work in Brisbane.
- Role and time within the organisation. This was easily available in their CVs. In some cased their LinkedIn profile of the expert was also used. The years of experience were an important factor in assessing their capability to make robust decisions.
- Linkages with relevant forums or publications associated with innovation in consulting engineering firms.
- Effective communication skills. All the experts belonged to senior management. It was however, assumed that due to their position within the organisation, they will have effective communication skills. In some cases their colleagues were asked about their ability to clearly and effectively communicate.
- They represent a broad range of organisations. Their areas of expertise include; project management, business cases, civil engineering, contract administration, highways, risk management, structural engineering, ICT, facilities management, and construction. Also, they had direct or indirect linkages with consulting engineering firms through in some cases through involvement on joint venture projects. They have also worked in the innovation space. Pill (1971) notes that individual are considered to be appropriate if they have related backgrounds and experiences in the subject matter that is being researched.
- Willingness to participate in the study. They were formally informed through email (sample provided in Appendix H 233) and participant

information form (sample attached in Appendix G 236**Error! Bookmark not defined.)**

This to some extent satisfies the requirements for an effective Delphi group set out by Chapman (1998) who notes that the group members must have the right experience and skills but more importantly the aspect of compatibility is required amongst them.

Initially a larger group of relevant people (16) were identified for consideration in to the Delphi expert panel. In line with suggestions from Babbie (2002), the snowball sampling technique was used to identify a relevant group. In this method, the researcher identified some eligible people and requested them to introduce other similar people. The above criteria were given equal weightings and the individual experts were ranked using a 1-5 Likert scale (1 least being relevant and 5 being most relevant). Each of the 16 candidates (sourced internationally and within Australia) were given a total score after reviewing them against the above criteria and a shortlist of the final 8 Delphi experts (names and role in the organisation withheld to keep their identities confidential) is shown in Table 4.1. This is in line with the sample size used by previous researchers /Delphi studies. A brief pen portrait without any specific information that may reveal their identity is provided herewith.

Table 4.1 *Portrait of Delphi experts*

Expert	Position/Organisation
A	As a Director at one of the leading global consulting engineering practice, A is responsible for 350 staff in eight offices, practicing in program/project management, resilience, security and risk, fire engineering, acoustics, planning, management consulting and sustainability. He has developed expertise in business strategy, program and project management, strategic project review, construction contract administration, contract/tender documentation, risk management, project facilitation, dispute resolution, and quality management/auditing. He has over 45 years of experience has been gained in both private and public sectors, including project work in Asia. More recently, he has contributed to successful projects in a senior review and mentoring capacity, setting the strategic direction of business and capital works programs during establishment, including conducting risk management and project facilitation workshops
B	B joined this multinational consulting engineering firm in 1986 as a graduate engineer. During his career B has acquired extensive international experience and recognition building on his engineering, project management, people management, and business management knowledge and skills. B has excellent track record of developing innovative and cost effective design solutions to challenging high-rise projects on congested and difficult sites. As Managing Director, B has over 35 years of experience in value and concept engineering, management of the design process, and project delivery.
C	Over 20 years of senior management experience in an architectural firm which is known for designing some of the most iconic projects in Queensland, Australia and globally.
D	D is the CEO of one of Australia's biggest non-government, not for profit charitable organisation. They have a number of facilities across

	Queensland and facilitate and encourage participation in sporting, recreation, cultural and welfare programs with an aim to improving the lives of individual members and the development of local communities throughout the state.
E	E is head of infrastructure for a multinational consulting engineering firm. He has worked on infrastructure projects in the UK, Asia, North Africa and PNG. He regularly directs multi-disciplinary groups on complex transport projects. He has particular skills in drawing together the diverse work streams necessary to undertake these projects and creating the environmental within which optimal solutions can be developed. Risk assessment and management as it impinges on all aspects of project delivery is of particular interest. He has developed tools to assist in the control of work flow, and in ensuring that goals set for any project remain the drivers to project delivery.
F	F leads the Integrated Project Delivery and BIM Systems team for one of the biggest contractors in Australia. Currently responsible for the integration and application of innovative Building Information Modelling technologies. With over 30 years of design management experience of working on large and complex infrastructure and building projects, F's current focus is on using technology as a means to innovating in industry and to leveraging BIM and other enabling technologies, to improve collaboration and increase efficiencies in the design and construction industry, enabling superior delivery of the built environment for our clients.
G	Adjunct and visiting professorships in Australia, Iceland and Sweden Formerly Director of the national R&D programme of a European country, Professor of Construction Management and Leading researcher in innovation in knowledge-based firms.
H	Director for Project Management at an Institute. Professor Project Management. High profile researcher since the last 20 years.

4.2.1 Number of Delphi Rounds

Schmidt (1997) notes that that the number of rounds of questions will vary from case to case and the researcher must know when, in effect, to stop polling.

Too many rounds, or too many items for consideration for ranking, may cloud consensus. He observes that the good use of statistical techniques should bring consensus out from the optimum number of rounds – whatever that number may be for the specific project.

In this regard, Loo (2002) considered that provided that the initial research leading up to the Delphi process was sound, and the process well organized and executed, then three or four rounds should be sufficient to secure the required level of convergence or reach the point of minimum returns. This appears likely for this research project provided convergence is reached within the three rounds.

4.3 CHALLENGES WITH THE DELPHI STUDY

Some of challenges and proposed measures to overcome them are discussed below:

- Most of the expert panelists are senior executives in their respective organisations. Responding to each Delphi round requires time commitment. There is a danger that they might not be able to continue the study and drop out midway due to their work commitments. A detailed face-to-face and telephonic follow-up discussions were undertaken to gain their interest. This helped in understanding their commitment and eagerness to contribute to the study. It was considered as part of the filtering criteria discussed in Section 4.2.
- It was also important to develop robust criteria to select an expert panel that can add real value to the research topic under review. By having experts on the panel who do not understand the research topic may result in having difficulties in achieving convergence in their feedback. A close and relevant set of criteria was developed to shortlist the experts.
- The questionnaire was based on the findings from a review of literature which could have added ambiguity for the experts as they were not involved in the literature review process. However, before sending it out to the expert panel, a pilot study was undertaken with research students and industry practitioner who were asked to review and complete the questionnaire. This helped in improving its quality and providing a rough estimate of time required to complete it.

4.4 ETHICAL CONSIDERATIONS

Neuman (2006) notes that ethical issues are the concerns, dilemmas and conflict that arise over the proper way to conduct research. QUT has a standard Ethics approval process in place to ensure that data collection is carried in line with university guidelines around confidentiality, engagement with external respondents and other ethics consideration. The ethics approval number for this PhD research is 0900000479.

4.5 STAGE 4- DATA COLLECTION AND ANALYSIS

4.5.1 Delphi Round 1- Validation- Purpose and Logistics

Researchers in the past have used Round 1 for formulation of ideas. In the case of this study, a slightly different approach is adopted as the model and issues associated with it were formulated and developed as part of the literature review. This is aligned to what previous researchers have done. Linstone (1999) and Loo (2002) emphasised the need of having a basis of the first set of questions. They can't be random scatter of questions on the subject matter. Linking them to the work of the previous researchers is a sound and robust approach. Round 1 in this case is being used to get an initial validation and expert's position on the model that was developed as part of the literature review. Clark et al (2006) emphasised on the need of the initial questions to be open ended to some extent that it provides an opportunity for ideas generation. The experts were asked to base their confirmation of the innovation activities in the context of its impact on project performance. The experts panel was asked to use a Likert scale of 1 (Not Relevant) to 5 (Most Relevant) to rate the relevance of the activities in the context of project performance. Provision was made for expert to add and rank additional activities. They were also asked to add additional comments if required. There were 22 measures grouped in 4 main themes. The context was discussed with the experts panel through face-to-face or telephonic conversation and then email was used which enabled robust management of communication and confidentiality. This is in line with the suggestions of Schemidt (1997) who recognised that although it will be easy to apply the Delphi methodology in a loose and generalised manner, it is important to closely manage the process.

Schemidt (1997) mandated the use of statistical techniques to facilitate the findings. De Meyrick (2003) undertook a review of 126 applications of Delphi Studies and established that simple Average, Median and Standard Deviation (S.D) statistics were commonly used across them. However Kendall's W Coefficient (to determine clustering in responses), Chi Square (to confirm the level of randomness in responses), ANOVA/ Turkey's Test (to compare the variation in responses) were also commonly and successfully used. In line with the above, my approach is to use Average, Median and S.D for statistical analysis and augment the results by using Kendall's Coefficient and Chi Square. Schemidt (1997) who recognised that although it will be easy to apply the Delphi methodology in a loose and generalised manner. It is important to closely manage the process. A smaller sample might be used, with results verification conducted with follow-up research or statistical analysis (Skulmoski et al, 2007). Schemidt (1997) mandated the use of complementary statistical techniques to facilitate the findings.

West and Cannon (1998) as well as Rogers and Lopez (2002) used the mean and standard deviation as consensus criterion. Murphy et al. (1998) were of the view that the median and the inter-quartile range are more robust than the mean and standard deviation. Keeney et al. (2011) identifies that the main statistical measures used for Delphi are median, mode and standard deviation, although mean and interquartile range are also frequently used .De Meyrick (2003) undertook a review of 126 applications of Delphi Studies and established that simple Average, Media and Standard Deviation Statistics were commonly used across them. Rowe and Wright's (1999) undertook a systematic review of literature and found out that a number of complementary descriptive statistical techniques were being used such median, mode, percentages for each event, ranks, upper and lower quartile ranges, statistical average of points for each factor. However, Kendall's W Coefficient (to determine clustering in responses used by Okoli and Pawlowski, 2004, Keil at al, 2002 and Schmidt, 2001), Chi Square (to confirm the level of randomness in responses by Dajani et al.), ANOVA/ Turkey's Test (to compare the variation in responses) were also commonly and successfully used. The above literature provides sufficient support to use these complementary statistical techniques for this research.

4.6.1.1 Round 1 - Outcomes:

All the 8 Delphi experts responded to the survey. Initially there were 22 innovation activities presented to them in Table 4.2. The experts identified ideas but they were not different to the ones identified from the literature review. A clear background of the origin of the innovation activities i.e. through review of literature was articulated in the questionnaire. However, further context was provided through telephonic and email communication with the individual experts.

Table 4.2 *Innovation Activities*

Number	Innovation Activity
	Research and Development Activity
1	Improving annual R & D budget
2	No of patents filled in the past year
3	No of active R&D projects
4	Total R&D as percentage of turnover
5	Partnerships with R&D organisations and tertiary institutions
6	Acquisition of new initiatives and technology options to facilitate business
	Communication activities on projects
7	Increasing the number of ideas put forward by team member to leaders
8	Reducing the average time from idea evolution to full implementation
9	Resources made available for continuous innovation
10	Cooperation between individuals
11	Using more opportunities to discuss innovation and reward smart ideas

	Client related activities
12	Increased and focussed marketing activities
13	Effective use of market intelligence to achieve a competitive edge
14	Optimising the savings achieved through successful operation efficiency ideas
15	Introduction of client management tools
16	Broadening the client portfolio
	Introducing systems
17	Improving the percentage sales from products introduced in the past few years
18	Improving IP and opportunities for commercialising & offering services on licencing arrangements
19	Introducing mechanisms for sharing and collecting data/products
20	Introducing a Knowledge Management System in SME's
21	Using innovative decision capability
22	Introducing particular technologies

4.6.1.1.1 Average, Total Scores and Range

The experts were asked to rate the above using a Likert scale from 1 to 5 (where 1= Not relevant, 2= Little relevance, 3= Quite relevant, 4= Very relevant, 5= Most relevant). They were asked to indicate their opinion of the relative importance and relevance (to impacting project performance) of each innovation activity in reference to consulting engineering firms. While considering project performance, they were asked to consider measures such as client satisfaction with budget, time and quality, design team satisfaction and meeting design fee/project budget & program. They were also asked to provide free text comments for their selections. They were also asked to add and rank any other criterion that you think is important.

IA*		Experts	Responses								
	A	B	C	D	E	F	G	H	Total	Average	S.D.

Table 4.3 *Standard Deviation & Average Results from Round 1*

1	4	4	4	4	2	4	2	3	27	3.25	0.88641
2	2	1	1	1	2	3	1	3	14	1.75	0.88641
3	3	3	3	3	3	3	4	3	25	3	0.53452
4	5	3	3	3	4	5	3	3	29	3.375	1.30247
5	4	5	5	5	4	4	3	4	34	4	0.75593
6	2	4	4	4	2	4	1	2	23	2.625	1.18773
7	2	4	4	4	3	3	3	4	27	3.375	0.74402
8	2	4	5	4	4	2	4	4	29	3.625	1.06066
9	4	3	4	4	4	4	4	4	31	3.875	0.35355
10	5	4	5	5	4	5	4	4	36	4.5	0.53452
11	4	4	4	3	3	5	4	4	31	3.875	0.64087
12	3	3	3	4	3	2	2	5	25	3.125	0.99103
13	4	4	5	5	2	4	2	5	31	3.875	1.24642
14	5	5	4	3	2	3	4	5	31	3.875	1.12599
15	2	4	4	2	3	1	4	4	24	3	1.19523
16	3	4	4	5	2	2	3	5	28	3.5	1.19523
17	3	2	2	2	2	2	2	2	17	2.125	0.35355
18	2	2	2	3	3	2	3	2	19	2.375	0.51755
19	4	3	4	3	3	2	4	2	25	3.125	0.83452
20	4	3	4	1	4	3	4	4	27	3.375	1.06066
21	2	3	4	2	3	3	4	2	23	2.875	0.83452
22	5	2	4	2	2	2	4	4	25	3.125	1.24642
Sum²	5476	5476	6724	5184	4096	4624	4761	6084			

*IA Innovation Activities

A detailed analysis using SPSS was undertaken to determine, Average, Standard Deviation and Range. The range is referred to as the possible aggregate results of individual factors. At this stage it is important to remove all outliers (this can be done before calculating the means and SDs) to ensure they do not skew the range output.

If the range is tightly clustered this infers that experts were, for whatever reason, hesitant to score extreme ratings. The analysis outlined is outlined in the Table 4.3 above.

The total sum for each activity has a range from 8 (if all rate it to be least relevant) to 40 (if all rate it to be most relevant). In this case the responses vary from a total score of 14 to 36. It seems that the respondents were reluctant to score extremes. Most of the activities have total scores within a range of 31 to 36 which shows that they are relevant (all have high scores) and should be retained to the next Delphi round. Also the variation between the minimum and maximum sum (14 & 36) is not significant which shows that there is consistency in respondent's scoring approach.

In the context of a Delphi study the mean score outlines how important experts considered the factors to be or whether the factors are important at all. In this case the experts have identified the cooperation between individuals (average 4.5) as the most important followed by Partnerships with R&D organisations and tertiary institutions (average 4.0) as having a very positive impact on project performance. According to the experts the Resources made available for innovation, Opportunities to discuss innovation, Effective use of market intelligence to achieve a competitive edge and Optimising the savings achieved through successful operational efficiency will have a similar impact on project performance (average value of 3.875).

The experts think that Number of patents filled in the last year will have the least impact on project performance which may be due to the fact that consulting engineers in Australia don't usually file patents.

By adding-up the mean for criteria within each main activity, it was established that the experts thought that introducing systems in a knowledge-based firm were most important to improve the performance of its projects followed by (in descending order of importance) Improving communication on projects , R&D activities and introducing client related initiatives. Also, another method to assess the relevance of the individual activities using average scores is to compare the total scores against the average score. If most of the totals scored for each factor is equal to or greater than the average this indicates that experts agree that the variables are important and should be included in the study e.g. the total of all the sums is 581 and averaged over 22 activities it comes out to be 26. All the activities except (2, 3, 6, 15, 17, 18, 19, 21

& 22) are above the average of 26 which means that they are important and favoured for inclusion in the list.

4.6.1.1.2 Standard Deviation

The standard deviation (S.D) is defined as the average amount by which scores in a distribution differ from the mean, ignoring the sign of the difference. On average if the S.Ds is high relative to the average scale, this indicates that the clustering of responses between experts is NOT close. This could be caused by an underlying issue or may be at random which may require further statistical analysis.

For Delphi Round 1 the lowest standard deviation was 0.35355 and the highest 1.30247 with nine factors had a standard deviation above 1.0. This shows that 40% of the criteria had higher than 1 standard deviation. Although, some of the standard deviation is quite high, it is still not strong enough to drop any of the criteria at this stage. On the other hand it is reassuring to see that that the agreement between the experts on the remaining 60% criteria is quite healthy. The disagreement in particular is quite high on Criteria 4, 13 and 16. The activities or criteria and associated scores are also graphically shown in Figure 4.1.

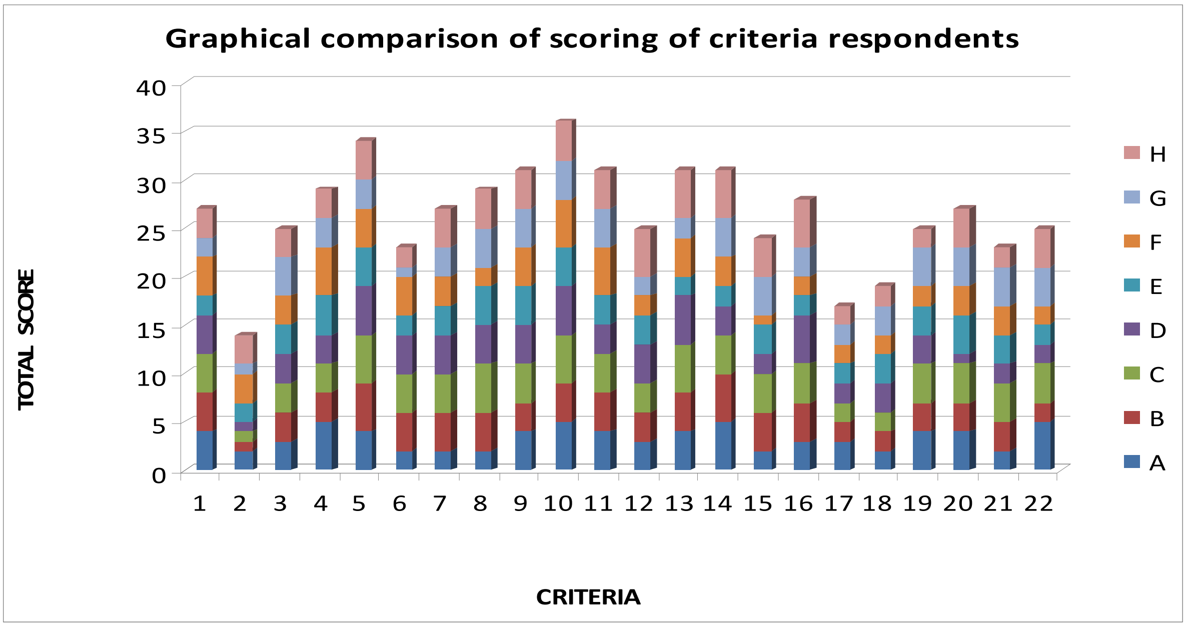


Figure 4.1. Delphi Round 1 Scores

In summary the experts have concurred that all the measures for innovation activity are important and can't be eliminated. However, there were no additional items added to the list. Overall the cooperation between individuals was considered the most to have the most positive impact on project performance. Although, we are mainly considering individual innovation activities across the main 4 themes but an overall analysis on each theme can be undertaken by adding-up the mean for criteria within each theme. It was established that the experts thought that introducing systems in a knowledge-based firm were most important to improve the performance of its projects. This was followed by (in descending order of importance) improving organisational communication, performing more R&D activity and Introducing client related initiatives. It is too early to establish any ranking as this may change through round 2 and successive rounds.

In addition to this there were some general comments by the experts which are outlined below. This may be an individual's perspective and not representing the focus of the expert panel:

- In the past R&D investment has been considered a measure of an organisation's innovativeness but it has not reflected in the way they deliver their projects.
- There is also a view that the R&D investment needs to be relevant to the focus of the core organisation.
- Research and Development in the context of facilities management is evidence based through identifying how changes can improve operations.
- Unlike consulting engineering firms, architectural practices don't have dedicated R&D investment funds. They form JV's with specialist knowledge companies.
- Contractors are not advanced on innovation on projects. There is some incremental R&D activity but it is not likely to be systematically done.
- To some of the organisations, business related innovation is not as important as the delivery of their project. The rate at which innovation is disseminated is quite important.

- Consulting engineering firms have always been a breeding ground for generation of ideas. However, their main challenge is being selective and not chasing everything. The main consideration needs to be how they are filtered and one of the main filtration criteria should be financial return to the organisation.
- Quality of communication is also an important consideration for innovation. A badly communicated idea no matter how effective it is most not likely to be pursued. Quality of communication helps in developing trust and confidence.
- It is key to the facility design and project delivery that all team members have the opportunity to input ideas into facility design and operation and that these are passed onto the project architect.
- Part of innovation is to give due consideration to clients and understand their needs.
- Project fees are considered to be a major deciding factor for the level of innovation that can be induced into projects. For some clients value engineering is innovation. The project procurement model may also impact the extent of innovation that can be pursued. If the contractor is only going to benefit from innovation then there is very less incentive for the consultant or other stakeholder to pursue innovation. In some cases Project Managers create a hindrance in the innovation process. Tight programme can also impact the amount of innovation that can be introduced on the project.
- Not all type of knowledge-based firms and consulting engineering firms need particular technologies to be innovative. Some of the smaller companies can innovate and perform better without formal systems. However, the larger consulting firms need formalised systems otherwise it will be a chaos.
- The introduction of systems is important to capture codified knowledge especially drawings, models, project data etc. for consulting engineering firms. However, it is also important to capture the tacit knowledge of

people around thinking, experience and competence. It is hard to neglect experience as a major factor in delivering innovation.

- All these measures have a direct impact on client satisfaction with budget, time and quality and design and construction team satisfaction with the project outcomes.
- One of the key areas to consider when developing systems is the integration of lessons learnt into the project delivery process. While information is captured there is still a major gap on how to use that information for achieving better outcomes in upcoming projects.
- Traditionally unlike consulting engineering firms, contractors don't highly value developing and retaining Intellectual Property (I.P).

The comments were used to identify new innovation activities or bolster the overall conclusions drawn from each round.

4.5.2 Delphi Round 2- Refinement

4.6.2.1 Purpose and Logistics

The response to the Round 2 was quite delayed. Most of the experts were busy due to their workload commitments. It was identified from the outcomes of round 1 that none of the activities can be left out at this stage as it is too early to discount their importance to this research. However, the objective of the second round was to distil the innovation activities which were of lesser importance. In this round the experts were provided with the 22 activities and asked to rank it using a rating of 1 (being most relevant) and 22 (being least relevant). The results from the first round were included in the questionnaire and the purpose of the round 2 clearly articulated.

4.6.2.2 Outcomes-Round 2

A box plot which is a simple method of depicting the descriptive results was used. Box plots may also have lines which are called whiskers extending vertically from the boxer which indicate the variations from outside the upper and lower quartiles. The spacing's between the different parts of the box help indicate the degree of spread or dispersion. The shadow box represents the inter-quartile range (i.e. the region where 50% of expert responses lie) and the single lines indicate the range of all the ranks. The dot within the shadow box indicates an average point. A dot at the bottom indicates a skewed response with most of the experts giving a low score but with a tail of higher scores e.g. Optimising the savings achieved through unsuccessful operational efficiency ideas. Outliers or extreme scores are indicated as dots outside the range. The results from this study (in Figure 4.2) suggest that, increased and focused marketing activity has one outlier, expert number 7. The outlier expert's response was 22 while the next highest rank was 15.

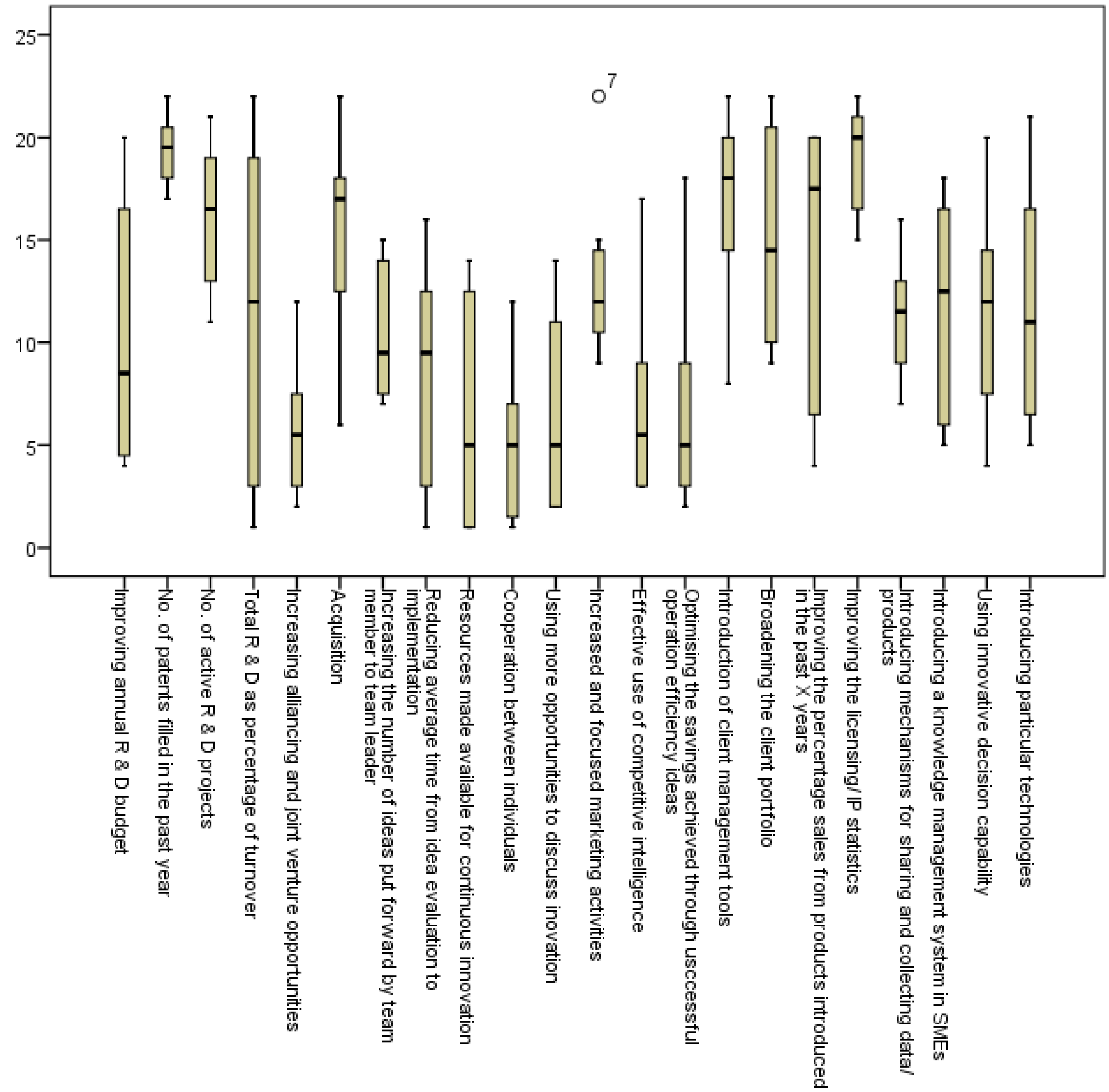


Figure 4.2. Delphi Round 2 Outcomes-Box Plots

4.6.2.3 Standard Deviation

Standard deviation provides an idea of spread of expert opinion on individual activities. However, an activity with a higher standard variation cannot be filtered out given that even one anomaly in a group of eight experts can have a significant impact on the standard deviation value. The highest standard deviation is 8.46 and the lowest 1.76. The average standard deviation value is approximately 6.26. 'Cooperation between individuals' has the lowest mean value and the standard deviation is quite low at 3.77 (as compared to the average S.D) which shows that there is sufficient convergence between the respondents to rate this activity high in its relevance to positively impact project performance for consulting engineering firms. This trend is consistent as 'No of patents filed in the past year' and 'Improving IP and opportunities for commercialising & offering services on licencing arrangements' are considered least important in terms of relevance and the standard deviation is quite low (lowest S.D 1.76 for 'No of patents filed in the past year') which shows that the agreement is quite high. These two activities can be dismissed but a further confirmation may be undertaken as part of Round 3. The first 5 most important innovation activities (based on the mean of their rank by the experts) in relation to impact on project performance are:

- Cooperation between individuals.
- Partnerships with R&D organisations and tertiary institutions.
- Resources made available for continuous innovation.
- Using more opportunities to discuss innovation and reward smart ideas (same rank as above).
- Optimising the savings achieved through successful operation efficiency ideas.

The least two important activities are:

- Improving IP and opportunities for commercialising & offering services on licencing arrangements.
- No. of patents filled in the past year.

This is very consistent with the results from the round 1 analysis. The results are shown in Figure 4.4.

Table 4.4 *Round 2 Standard Deviation, Mean and Maximum Analysis*

Innovation Activities	**N**	**Mean**	**S.D**	**Min**	**Max**
Improving annual R & D budget	8	10.3750	6.90626	4.00	20.00
No. of patents filled in the past year	8	19.3750	1.76777	17.00	22.00
No. of active R & D projects	8	16.1250	3.64251	11.00	21.00
Total R & D as percentage of turnover	8	11.3750	8.46737	1.00	22.00
Partnerships with R&D organisations and tertiary institutions	8	5.7500	3.32738	2.00	12.00
Acquisition of new initiatives and technology options to facilitate business	8	15.3750	5.26274	6.00	22.00
Increasing the number of ideas put forward by team member to team leader	8	10.5000	3.38062	7.00	15.00
Reducing average time from idea evaluation to implementation	8	8.3750	5.50162	1.00	16.00
Resources made available for continuous innovation	8	6.5000	5.80640	1.00	14.00
Cooperation between individuals	8	5.0000	3.77964	1.00	12.00
Using more opportunities to discuss innovation and reward	8	6.5000	5.09902	2.00	14.00

smart ideas					
Increased and focused marketing activities	8	13.1250	4.12094	9.00	22.00

Innovation Activities	**N**	**Mean**	**S.D**	**Min**	**Max**
Effective use of market intelligence to achieve a competitive edge	8	6.8750	4.82368	3.00	17.00
Optimising the savings achieved through successful operation efficiency ideas	8	6.7500	5.39179	2.00	18.00
Introduction of client management tools	8	16.8750	4.70372	8.00	22.00
Broadening the client portfolio	8	15.1250	5.38351	9.00	22.00
Improving the percentage sales from products introduced in the past few years	8	14.0000	7.19126	4.00	20.00
Improving IP and opportunities for commercialising & offering services on licensing arrangements	8	19.0000	2.67261	15.00	22.00
Introducing mechanisms for sharing and collecting data/ products	8	11.2500	3.01188	7.00	16.00
Introducing a knowledge management system in SMEs	8	11.6250	5.62996	5.00	18.00
Using innovative decision capability	8	11.5000	5.15475	4.00	20.00
Introducing particular	8	11.7500	5.89794	5.00	21.00

technologies

4.6.2.4 Kendal's Coefficient of Concordance (W) and Chi Square Analysis

Kendall's coefficient is a measure of agreement among judges or experts where each case is one expert's rating of several items (in this case innovation activities). It is a method of examining non-parametric data, which provides an indication about the level of concordance that exists between experts. The Chi-Square test provides an indication if any deviation in expert opinions were random or whether there were some other underlying issues that may have caused the experts to deviate in their rankings of the innovation activities. Kendall's coefficient of concordance W, computed as follows.

$$W = \frac{12S}{m^2(n^3 - n)}$$

Where m and n are defined above and S is the sum of squared deviations, defined as follows.

$$S = \sum_{i=1}^{n} (R_i - \bar{R})^2$$

R_i is the total rank given to CSF i, and $\bar{R}$ is the mean of these total ranks.

$$R_i = \sum_{j=1}^{m} r_{i,j}\,; \quad \bar{R} = \frac{1}{2} m(n+1)$$

The Kendall's coefficient of concordance indicates the current degree of agreement among the panel members by taking into account the variations between the rankings (Doke and Swanson, 1995). The Chi-Square test complements the results from Kendall's coefficient and is conducted within the same analysis in SPSS. If the chi square analysis results confirm that the deviation is at random then there are no hidden or underlying issues explaining the deviation between experts. However, to determine the appropriateness of Chi-Square, degree of freedom (df) and chi square distribution table will need to be considered. To determine an appropriate chi-square the following data set (Table 4.5) can be used.

Table 4.5 *Chi Square Values*

df	P = 0.05	P = 0.01	P = 0.001
1	3.84	6.64	10.83
2	5.99	9.21	13.82
3	7.82	11.35	16.27
4	9.49	13.28	18.47
5	11.07	15.09	20.52
6	12.59	16.81	22.46
7	14.07	18.48	24.32
8	15.51	20.09	26.13
9	16.92	21.67	27.88
10	18.31	23.21	29.59
40	55.76	63.69	73.41
50	67.51	76.15	86.66
75	96.22	106.39	118.60
90	113.15	124.12	137.19

100	124.34	135.81	149.48

Full table available at http://home.comcast.net/~sharov/PopEcol/tables/chisq.html

Table 4.6 *Round 2 - Kendall's Coefficient of Concordance*

Test Statistics	
N	8
Kendall's W	.435
Chi-Square	73.124
Df	21
Asymp. Sig.	.000

Sheskin (2004) notes that the Kendall's coefficient can range from 0 which indicates no agreement to 1 which indicated complete agreement. The results from analysis the responses from round 2 suggest a Kendall W value of 43.5% (as outlined in Table 4.6) of the experts agreed on innovation activities which reflect a weak to 'lower degree of sound' agreement. Based on this it is suggested to undertake another Delphi round to ascertain if the agreement can be improved to a sound level at 60% or good level which is above 70%. However if the result is significant which in the case of this research applies as we have 8 experts which is the recommended healthy data set for a Delphi study, then it is considered to be average level of agreement. If we are able to achieve to a better convergence or if no improvement is realized, the Delphi iterations can be stopped due to reaching point of minimum returns. The current value of Kendall's W provides an indication that the experts are applying similar standard in ranking the innovation activities.

The Chi-Square test provides an indication if any deviation in expert opinion were random or whether there were some other underlying issues that may have caused the experts to deviate in their rankings of the innovation activities.

The degrees of freedom for this study are 21 (number of variables minus one). Therefore, according to the Chi-Square data at the link above, the chi-square should be at least 32.67 @ p =0.05, 38.93 @ p = 0.01, and 46.80 @ p = 0.001 To explain, any chi-square score above 46.80 suggests that any deviation is highly consistent with a random variance. To summarise, a chi-square of 73.12 suggests that the differences between the experts' rankings were at random. There are no hidden or underlying issues explaining the deviation between experts.

4.6.2.5 Multiple Comparison Analysis (MCA)

The Multiple Comparison Analysis allows the researcher to establish which variables assessed in round 2, are of high priority to be considered in the third round. In the case of this study, ANOVA (Analysis of Variance) is a statistical technique to analyse the difference between group means. It is essentially a data reduction technique which adds parsimony to the Delphi study. Although the analysis undertaken using the Mean scores gives a good idea of the impact of innovation measures on project performance, The MCA will be used to further support this analysis and add to the rigor of the analysis being undertaken for this study. ANOVA (Analysis of Variance) is a statistical technique to analyses the difference between group means. The following steps are undertaken as part of the Multiple Comparison Analysis:

The variable with the highest mean value is considered which in the case is 'Number of patents filled in the past year' (average score 19.375).

After setting the highest mean value, a one-way ANOVA-Tuckey's test was undertaken. It needs to be determined if we have a significant F ratio for which you determine the degree of freedom (df), the F ratio and the F- probability or significance. The values are shown in Table 4.7 and corresponding graph shown in Figure 4.3 below:

Table 4.7 *Multiple comparison analysis: ANOVA – Tuckey's test*

ANOVA						
Innovation Activities		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Improving annual R & D budget	Between Groups	205.375	5	41.075	.639	.703
	Within Groups	128.500	2	64.250		

	Total	333.875	7			
No. of active R & D projects	Between Groups	63.875	5	12.775	.881	.608
	Within Groups	29.000	2	14.500		
	Total	92.875	7			

ANOVA

Innovation Activities	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**	.748
	Within Groups	212.500	2	106.250		
	Total	501.875	7			
Partnerships with R&D organisations and tertiary institutions	Between Groups	59.000	5	11.800	1.276	.494
	Within Groups	18.500	2	9.250		
	Total	77.500	7			
Acquisition of new initiatives and technology options to facilitate business	Between Groups	81.375	5	16.275	.289	.886
	Within Groups	112.500	2	56.250		
	Total	193.875	7			
Increasing the number of ideas put forward by team member to team leader	Between Groups	79.000	5	15.800	31.600	.031
	Within Groups	1.000	2	.500		
	Total	80.000	7			
Reducing average time from idea evaluation to implementation	Between Groups	99.375	5	19.875	.353	.849
	Within Groups	112.500	2	56.250		
	Total	211.875	7			
Resources made available for continuous innovation	Between Groups	167.500	5	33.500	.978	.576
	Within Groups	68.500	2	34.250		
	Total	236.000	7			
Using more opportunities to discuss innovation and reward smart ideas	Between Groups	92.000	5	18.400	.409	.818
	Within Groups	90.000	2	45.000		
	Total	182.000	7			
Increased and focused marketing activities	Between Groups	102.875	5	20.575	2.572	.303
	Within Groups	16.000	2	8.000		
	Total	118.875	7			
Effective use of market	Between Groups	148.375	5	29.675	4.093	.208

intelligence to achieve a competitive edge	Within Groups	14.500	2	7.250		
	Total	162.875	7			

ANOVA

Innovation Activities	Sum of Squares	df	Mean Square	F	Sig.	.748
Optimising the savings achieved through successful operation efficiency ideas	Between Groups	189.000	5	37.800	5.214	.169
	Within Groups	14.500	2	7.250		
	Total	203.500	7			
Introduction of client management tools	Between Groups	117.875	5	23.575	1.274	.495
	Within Groups	37.000	2	18.500		
	Total	154.875	7			
Broadening the client portfolio	Between Groups	128.375	5	25.675	.689	.681
	Within Groups	74.500	2	37.250		
	Total	202.875	7			
Improving the percentage sales from products introduced in the past few years	Between Groups	106.000	5	21.200	.166	.954
	Within Groups	256.000	2	128.000		
	Total	362.000	7			
Improving the licensing/ IP statistics	Between Groups	13.000	5	2.600	.141	.966
	Within Groups	37.000	2	18.500		
	Total	50.000	7			
Introducing mechanisms for sharing and collecting data/ products	Between Groups	54.500	5	10.900	2.422	.318
	Within Groups	9.000	2	4.500		
	Total	63.500	7			
Introducing a knowledge management system in SMEs	Between Groups	160.875	5	32.175	1.055	.552
	Within Groups	61.000	2	30.500		
	Total	221.875	7			

Using innovative decision capability	Between Groups	161.000	5	32.200	2.576	.303
	Within Groups	25.000	2	12.500		
	Total	186.000	7			
Introducing particular technologies	Between Groups	103.000	5	20.600	.293	.884
	Within Groups	140.500	2	70.250		
	Total	243.500	7			
No. of patents filled in the past year	Between Groups	19.375	5	3.875	3.100	.262
	Within Groups	2.500	2	1.250		
	Total	21.875	7			

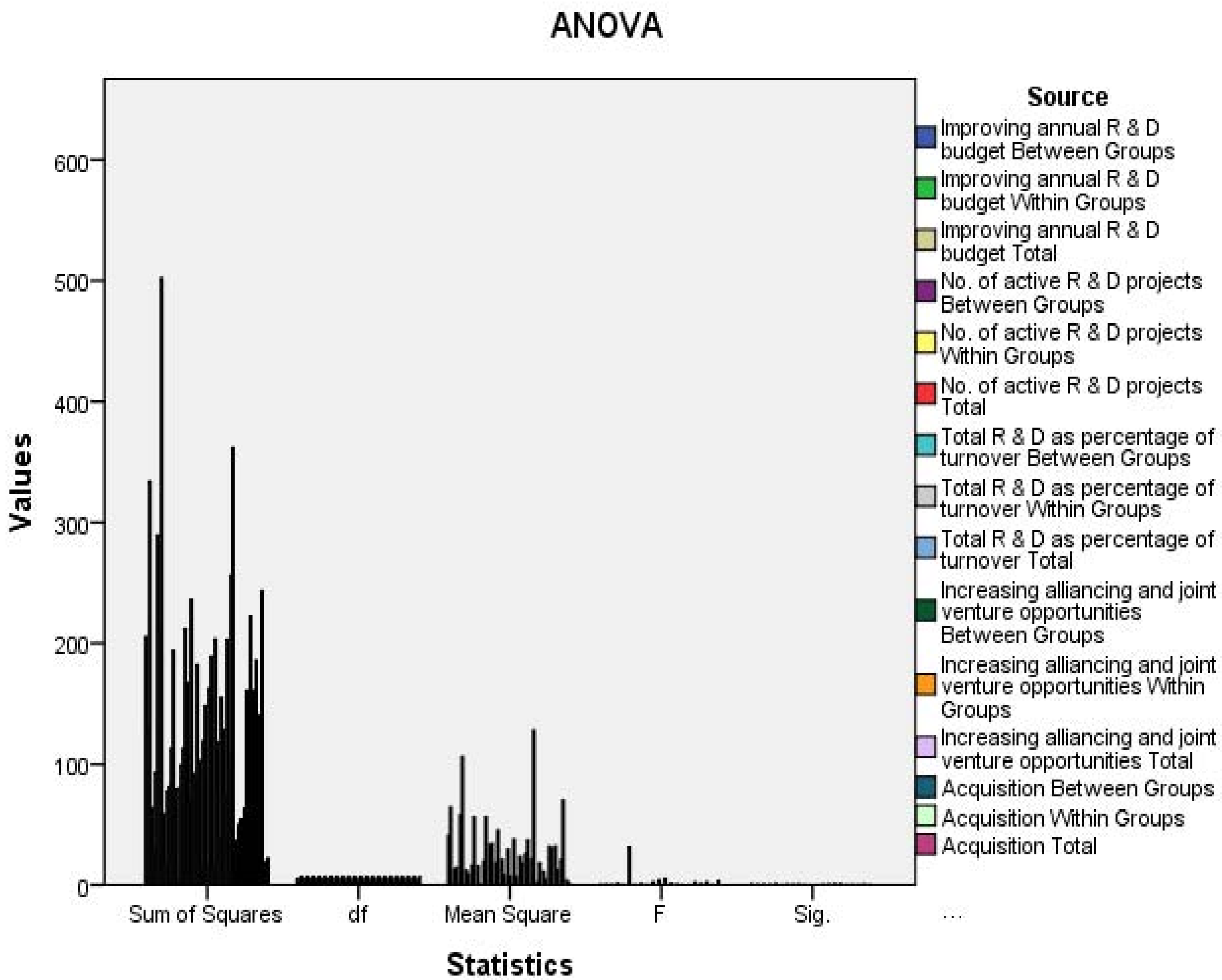


Figure 4.3. F probability for ANOVA

Furthermore; the priority factor selected for the first ANOVA was the variable with the lowest average rank (as 1 is considered to be more important in terms of ranking). In this case it was ‘Cooperation between individuals’. The results from the ANOVA highlight only one variable that varied significantly from the priority factor i.e. ‘Increasing the number of ideas put forward by team member to team leader’ , p = 0.031). This will not be filtered from the list.

Another ANOVA round is undertaken with the second priority factor ‘Partnerships with R&D organisations and tertiary institutions’. There is no p value (less than 0.015) which means these measures should be retained for the next Delphi round.

Table 4.8 *Multiple comparison analysis: ANOVA – Tuckey’s test with second priority measure*

ANOVA						
Innovation Activities		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Improving annual R & D budget	Between Groups	333.875	6	55.646	.	.
	Within Groups	.000	1	.000		
	Total	333.875	7			
No. of active R & D projects	Between Groups	92.875	6	15.479	.	.
	Within Groups	.000	1	.000		
	Total	92.875	7			
Total R & D as percentage of turnover	Between Groups	301.875	6	50.313	.252	.907
	Within Groups	200.000	1	200.000		
	Total	501.875	7			
Acquisition of new initiatives and technology options to facilitate business	Between Groups	185.875	6	30.979	3.872	.371
	Within Groups	8.000	1	8.000		
	Total	193.875	7			
Increasing the number of ideas put forward by team member to team leader	Between Groups	62.000	6	10.333	.574	.765
	Within Groups	18.000	1	18.000		

	Total	80.000	7			
Reducing average time from idea evaluation to implementation	Between Groups	161.875	6	26.979	.540	.778
	Within Groups	50.000	1	50.000		
	Total	211.875	7			

Innovation Activities		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig**
Resources made available for continuous innovation	Between Groups	236.000	6	39.333	.	.
	Within Groups	.000	1	.000		
	Total	236.000	7			
Using more opportunities to discuss innovation and reward smart ideas	Between Groups	180.000	6	30.000	15.000	.195
	Within Groups	2.000	1	2.000		
	Total	182.000	7			
Increased and focused marketing activities	Between Groups	114.375	6	19.063	4.236	.356
	Within Groups	4.500	1	4.500		
	Total	118.875	7			
Effective use of market intelligence to achieve a competitive edge	Between Groups	162.875	6	27.146	.	.
	Within Groups	.000	1	.000		
	Total	162.875	7			
Optimising the savings achieved through successful operation efficiency ideas	Between Groups	131.500	6	21.917	.304	.880
	Within Groups	72.000	1	72.000		
	Total	203.500	7			
Introduction of client management tools	Between Groups	146.875	6	24.479	3.060	.412
	Within Groups	8.000	1	8.000		
	Total	154.875	7			
Broadening the client portfolio	Between Groups	118.375	6	19.729	.233	.916
	Within Groups	84.500	1	84.500		

	Total	202.875	7			
Improving the percentage sales from products introduced in the past few years	Between Groups	290.000	6	48.333	.671	.732
	Within Groups	72.000	1	72.000		
	Total	362.000	7			
Improving the licensing/ IP statistics	Between Groups	48.000	6	8.000	4.000	.365
	Within Groups	2.000	1	2.000		
	Total	50.000	7			
Introducing mechanisms for sharing and collecting data/ products	Between Groups	45.500	6	7.583	.421	.826
	Within Groups	18.000	1	18.000		
	Total	63.500	7			
Introducing a knowledge management system in SMEs	Between Groups	171.875	6	28.646	.573	.765
	Within Groups	50.000	1	50.000		
	Total	221.875	7			
Using innovative decision capability	Between Groups	161.500	6	26.917	1.099	.623
	Within Groups	24.500	1	24.500		
	Total	186.000	7			
Introducing particular technologies	Between Groups	243.500	6	40.583	.	.
	Within Groups	.000	1	.000		
	Total	243.500	7			
No. of patents filled in the past year	Between Groups	13.875	6	2.313	.289	.888
	Within Groups	8.000	1	8.000		
	Total	21.875	7			

4.6.2.6 Additional Measures of Innovation Activity

Although, additional measures were not clearly identified by the experts as part of Round 1, it was important to capture some of their comments outlined above. Hence, a further review helped in grouping these comments into nine additional activities that have been identifies as part of the Delphi validation process and need to be added to the initial framework developed on the basis of literature review and are outlined as follows:

- Increased opportunity for staff development
- Introducing useful organisational change and leadership support
- Improving staff training on knowledge sharing
- Introducing incentive mechanisms to help development of new abilities/ motivation
- Selection of the ideas that bring the best return
- Involvement of all stakeholders/ key personnel in the design process
- Share lessons learnt across projects
- Investment into research that optimizes project outcomes
- Rate at which innovation is disseminated throughout the firm

Due to their focus on the knowledge workers in consulting engineering firms, the category encapsulating the above was grouped into the 'staff related innovation activities' theme. Table 4.9, Table 4.10 and Table 4.10 below outline their mean and rank.

Table 4.9 *Round 2 Additional Innovation Activities-Standard Deviation, Mean and Maximum Analysis*

Descriptive Statistics

Innovation Act.	**N**	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**
Increased opportunity for staff development	8	3.6250	.51755	3.00	4.00
Introducing useful organisational change and leadership support	8	3.7500	.70711	3.00	5.00
Improving staff training on knowledge sharing	8	3.7500	.88641	2.00	5.00
Introducing incentive	8	3.6250	1.18773	2.00	5.00

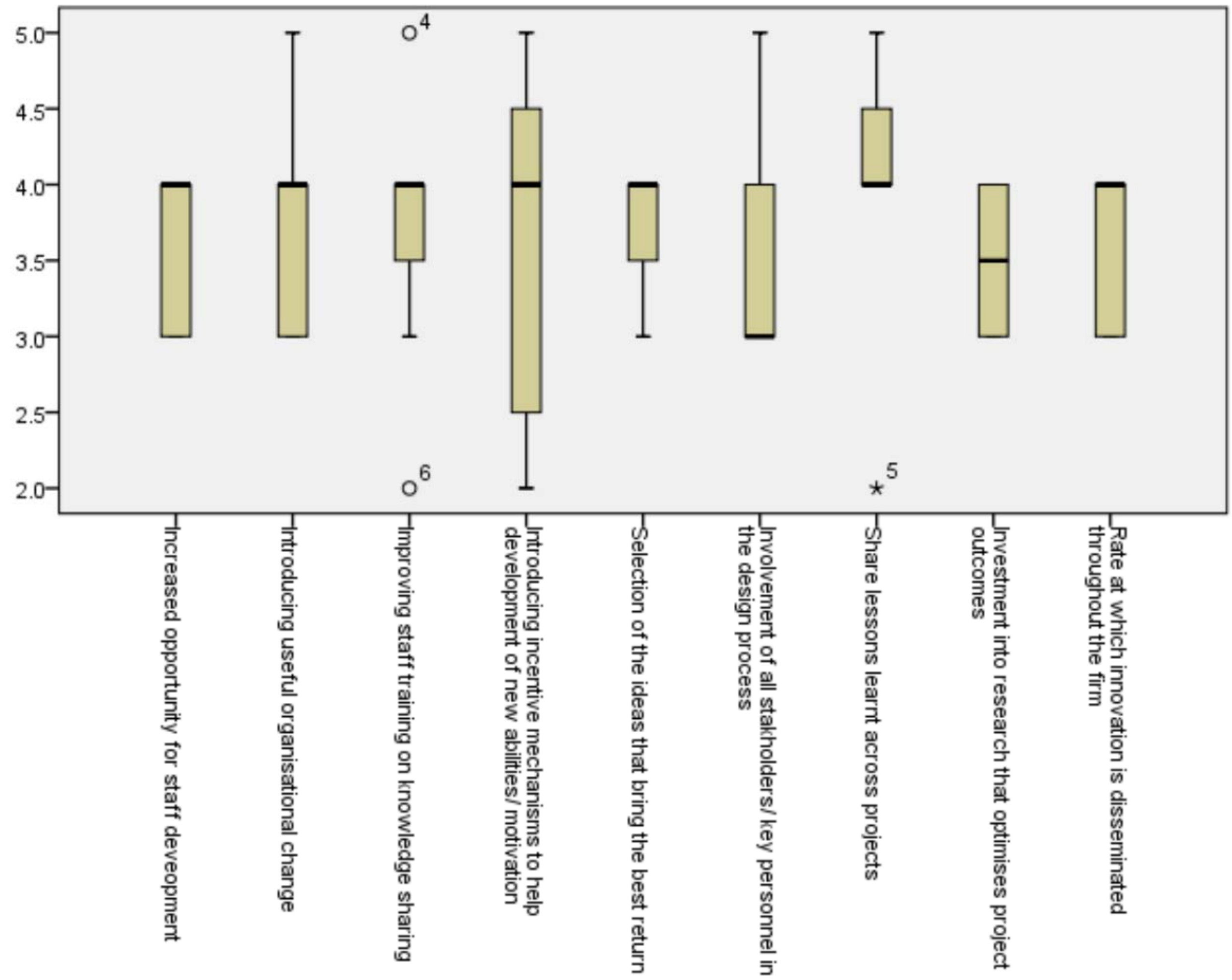
mechanisms to help development of new abilities/ motivation					
Selection of the ideas that bring the best return	8	3.7500	.46291	3.00	4.00
Involvement of all stakeholders/ key personnel in the design process	8	3.5000	.75593	3.00	5.00
Share lessons learnt across projects	8	4.0000	.92582	2.00	5.00
Investment into research that optimizes project outcomes	8	3.5000	.53452	3.00	4.00
Rate at which innovation is disseminated throughout the firm	8	3.6250	.51755	3.00	4.00

Table 4.10 *Round 2 Additional Innovation Activities- Mean Rank*

Innovation Activities	**Mean Rank**
Increased opportunity for staff development	4.63
Introducing useful organisational change and leadership support	5.00
Improving staff training on knowledge sharing	5.69
Introducing incentive mechanisms to help development of new abilities/ motivation	5.00
Selection of the ideas that bring the best return	5.38
Involvement of all stakeholders/ key personnel in	4.19

the design process	
Share lessons learnt across projects	6.25
Investment into research that optimizes project outcomes	4.19
Rate at which innovation is disseminated throughout the firm	4.69

Box plot in Figure 4.4 shows ‘improving staff training on knowledge sharing systems’ has two outliers (experts 6 and 4) and ‘sharing lessons learnt’ also have one outlier (expert 5) .



[redacted]

Figure 4.4. Box plots from Additional Activities from Round 2

It is important to undertake Round 3 with all the 31 innovation activity measures (22 previous ones and 9 new ones). This round will help in getting a final confirmation from the experts on their preferences activities that impact project performance. It will also help in filtering any of the activities which are not as relevant.

4.6.3 Delphi Round 3- Confirmation of Priorities

4.6.3.1 Purpose and Logistics:

The main purpose of round 3 was:

To come up with a prioritised framework that includes all the innovation activities which have an impact on project performance for consulting engineering firms.

Achieve convergence or point of minimum returns to terminate the Delphi study.

To confirm if any innovation activities can be filtered from the final validated framework. This stage is meant to eliminate the least relevant criteria.

The 31 innovation activities and the relative total weighting scores were presented to the eight experts are outlined in Table 4.11.

Table 4.11 *Innovation Activities Presented to the Experts*

Innovation Activities- Impacting Project Performance for Consulting Engineering Firms	**Total weighting based on ranking**
Research and Development Activity	
Improving annual R & D budget	27
No of patents filled in the past year	14
No of active R&D projects	25
Total R&D as percentage of turnover	29
Partnerships with R&D organisations and	34

Innovation Activities- Impacting Project Performance for Consulting Engineering Firms	Total weighting based on ranking
tertiary institutions	
Acquisition of new initiatives and technology options to facilitate business	23
Investment into research that optimises project outcomes	23
Rate at which innovation is disseminated throughout a firm	23
Communication activities on projects	
Increasing the number of ideas put forward by team member to leaders	27
Reducing the average time from idea evolution to full implementation	29
Resources made available for continuous innovation	31
Cooperation between individuals	36
Using more opportunities to discuss innovation and reward smart ideas	31
Selection of ideas that bring the best return	30
Involvement of all stakeholders /key personal in the design process	30
Client related activities	
Increased and focussed marketing activities	25

Innovation Activities- Impacting Project Performance for Consulting Engineering Firms	**Total weighting based on ranking**
Effective use of market intelligence to achieve a competitive edge	31
Optimising the savings achieved through successful operation efficiency ideas	31
Introduction of client management tools	24
Broadening the client portfolio	28
Introducing systems	
Improving the percentage sales from products introduced in the past few years	17
Improving IP and opportunities for commercialising & offering services on licencing arrangements	19
Introducing mechanisms for sharing and collecting data/products	25
Introducing a Knowledge Management System in SME's	27
Using innovative decision capability	23
Introducing particular technologies	25
Share lessons learnt across projects	28
Staff related innovation activity	
Increased opportunity for staff development	29
Introducing useful organisational change and leadership support	30
Improving staff training on knowledge sharing	30 29

Innovation Activities- Impacting Project Performance for Consulting Engineering Firms	**Total weighting based on ranking**
Introducing incentive mechanisms to help development of new abilities/motivation	

The experts were asked to rank it using a rating of 1 (being most relevant) and 31 (being least relevant). The results from round 2 were included in the questionnaire and the objective of the round 3 was clearly articulated.

4.6.3.2 Outcomes-Round 3

The box plots based on the responses from round 3 are shown in Figure 4.5. The following innovation activities have had outliers or extreme scores:

Resources made available for continuous innovation.

- Cooperation between individuals.
- Introducing particular technologies.
- Broadening the client portfolio.

However, to better understand the spread of expert opinion on each innovation activity, it is important to look at the standard deviation data which is discussed next.

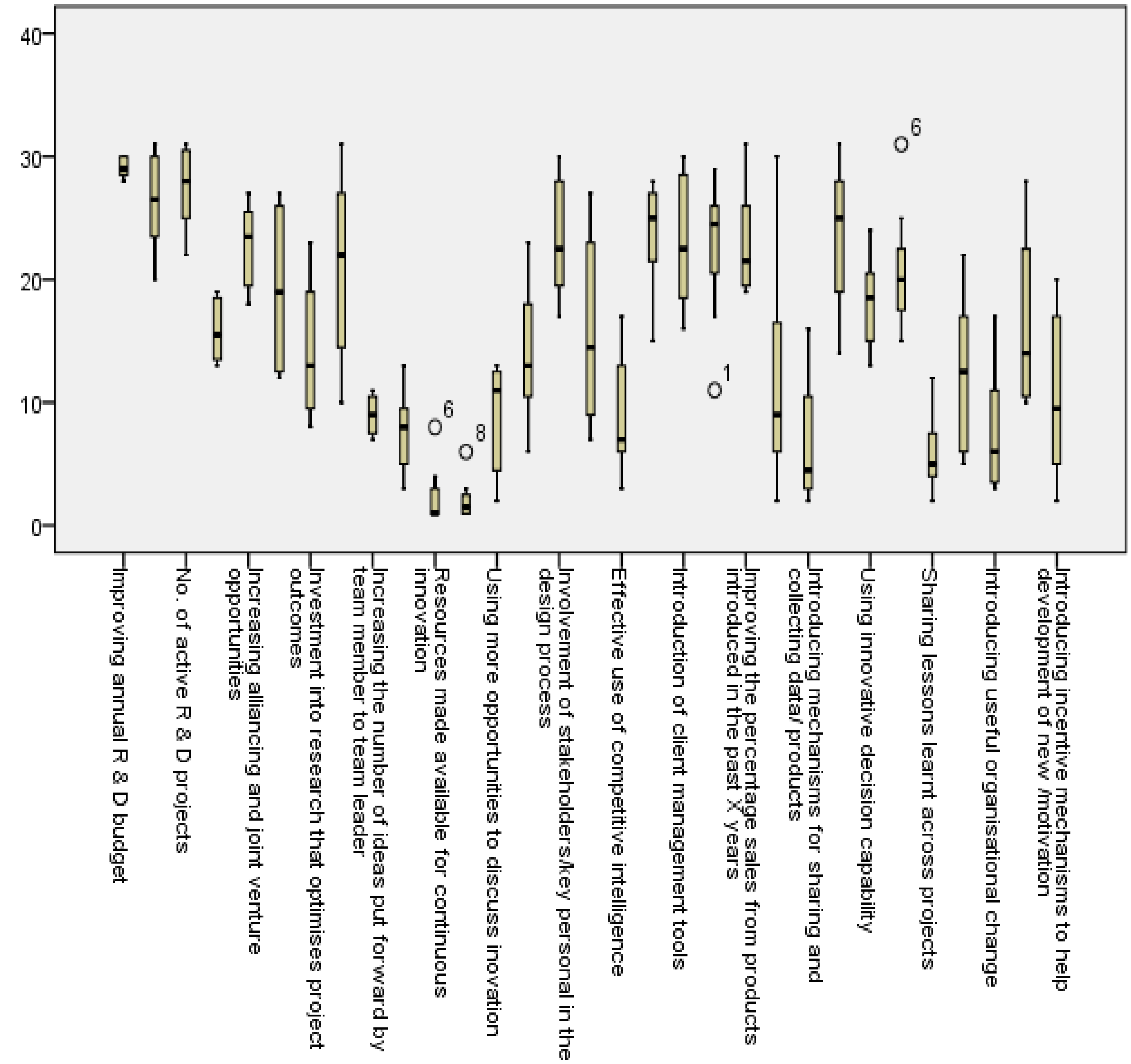


Figure 4.5. Round 3 Box Plot Analysis

4.6.3.3 Standard Deviation- Round 3 Analysis

Round 3 ‘Standard Deviation’ and ‘Mean’ values are shown in Table 4.12. The highest standard deviation is 11.863 and the lowest 3.615. The average standard deviation value is approximately 4.8. Consistent with Round 2 outcomes, ‘Cooperation between individuals’ has the lowest mean value (2.125) and the standard deviation at 1.726 is lower than the mean standard deviation which shows that there is sufficient convergence between the respondents to rate this activity high in its relevance to assessing the impact of innovation activity on project performance of consulting engineering firms. The trend from Round 2 continues as 'No. of patents filed in the past year' and 'Improving IP and opportunities for commercialising & offering services on licencing arrangements' have a high mean value and hence being considered less relevant. The standard deviation for both the activities is lower than the mean standard deviation value which shows that the agreement is high. This means that these activities can be dismissed going forward. Also, further analysis of the data on standard deviation and mean values the following innovation activities are of little relevance and can be dismissed for the purpose of this exercise:

- Improving annual R& D budgets (Mean 29.12 and very low S.D of 0.834).
- Number (No.) of patents filled in the past year (Mean 26.37 and S.D of 4.13).
- No. of active R&D projects (Mean 27.5 and S.D 3.33).
- Partnerships with R&D organisations and tertiary institutions (Mean 22.75 and S.D 3.3).
- Optimising the savings achieved through unsuccessful operational efficiency ideas (Mean 23.75 and S.D 4.71).
- Improving the percentage sales from products introduced in the last few year (Mean 23.00 and S.D 4.27).
- Introduction of client management tools (Mean 23.1250 and S.D 5.566).
- Broadening the client portfolio (Mean 22.750 S.D 5.87).

The standard deviation of most of the above is lower than the average standard deviation of 4.8. Due to their relatively lower relevance and sound agreement between the experts, it is not unreasonable to exclude them from the research model going forward. There are two activities which are consistently ranked of lower relevance and their S.D is very slightly higher than the mean S.D. A further analysis is included in the section on the development of the prioritised model.

Table 4.12 *Round 3 Standard Deviation Analysis*

Descriptive Statistics					
Innovation Activities	**N**	**Min**	**Max**	**Mean**	**Std. Deviation**
Improving annual R & D budget	8	28.00	30.00	29.1250	.83452
No. of patents filled in the past year	8	20.00	31.00	26.3750	4.13824
No. of active R & D projects	8	22.00	31.00	27.5000	3.33809
Total R & D as percentage of turnover	8	13.00	19.00	15.8750	2.53194
Partnerships with R&D organisations and tertiary institutions	8	18.00	27.00	22.7500	3.37004
Acquisition of new initiatives and technology options to facilitate business	8	12.00	27.00	19.2500	6.69221
Investment into research that optimises project outcomes	8	8.00	23.00	14.2500	5.65054
Rate at which innovation is disseminated through a firm	8	10.00	31.00	21.0000	7.69044
Increasing the number of ideas put forward by team member to team leader	8	7.00	11.00	9.0000	1.69031
Reducing average time from idea evaluation to implementation	8	3.00	13.00	7.6250	3.29231
Resources made available for continuous innovation	8	1.00	8.00	2.3750	2.50357
Cooperation between individuals	8	1.00	6.00	2.1250	1.72689
Using more opportunities to discuss innovation and reward smart ideas	8	2.00	13.00	8.8750	4.51782

Descriptive Statistics					
Innovation Activities	**N**	**Min**	**Max**	**Mean**	**Std. Deviation**
Involvement of stakeholders/key personal in the design process	8	17.00	30.00	23.3750	4.83846
Increased and focused marketing activities	8	7.00	27.00	15.8750	7.66136
Effective use of market intelligence to achieve a competitive edge	8	3.00	17.00	9.0000	4.81070
Optimising the savings achieved through successful operation efficiency ideas	8	15.00	28.00	23.7500	4.71320
Introduction of client management tools	8	16.00	30.00	23.1250	5.56616
Broadening the client portfolio	8	11.00	29.00	22.7500	5.87367
Improving the percentage sales from products introduced in the past X years	8	19.00	31.00	23.0000	4.27618
Improving the licensing/ IP statistics	8	2.00	30.00	11.8750	9.01487
Introducing mechanisms for sharing and collecting data/ products	8	2.00	16.00	6.7500	5.54849
Introducing a knowledge management system in SMEs	8	14.00	31.00	23.6250	5.97465
Using innovative decision capability	8	13.00	24.00	18.1250	3.68152
Introducing particular technologies	8	15.00	31.00	20.7500	5.06388
Sharing lessons learnt across projects	8	2.00	12.00	5.8750	3.18198
Increased opportunity for staff development	8	5.00	22.00	12.2500	6.51920
Introducing useful organisational change and leadership support	8	3.00	17.00	7.6250	5.23552

Introducing staff training on knowledge sharing	8	10.00	28.00	16.5000	6.90755
Introducing incentive mechanisms to help development of new /motivation	8	2.00	20.00	10.6250	6.73875
Valid N (listwise)	8				

4.6.3.4 Kendal's Coefficient of Concordance (W) and Chi Square Analysis

Kendall's Coefficient W is used to measure the agreement between the experts. Sheskin (2004) notes that Kendall's Coefficient of Concordance allows a researcher to determine the degree of agreement between 'm' sets of ranks and 'n' objects which is termed as inter-judge reliability. It is a method of non-parametric data to establish the level of concordance that exists among experts or respondents. Sheskin (2004) and Brancheau et al (1987) note that a 0 value for W reflects no agreement and 1 reflects complete agreement. $W \geq 0.7$ reflects a good agreement. A 'W' value between 0.6 and 0.7 reflects a sound agreement. Meanwhile, in order to obtain a measure of consistency, the Kendall's Coefficient of Concordance (W) across both the rounds was calculated with the aid of the SPSS software.

A W value below 0.6 is considered to represent a weak (moving towards a sound) agreement. Some researchers in the past have used a null hypothesis where $W = 0$ i.e. there is no agreement among the participants as a test to ascertain if the Delphi should be continued or terminated. According to the level of significance (0.000) which is less than 0.05, the null hypothesis that the respondent's ratings within the group are unrelated to each other would have to be rejected. The findings from the Kendall's test clearly reject the null hypothesis and the alternate hypothesis that there is good agreement between the experts is accepted. The current value of Kendall's W provides an indication that the experts are applying similar standard in ranking the innovation activities. The results from Round 3 indicate (Table 4.13) a significant improvement in W value has increased to 70.8% (from previously of 43.5%) which clearly shows a good agreement which is sufficient to terminate the Delphi study as it has led the experts to point of diminishing returns (Linstone and Turoff, 1975; 2011).

Table 4.13 *Round 3 Kendall's Coefficient of Concordance Results*

Test Statistics	
N	8
Kendall's W	.708
Chi-Square	169.970
Df	30
Asymp. Sig.	.000

The Chi-Square test provides an indication if any deviation in expert opinion were random or whether there were some other underlying issues that may have caused the experts to deviate in their rankings of the innovation activities.

The degrees of freedom (df) for this study are 30 (number of variables minus one). Therefore, according to the above, the chi-square should be at least 44.9 @ p =0.05, 52.19 @ p = 0.01, and 61.10 @ p = 0.001. To explain, any chi-square score above 61.10 suggests that any deviation is highly consistent with a random variance. To summarise, a Chi-Square of 169.97 suggests that the differences between the experts' rating were mainly random. This is in line with the research undertaken by Rowe and Wright (1999) which identifies that the Chi Square analysis is complementary to Kendall and helps to establish if the selections made by the experts were random or somehow being forced on them. The Chi Square determination from Round 3 is sufficient to establish that there are no hidden or underlying issues explaining the deviation between experts.

4.6.3.5 Elimination of least relevant criteria to finalise a prioritised model

The study is at that stage where we are in a position to only retain the innovation activities which have a relatively more positive impact on project performance. After undertaking a number of complementary statistical analysis, we can confidently leave out the innovation activities which although have some positive impact on project performance is not significant to retain in the prioritised innovation activity model. For some of the innovation activities there could be seen a recurring trend across the three rounds of the Delphi study.

There is sufficient agreement between the experts to filter out the least relevant criteria and finalize a prioritized innovation activity model that can be used to assess the impact innovation activity on project performance for consulting engineering firms. The following points are presented in support of establishing a prioritization model:

- Innovation activity 'No. of patents filed in the past year' have been consistently rejected by experts across the last 2 stages of the Delphi study. The experts have consistently ranked it higher and these therefore after the consistent ranking are being judged not relevant and being eliminated from further inclusion in the model. It is important to note that the thinking and decision making process of the experts has evolved across the consecutive Delphi rounds e.g. they rated the innovation activity associated with improving licensing and commercialization higher in Round 3 as compared to Round 2. This was also because more data and verbal discussions were held with individual experts to answer their queries. The low ranking of the innovation activity associated with 'No. of patents' can be attributed to the comments made by some of experts that these might not be relevant to the context of consulting engineering firms or architectural firms e.g. there is very little opportunity to file any patents as the R&D undertaken in consulting engineering or architectural firms is project specific only and very informal. In most cases investigations into building types and trend are undertaken rather than investing into formal R&D where there is an opportunity to file patents or negotiate Intellectual Property (IP) rights or issues.
- The next three innovation activities to consider are 'No. of active R&D projects', 'Improving annual R&D budget' and 'Partnerships with R&D organisations and tertiary institutions'. The experts have consistently ranked these higher and not relevant to the context of this study. There is consistent feedback from the Delphi experts regardless of their role as a client, consultant or contractor in the project governance team structure.

- The general view is that there is relatively lesser investment into these R&D related innovation activities due to lack of dedicated budget allocation. There is some in-kind and cash investment into R&D activities directly linked to a project or that can be reimbursed in fees by the end client. This view was also shared by some of the Delphi experts who had a contractor background. Their view is that distinct R&D related activities are not well associated with construction. There is some incremental R&D arguably undertaken but there is no systematic approach towards it. One of the experts who is asset owner/operator and client for consulting engineering firms point out that there is no real spending in R&D but their organization shares ideas and planned improvements with local government in Queensland when developing new Greenfield sites or in refurbishment of existing facilities. One of the experts acknowledged that allocating sufficient time and budget for staff to get involved into R&D activities is a key driver for them and they are always looking at leveraging opportunities with established R&D institutions. One of the experts noted that for their organization, innovation is business related and focused supporting technical or business leadership. It was pointed out again the rate at which the innovation is disseminated is the key. The key for them is to identify technologies and harness them together in new ways to improve the capability and efficiency of their organization.
- The innovation activities 'Optimising savings achieved through successful operation and efficient ideas', 'Introduction of client management tools' and 'Broadening the client portfolio' have been consistently across all the rounds ranked them high and not very relevant. The comparatively lower Standard Deviations also show that there is convergence between the experts. This is also consistent with some of the feedback from some of the experts. The Delphi expert with a contracting background noted that client focused tools and marketing activities are not utilized effectively in their organization and there is a lack of acknowledgement that this has a direct impact of project performance. Client based Delphi expert ranked these activities comparatively higher and noted that these have enabled the organization to market their operations e.g. local government which in

most cases is a funding partner been more flexible in adopting their design requirements which was achieved through better client management tools and activities. One of the Delphi expert mentioned that some clients are not interested in innovation due to their risk aversion and a realization that there are direct benefits from investment into it. Experts also noted that project profitability especially in the current economic environment restricts the amount of innovation activity. There is a view that innovative solutions dictate an increase in design time and cost.

- There was also a view across the experts that they could not find the relevance of 'Improving the percentage sales from products introduced in the last few year' to consulting engineering firms so have rated it less relevant.

Based on the above analysis using mean rating and standard deviation, a revised model comprising a filtered list of innovation activities is shown in the Table **4.14** below.

Table 4.14 *Revised Model Based on Filtered Innovation Activities*

Innovation Activities Model
Total R&D investment as a percentage of turnover
Acquisition of new initiatives and technology options to facilitate business of other companies and investment into innovative initiatives
Investment into research that optimises project outcomes
Rate at which innovation is disseminated through a firm
Increasing the number of ideas put forward by team member to team leader
Reducing average time from idea evaluation to implementation
Resources made available for continuous innovation
Cooperation between individuals

Using more opportunities to discuss innovation and reward smart ideas
Selection of ideas that bring the best return
Involvement of stakeholders/key personal in the design process
Increased and focussed marketing activities
Effective use of market intelligence to achieve a competitive edge
Improving licencing and intellectual property related measures
Introducing mechanisms for sharing and collecting data/ products
Introducing a knowledge management system in SMEs
Using innovative decision capability
Introducing particular technologies
Sharing lessons learnt across projects
Increased opportunity for staff development
Introducing useful organisational change and leadership support
Introducing staff training on knowledge sharing
Introducing incentive mechanisms to help development of new /motivation

The above filtered model and the corresponding ranking data from round 3 was used to validate the final relative rankings of innovation activities forming part of a prioritised model that can be used to assess the impact of innovation intensity on project performance. Importance indexes and other similar prioritization tools have been used by previous researchers (Khan et al, 2014) to rank identified risks in order of their perceived importance In line with previous research, the prioritization for this research model was based on an overall rating index which was computed using the following modified equation by Mezher [45] & Mian [46]:

$$O.R = \left(\sum_{i=1}^{n} \frac{q_i}{a} \right) \qquad \text{(Eq. 1)}$$

Where O.R denotes overall rating index and qí is a variable that represents the criteria or question where i = 1, 2, 3, 4…..n where ‘n’ = to the number of questions which in this case is 22. The denominator of ‘a’ represents the number of Delphi experts. This is a slight variation of the index used by Khan (2014). The Overall Rating Index (and average scores for each criteria) which was based on Eq. 1 was then used to rank the innovation activities as shown in Table 4.15.

Table 4.15 *Importance Index Calculation*

Innovation Activities	**O.R**	**Rank**
Total R&D as a percentage of turnover	15.875	16
Acquisition of new initiatives and technology options to facilitate business of new initiatives and companies to facilitate business	19.25	19
Investment into research that optimises project outcomes	14.25	14
Rate at which innovation is disseminated throughout a firm	21	21
Increasing the number of ideas put forward to the team leader by design team members	9	8
Reducing average time from idea generation to	7.625	5

implementation		
Resources made available for continuous innovation	2.375	2
Cooperation between team members	2.125	1
Using opportunities to discuss innovation	8.875	7
Selection of ideas that bring the best return	14	13
Involvement of all stakeholders/key project person in the design process	23.375	22
Increased and focussed marketing activities	15.875	15
Effective use of market intelligence for competition	9	9
Improving IP and opportunities for commercialising & offering services on licencing arrangements	11.875	11
Introducing mechanisms for sharing and collecting data/products	6.75	4
Introducing a knowledge management system	23.625	23
Using innovative decision making tools	18.125	18

Introducing particular technologies for training staff	20.75	20
Sharing lessons learnt from projects	5.875	3
Increased opportunity for staff development	12.25	12
Introducing useful organisational change and leadership support	7.625	6
Improving staff training on knowledge sharing	16.5	17
Introducing incentive mechanisms to help development of new capability / staff motivation	10.625	10

4.6 ROUND 4- FURTHER CONFIRMATION THROUGH FEEDBACK & WORKSHOP

The Delphi process was concluded by presenting the prioritised innovation activities model to the experts. This is in line with the suggestions of Hefferan and Mian, 2006). They note that it is not uncommon to end the Delphi process normally with presenting the outcomes of the Delphi round 3 (preferably in a workshop environment) to the expert panel and get a final confirmation and feedback on the final outcomes and results. At this stage the main ideas for the study have been formulated and the innovation model is in an advanced stage so a face-to-face discussion will not inhibit the expert's creativity and idea generation. It was hard to get all the experts in one place at one time due to their work commitments and differing time zone (international experts were part of the panel). This issue was overcome by presenting the outcomes to a smaller sub group, capturing their feedback and then presenting to other members on an individual basis. Previous researchers have used this approach.

Hsu et al. (2007) noted that the use of email and teleconferencing can facilitate the Delphi process. Witkin & Altschuld (1995) confirmed that electronic technology provides an opportunity to fast track the Delphi process. It also improves the potential of rapid feedback.

Although, the final round of validation was successfully completed but significant time was spent on the back and forth clarifications and multiple discussion iterations through face-to-face and telephone meetings. The credibility of the model was further improved as the prioritization and activities were discussed and validated. The workshop also helped in identifying important considerations that were captured in the conclusions and will be a good starting point for future researchers to consider for extending this research. No new variables were added to the model but the comments in particular were important to support the conclusions drawn from the overall study. There was general consensus on the results and the validity of the Delphi process. This round was a departure from the normal Delphi where experts are kept anonymous. However, the results were not compromised as the experts mainly discussed and validated the prioritised model which had already been developed as part of round 3. Some useful insights were received through the workshop and feedback process which has been captured in the conclusions drawn from the study. The approach undertaken to conclude this feedback round included:

- Presentation of the prioritised model to the expert panel and asking for their direct feedback on the innovation activities rank in relation to their impact on project performance. They were asked if they would rank them differently depending for different performance measures included in the study.
- Collaborative engagement with the group: the influence of dominant individuals (Halo effect) was minimized through maintaining respondent anonymity and passing on individual questionnaires through the initial rounds of Delphi process but the final feedback and face-to-face discussion helped in achieving a group consensus and fine tuning of the model.
- A facilitation approach: that helped in keeping experts motivated so that they are encouraged to add value through innovative and relevant ideas.

Ludwig (1994) specifically addressed subject motivation as the key successful conclusion of a Delphi study.

Before the Delphi study is closed, it is important to summarise some of the conclusions drawn from the overall study including the final workshop. This will also help supplement some of the views that have evolved through the preceding stages of the study. The conclusions drawn were:

- The Delphi process was facilitated successfully as there were no drop outs of experts. The questionnaires were completed with statistical ranking feedback and also enriched by textual comments that added to the credibility and relevance of the study. The outliers were asked to justify their selection with comments. This is aligned with Rowe and Wright (1999) suggestion that feedback from and to experts on the reasons of their ratings has shown to improve the accuracy of group judgements.
- The use of e-Delphi (term coined by Somerville, 2007) helped in reducing time and expense of the process significantly and also it was easier to provide to experts and manage detailed data.
- The initial use of standard deviation and mean aided by Kendall's and Chi Square statistical analysis helped in establishing sufficient consensus after which the Delphi was terminated. It is important to note that there was a significant change in the concordance from Round 2 to Round 3 due to the information provided to the experts that helped them to better understand the focus and objectives of the study. This was mainly done by presenting the data from the previous rounds. Discussions were also undertaken to clarify their queries. However, special consideration was given to avoid discussions that in any way impacted their judgement process throughout the study. However, a feedback round was also held to further improve the credibility of the research model. This was meant to get a final confirm on the prioritisation and incorporate any variations to the model that improves its robustness and relevance. This frequency of Delphi rounds for this research is well aligned to the work of previous researchers as most of the Delphi studies to reach stable consensus or point of diminishing returns

have used three rounds (Xia Bo & Chan, 2011). Researchers note that too many rounds can waste the time of experts.

- Sufficient consensus was achieved in three rounds followed by a final feedback round. This is aligned to the work of previous researchers as most of the Delphi studies to reach stable consensus or point of diminishing returns have used three rounds (Xia Bo & Chan, 2011). Researchers note that too many rounds can waste the time of experts. The key to success of this Delphi study was:
  - Careful planning and close management.
  - Use of relevant, clear and easy to understand questions posed across all the rounds
  - Maintenance of momentum throughout the study, regular engagement and encouragement using a facilitation approach and keeping the experts focussed on the final outcome helped in its successful completion.
  - Standard Deviation and Median scores helped in developing a quick understanding across the group. Due to the close clustering of data other complementary statistical techniques such as Kendall's coefficient, Chi Square and ANOVA were used to aid the prioritisation process. The additional statistical analyses applied to the same data helped to ratify the conclusions drawn from the study.
- The use of experts who belonged to relevant organisations (in the context of the study) and have had held senior roles helped in improving the validity of the study. The robustness of the study can also be gauged from the fact there was minimal variations within the innovation activity numbers i.e. the innovation activities identified (22 in total) from the literature review increased through the initial validation Delphi rounds (33 in total) but decreased as the model was further refined (23 in total). The model at the end represented the agreement and consensus of the experts.
- The Delphi experts through their feedback validated the approach which was the basis of the development of the conceptual model. They noted that some of the innovation activities were generic or high level. In their view

the open-endedness provides a huge opportunity for the organisation when implementing these activities to specifically look at enablers or solutions that are tailored to the make-up of that organisation. This will help in putting in place an innovative solution that is tailored, cost effective and efficient.

It was also noted that some of the innovation activities e.g. 'Total R&D as a percentage of turnover' can be used to measure the extent of innovation activity. Organisations can utilise these to monitor their yearly progress and benchmark their investment into innovation against some of their competitors.

- As part of validating the innovation model there was general consensus across the experts that Innovation activity in consulting engineering firms can be broadly grouped into and are a function of the following themes:
  - Communication activities on projects
  - R&D activities
  - Staff related activities.
  - Client related activities
  - Introducing innovative systems

  The 'introduction of systems' and 'staff focused activities' have similar number of sub-activities but the staff focussed activities were rated to have a more positive impact on project performance. 'Client related activities' are lesser in number as compared to the 'R&D activities' but ranked higher to make a more positively to impact project performance. As the process evolved the experts were more focussed on validating the relevance of innovation sub-activities without paying too much attention to how they were grouped into a theme. It is also important to note that the 'staff related theme' was not identified through the literature and added through the Delphi process and is an addition to the existing body of knowledge that can be used when assessing innovation for consulting engineering firms. It also supports the view that knowledge workers are the most important aspect of consulting engineering firms and innovation activities that are specifically focussed to them should be included when considering consulting engineering firms. A detailed analysis of the sub activities is as follows:

- **Communication activities on projects:** Each of these are in turn are spilt into sub – activities. It is important to note that 'communication focussed innovation theme' includes the highest number of sub activities (7) and most of them are rated highly. Most of the experts ranked *innovation activities that improve communication* highly. Overall, 'Cooperation between individuals' and 'Resources made available for contributing to continuous innovation' were ranked 2 and 1 respectively.

  The experts thought that these two can have a direct positive impact on client and team satisfaction which in turn will result in efficiencies in project and design fee. These communication activities in their view also had a significant impact on the project timelines. There were no activities across this theme that dropped out through the Delphi refinement and the final round 4 workshop process which clearly highlights its importance. The Delphi experts associated with client-based organisations particularly emphasised the importance of communication on projects. The CEO of an organisation who manages a large asset portfolio noted: 'It is a key to successful facility design and project delivery that all team members including client representatives have the opportunity to input ideas into facility design and operation and that these are reflected through to project architect for the development of a project and also for input and consideration into future stages'.

  More recently across consulting engineering firms in Australia, top management is looking at introducing initiatives that can improve communication channels with the client and other stakeholders. These organisations are looking at introducing innovative solutions that can facilitate clear communication on projects and provide platforms where engineers can openly share and pursue their ideas which are cost effective (for clients and their firms) and produce quality end product. Some of the recent technology solutions being adopted by consulting engineering firms for robust design management includes Project Wise, Aconex etc. Similarly for effective client management, CRM is being implemented across large engineering firms. The main objective is to enable frequent and effective ways of direct communication between project stakeholders. A high significance (rank 5) was attributed to 'reducing average time from idea generation & evaluation) to its implementation'. This clearly showed that the experts were keen to expedite the process of innovation towards its implementation especially if these have a direct impact on project performance so that the organisation can realise its intended benefits in a timely and efficient manner.

- **R&D related innovation activities:** There were 4 innovation activities that made the shortlist of Delphi experts. There is a general perception in the industry that research and development rank highly and have a marked significance when considering impact on organisational and project performance. This view is also supported by existing body of knowledge. However, the output from the Delphi results in changing this view about consulting engineering firms. However, this study has identified a different perspective as most of the R&D innovation activities are ranked as being of lower statistical significance than the 'communication focussed innovation activities' while considering their impact on project performance. The experts are of the view that that due to the squeezing market conditions and since the dawn of GFC, investments into research and development is diminishing. One of the contracting based expert noted that 'IP produced due to research and development activity is not highly valued by construction companies'.

They also note that construction is not known for distinct R&D. But some incremental R&D is arguably undertaken on each project. It is unlikely to be systematically done. A panel expert who works for a leading Australasian architect noted that:

'Generally not relevant to architectural firms, R&D is specific to projects and very informal. No budget assigned but investigations into building types and trends are undertaken'.

This finding is specifically relevant to consulting engineering firms and knowledge-based firms in general as it can help in prioritising their investment into innovation activities. It echoes the concerns of some of the industry leaders in Queensland who feel that investing into R&D may have a positive impact on their profile in the market and their staff development but is not trickling down to have a significant direct impact on the performance of their projects especially not as significant impact on client or design team satisfaction as expected from other innovation activities. The direct impact on delivering projects within project budgets or project timelines are also not as significant. There is a need for tertiary institutions and R&D firms to look at tailoring their research topics and identifying innovation focussed R&D activities that are tailored to the projects of these organisations and can have better results on project performance for knowledge-based firms. It is important to note that 'Total R&D investment as a percentage of turnover' is more of a measure than a activity. But it is not hard to establish that the intent of experts is for consulting firms to invest into innovation activities that directly contribute towards measuring and improving their performance towards this metric. It is also important to align the investment should be specifically to realising real business drivers and look at optimising performance improvement. It might be valuable for large engineering houses to identify specific activities to support this measure as part of future research.

- **Innovation activities related to staff development**: All these activities were consistently ranked higher by experts. Three out of four were ranked lower than 12 with one of the activity ranked 6. There was a consensus that motivated staff can bring improved performance to projects. Hence, careful consideration needs to be given to activities that add to staff motivation in areas such career development, financial reward, fun and challenge. It is interesting to note that this area was not explicitly identified in the work done on innovation by previous researchers and was not included in the developed model which was based on a literature review. This is an addition to the existing body of knowledge for consulting engineering firms. The validation process through Delphi resulted in enhancing the robustness and relevance of the conceptual model. The theme comprised of a number of activities. It is quite evident that most of these have a direct impact on project performance and delivery e.g. a lack of knowledge management and the inability of staff to use it will have a direct impact on effectiveness and efficiencies of knowledge share across projects and within multiple stakeholders working on a single project. The consistently higher relative significance and rating across all the above innovation activities is a testament of the importance of the human assets that are the building blocks of consulting engineering firms. It echoes the observations by Grant (1996) who defines KBFs as those where vital input in production and the key source of value is knowledge, where employees embody this knowledge. This view is further strengthened by the research from Herling et al (2000) who notes that the human resource is of utmost importance as it epitomises knowledge which is the point of difference for the organisation. It is recommended that top management within consulting engineering firms looks at ongoing investment across the innovative activities that enhances staff development, training and development which as established by this research model will in turn have a significant impact on improving project performance. 'Introducing incentive mechanisms to help development of new capability / staff motivation' and 'Increased opportunity for staff development' are very similar but the former focuses on development of new capability specifically tailored to specific people which is over and above the standard and generic development available to that staff. The tailored development may require a substantial investment but can be easily retrieved back by the business opportunities created by acquiring the new skill set.

- **Client related innovation activities**: Previous researchers have identified client related innovation activities as having a positive impact on project performance. However, through the Delphi process it was evident that there impact is not as positively significant as compared to the other themes and some of them were eliminated through the process. Due to their less relevance only two out of the five activities were retained through the Delphi validation process. 'Increased and focussed marketing activities' and 'Effective use of client and market sector related intelligence for competition' were ranked lower at 15 and 9 respectively. There was an acknowledgement by one of the experts that for consulting engineering firms to run a business, they need to know their clients and competition. However, this was also appended by an acknowledgement that organisations especially in the construction industry are not continuously investing into marketing themselves or understanding their clients better. The reason for client related activities being rated low can also be attributed to the low importance given by technical leaders to client management and understanding client expectations. These might have been rated higher if the context of this research was other than consulting engineering firms where the emphasis is not as much on the technical capability and design. Some of the client-based organisation ranked these activities comparatively higher and noted that by investing into client-related innovation activities, consulting firms might be able to secure more work and also deliver projects that are better aligned to client expectations. A client-based expert mentioned: 'That some clients are not interested in innovation due to their risk aversion and lack a realization that there are direct benefits from investment into it.'

- **Introducing innovative systems**: Two of the activities included in the innovation activities related to introducing systems and technologies were rated high. 'Sharing of lessons learnt' was ranked at 3 and 'Introducing mechanisms for sharing and collecting data/products' was ranked 4. One of the experts noted that:

'Past innovation is often the basis for further development where new concepts feed from older ones'.

The introduction of 'a knowledge management system in SMEs' was not rated as highly as expected. This may be due to the view being developed by modern researchers and practitioners that KMS's are now a necessity for engineering firms to operate rather than a value adds being driven by innovation. Consulting engineering firms need them to run their day to day businesses. Hence, it seems that experts consider a KMS to be a necessity rather than a need that all consulting engineering firms must acquire to achieve business and technical excellence. It is important to note that whilst a knowledge management system may capture knowledge it is the ability to access this and knowing where to look that will be the key. From this perspective, it is hard to neglect experience as a major factor in delivering innovation. The managing director of a multinational consulting firm noted:

‘Shared knowledge reduces delivery time, re-invention and re-work and as a result improves efficiency’.

Another expert re-emphasised that knowledge management is a key and organisations needs to do it more systematically. This is consistent with the research undertaken by Crawford (2006) who notes that the use of lessons learnt is rapidly gaining importance. Work on introducing relevant lessons learnt tools is already underway across leading consulting engineering firms like Arup, GHD, Aurecon and SKM who looking at on-shelf/one-stop tools that can collate the lessons learnt on their projects and capture:

- project performance assessments
- project audits and reviews
- Health checks
- Benefits realisation
- project completion audits
- post mortems/ project close out
- reviews
- appraisals
- after-action reviews
- debriefings and post-implementation evaluations

- The experts were of the opinion that the above innovation activities have a direct impact on project performance. However, the data analysis helps us to establish that some of them have a more positive and significant impact due to their relative importance as compared to the others. The innovation activities which had a least positive impact were omitted through the Delphi process. This helped in coming up with a prioritised innovation management model. The Kendall’s coefficient supported the levels of consensus reached across the Delphi rounds. There was clear agreement on defining project performance in consulting engineering by measures such as:
    - Client satisfaction with time, design quality and budget
    - Design team satisfaction.
    - Meeting design fee/project budget & program

Let's consider the example of 'Communication between individuals'. The Delphi experts have validated the work of the previous workers that this activity as a positive impact on achieving Client satisfaction with time, design quality and budget and Design team satisfaction. It will also help in Meeting design fee/project budget & program. The Delphi process has also established that this activity has the most positive impact (rank 1) on the above performance measures. Although, this research has not prioritised the performance measures but some experts were of the view that some of the measures more important from the others e.g. one of the experts reconfirmed through the final Delphi workshop that:

'Project profitability is always an aim and often innovative solutions dictate an increase in design time and cost'.

A Delphi expert who was a director at one of the leading global consulting engineering firm mentioned *'that for them innovation activities that have a direct impact on achieving client satisfaction with quality were the most important. According to them 'innovation activity is driven by the desires of staff to do things mainly in response to perceived market need and secondly to make systems and processes more efficient and effective for staff to use' (details kept anonymous).*

A CEO of a community organisation which owns and operates a large buildings asset base across Queensland noted that design team satisfaction and success can be improved by introducing systems that improve the document learnings from one project to another. This can help in improving the outcomes achieved in the building design and operational procedures achieved in the new buildings. The Delphi expert with a contracting background noted that client focused marketing activities are not utilized effectively in their organization and there is a lack of acknowledgement that this has a direct impact of project performance. There was a general consensus that most of these performance measures are inter-related and get significantly impacted by the innovation activities forming the innovation model.

- The majority of the experts have not made any explicit references towards linking the project performance or innovation activities to external socio-political environment, size or location of the project. However, one of the experts noted that the some innovation activities for example introduction of systems and technologies and the extent to which they are introduced may be dependent on the size of the consulting engineering firm. Large firms need more structure; otherwise it could be a chaos. They emphasise on the need for looking at activities which can be scaled to the size and location of a consulting engineering firm. This is an area which can be further explored in future research.

  Some of the activities have exactly the same importance through the same O.R rating. For the sake of simplicity I have given them a separate rating e.g. 'Increasing the opportunity for idea generation to realize its implementation' was ranked 8 and 'Effective use of client and market sector related intelligence for competition' ranked 9 although they both have an Overall Rating (O.R) score of 9.

- Also, the phrasing of some of the activities was also tweaked on the basis of consultation with the experts so that it is easier for the model to be understood and implemented by the industry.

This Delphi study has helped us successfully test and validate our two-pronged proposition;

Innovation activity in consulting engineering firms is a function of R&D activity, communication activities on projects, introducing innovative systems, and client related activities. Each of these are in turn are spilt into sub – activities. And that these activities have a direct positive impact on project performance.

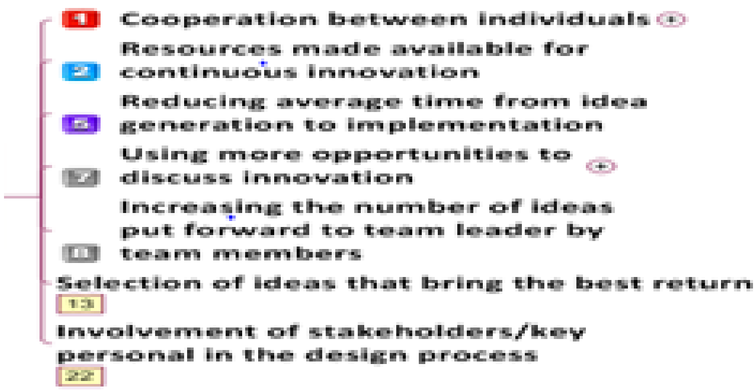
This research is deemed useful to the industry as it can produce effective, practical, relevant and robust outcomes. It aligns with the complex and inter-related issues that manifested themselves on projects in consulting engineering firms.

4.7 USING THE VALIDATED MODEL TO ASSESS THE IMPACT OF INNOVATION ACTIVITY ON PROJECT PERFORMANCE

A final validated innovation management model is shown in Figure 4.6. The different parts forming part of the model are described below in more detail. The dark blue box

in the middle identifies the project performance measures and also notes the main title of this research. The light blue boxes

(5 main themes in total in Figure 4.6) linked to the middle box identify the innovation activities. The sub activities that are linked to the above innovation activities preceded by their respective ranks (in multi-colour boxes) are as under



The annual innovation survey undertaken by Boston Consulting Group identifies that a lot of firms spend a lot of time in innovation but they are not able to realize the benefits of it to achieve a competitive advantage. The problem does not lie in the generation or development of the model but more in the implementation of it.

It is important to note that this as part of this research I have developed a baseline conceptual model. It is important to appropriately implement in a consulting firm to realize its benefits. The model itself gives the most important considerations when contemplating innovation management and its impact on project performance. But for researchers and members of consulting engineering firms to actually extend and assess individual organizations, below is a framework to appropriately utilize the information from the validated model. In simplistic words, in order to assess the impact of innovation activity on project performance for consulting engineering firms, the validated model from this research has to be appropriately used and implemented. The utilization or implementation approach is based is based on the health check model developed by Mian (2005). The model identified some parallels between construction project health and human physical health.

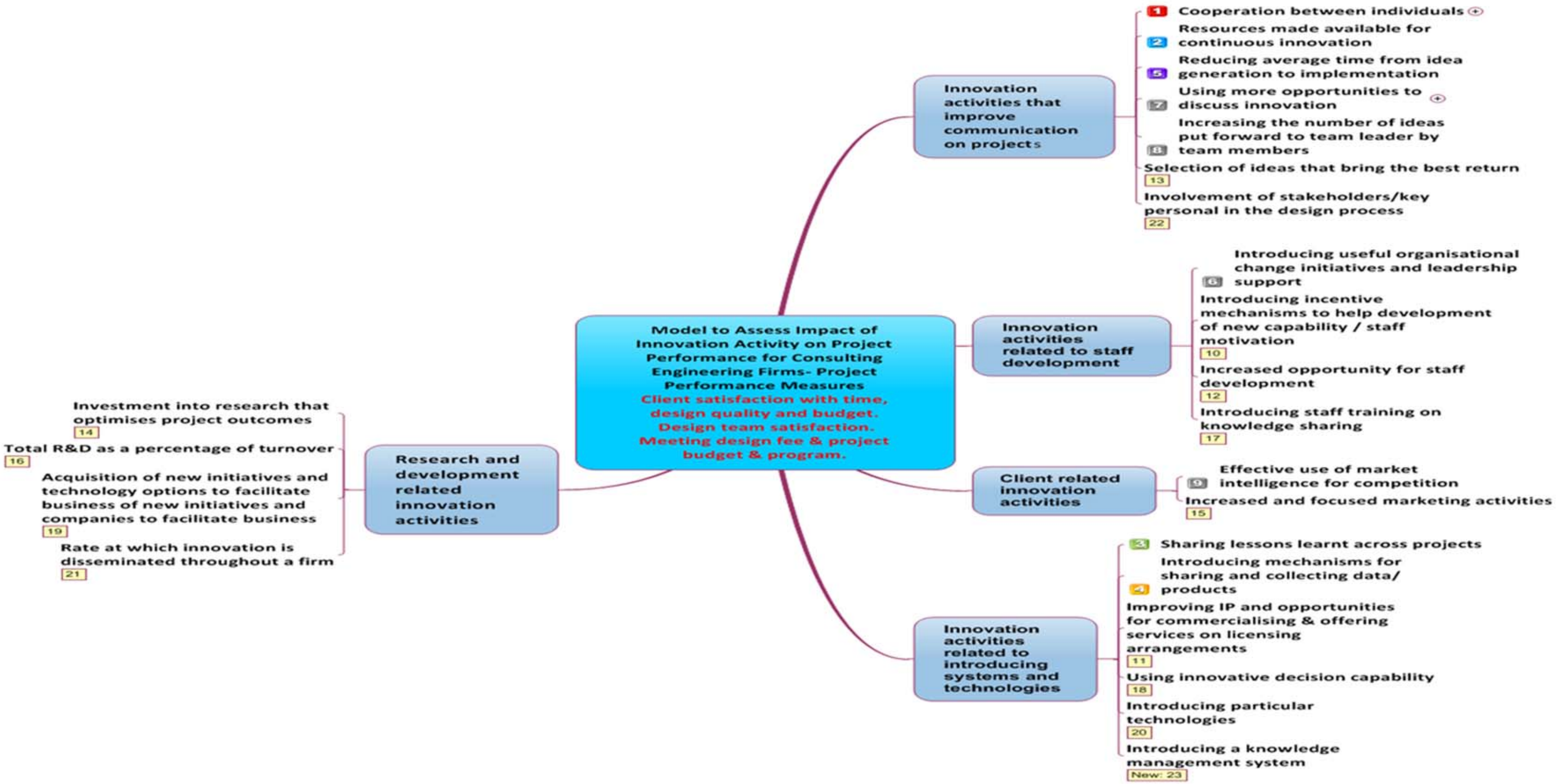


Figure 4.6- The Final Validated Innovation Management Model*

***To use the above model to assess the impact of innovation activity on project performance, please refer to page 150.**

A stepwise approach to assess the impact of innovation activities on project performance is outlined below and shown in the Figure 4.7:

- **Stage 1- Assess-** Drawing the parallels to the Health Check Model by Mian (2005), this stage is similar to assessing the symptoms to quickly assess the health of a project. A gap analysis is to be undertaken to compare innovation activity within the organisation under review against the innovation management model (Figure 4.6) developed through this research. The conceptual model clearly identifies the innovation activities that a consulting engineering firms needs to have if it wants to maximise the impact on project performance. It also points to the important ones as compared to the ones which are less important. This helps in moving away from a 'hit and miss' approach towards making an informed decisions on investment into only those innovation activities that maximise the benefits on project delivery.
- **Stage 2- Analyse –** Drawing the parallels with the Health Check Model, this stage similarly determine the state of health which can be assessed by measuring key areas and comparing these values to established norms. As part of this stage of the assessor undertakes a deeper analysis to understand the innovation activities and how they benchmark internally –across the different projects within the same organisation and/or externally- with other organisations in the same industry. For example while considering 'sharing lessons learnt across project', there will be a need to assess the vehicles of sharing the lessons learnt, their effectiveness and compare then against good practice within the same or competitor consulting engineering organisations. Similarly picking another example 'increased opportunity for staff development', there will be a need to analyse the training opportunities that can directly develop the capability of project-based staff. We will again need to benchmark this against other competitors. It is also important to note that some of these activities may be manifested differently in different organisations depending upon their size, internal management structures and strategic direction.
- **Stage 3 - Lessons Learnt -** Drawing the parallels to the Health Check Model (Mian, 2005), this stage is similar to proposing remedies that can

often be prescribed to return good health. As part of this stage the assessment is completed and the lessons learnt from the findings from the above two stages can be used to identify improvement measures or remedial measures that can be fed back (a continuous improvement cycle) to improve the impact of innovation management across projects within an organisation. For example if it is found that this organisation is not providing appropriate and relevant 'opportunity for staff development', then what are the lessons learnt from other organisations that can be extended to and implemented to the organisation.

It is quite clear that having the innovation model is one thing but using it to successfully assess the impact of innovation activity on project performance requires the assessor to follow the above approach.

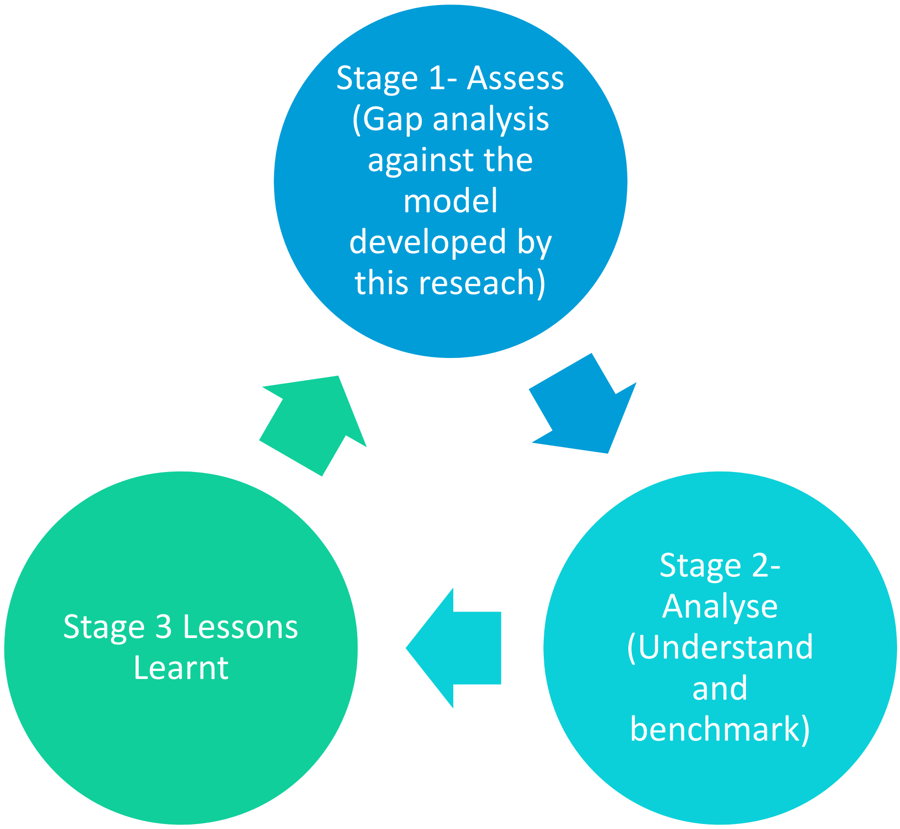


Figure 4.7 Road Map to Assessing the Impact of Innovation Activity on Project Performance.

Chapter 5: Conclusions and Recommendations for Future Research

This research has developed a model that can be used to assess the impact of innovation activity on project performance for consulting engineering firms. The model includes a prioritised list or criteria of innovation activities that have been ranked on the basis of their relative impact on project performance. The model can be easily implemented in a consulting engineering firm to assess if they have invested in the appropriate innovation initiatives that will directly improve their project performance which is measured by client satisfaction with time, design quality and budget, design team satisfaction and meeting design fee and project budgets & timeline.

5.1 RESEARCH PROPOSITION

As part of this research two propositions were proposed and tested.

Proposition # 1:

Innovation activity in consulting engineering firms is a function of R&D activities, communication activities on projects, introducing innovative systems, and client related activities. Each of these are in turn are spilt into sub – activities.

Proposition # 2:

Innovation activity positively impacts project performance for consulting engineering firms.

The two propositions were combined to form the basis of the development of the conceptual model. The model was tested and validated by a Delphi process. The overall proposition is:

Innovation activity in consulting engineering firms is a function of R&D activities, communication activities on projects, introducing innovative systems, and client related activities. Each of these are in turn are spilt into sub-activities. And that these activities have a direct positive impact on project performance.

5.2 REVIEWING OBJECTIVES

The objectives of this research have been met. The main objective of this research was to develop a model that assesses the impact of innovation activities on project performance. It is my view that this research will assist the CEO's and key decision makers in consulting engineering firms to select and implement only those innovation activities that have a direct and positive impact on project performance. They will be in a position to make an informed decision rather than going with a gut feeling and wasting precious resources on a scatter gun approach. The literature review was the basis of developing a model which was then tested and validated by a Delphi study. The validation also helped in developing a priority ranking (with appropriate relative importance allocated) which will help in identifying the innovation activities that have a more relative positive impact on project performance for consulting engineering firms. It is envisaged that the research will also help in adding to the existing body of knowledge in the areas of:

- Innovation especially in the context of knowledge-based firms in general and consulting engineering in particular.
- Better people's understanding of consulting engineering firms and their similarities or differences with knowledge-based firms.
- Innovation activity in the context of consulting engineering firms in particular.
- Project performance measures for consulting engineering firms.

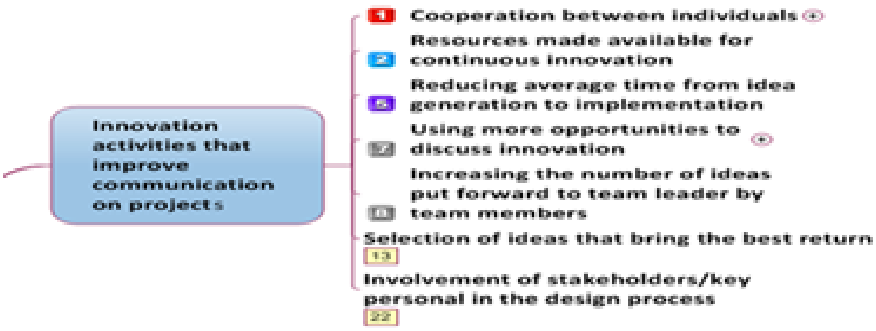
5.3 CONCLUSIONS

The literature review helped in developing the conceptual model. Delphi analysis was used to test and validate the model. The Delphi process was also used to assign relative weightings through a priority ranking. The innovation model and how it can be utilised to assess the impact of innovation activity on project performance was discussed in Chapter 4.

A number of sound, relevant and robust conclusions emerged from this research study which were also discussed in more detail in Chapter 4 and are outlined as follows:

- Consulting engineering are also knowledge-based firms. There are more commonalities and only subtle differences with other type of knowledge-based firms. The differences are mostly around their client base, business and operations activities. The use of knowledge workers, which is a key source of their existence, is a common thread which runs through all of them.
- This research extends the concept of innovation to projects which was previously associated with organisations as a whole. It also establishes the linkages between innovation activity and project performance. Previously, most of the researchers have linked organisational performance to innovation activity.
- A number of interrelated themes of innovation activities need to be considered when considering consulting engineering firms. This research is based on a holistic model of innovation which goes beyond the 'tunnel vision thinking' of only considering innovation as a cost cutting or value engineering exercise.
- Following on from the previous point, Innovation activity in consulting engineering firms can be broadly grouped into and are a function of the following themes:
    - R&D activities
    - Communication activities on projects
    - Introducing innovative systems
    - Client related activities
    - Staff related activities.

- Though the above innovation activities have a direct impact on project performance, some of them have a more positive and significant impact due to their relative importance as compared to the others. The innovation activities which had a least positive impact were omitted through the Delphi process. This helped in coming up with a prioritised innovation management model.
- Communication activities on projects: Each of these are in turn are spilt into sub-activities. It is important to note that 'communication focussed innovation theme' includes the highest number of sub-activities (7) and most of them are rated highly. Most of the experts ranked innovation activities that *improve communication* highly. Overall, 'Cooperation between individuals' and 'Resources made available for contributing to continuous innovation' were ranked 2 and 1 respectively. This is consistent with the suggestions of the literature on innovation management where researchers (Brown & Eisenhardt, 1995, Cooper, 2001 and Lovelace et al., 2001) emphasise the importance of 'cross team communication' and 'collaboration'. The theme comprised of the following activities:



The experts thought that these two can have a direct positive impact on client and team satisfaction which in turn will result in efficiencies in project and design fee. These communication activities in their view also had a significant impact on the project timelines. There were no activities across this theme that dropped out through the Delphi refinement and the final round 4 workshop process which clearly highlights their relative importance. The Delphi experts associated with client-based organisations particularly emphasised the importance of communication on projects. The CEO of an organisation who manages a large asset portfolio noted:

‘It is a key to successful facility design and project delivery that all team members including client representatives have the opportunity to input ideas into facility design and operation and that these are reflected through to project architect for the development of a project and also for input and consideration into future stages’.

More recently across consulting engineering firms in Australia, top management is looking at introducing initiatives that can improve communication channels with the client and other stakeholders. These organisations are looking at introducing innovative solutions that can facilitate clear communication on projects and provide platforms where engineers can openly share and pursue their ideas which are cost effective (for clients and their firms) and produce quality end product. Some of the recent technology solutions being adopted by consulting engineering firms for robust design management includes Project Wise, Aconex etc. Similarly for effective client management, CRM is being implemented across large engineering firms. The main objective is to enable frequent and effective ways of direct communication between project stakeholders. A high significance (rank 5) was attributed to ‘reducing average time from idea generation & evaluation) to its implementation’. This clearly shows that the experts were keen to expedite the process of innovation towards its implementation especially if these have a direct impact on project performance so that the organisation can realise its intended benefits in a timely and efficient manner.

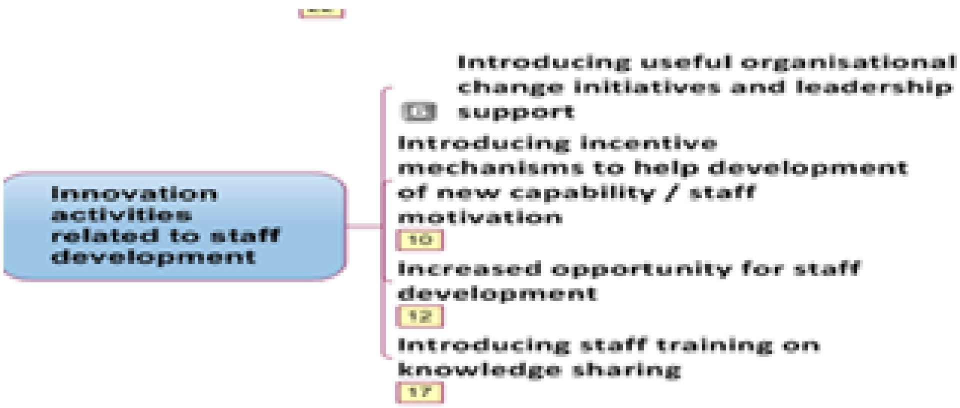
- **R&D related innovation activities:** There were 4 innovation activities that made the shortlist of Delphi experts. There is a general perception in the industry that research and development rank highly and have a marked significance when considering impact on organisational and project performance. This view is also supported by existing body of knowledge. However, the output from the Delphi results is changing this view about consulting engineering firms. This study has identified a different perspective as most of the R&D innovation activities are ranked as being of lower statistical significance than the 'communication focused innovation activities' while considering their impact on project performance. The experts are of the view that that due to the unfavourable market conditions and since the dawn of GFC, the investment into research and development is diminishing. One of the contracting based expert noted that 'IP produced due to research and development activity is not highly valued by construction companies'. The theme comprised of the following activities:

They also note that construction is not known for distinct R&D. But some incremental R&D is arguably undertaken on each project. It is unlikely to be systematically done. A panel expert who works for a leading Australasian architect noted that:

In general, not relevant to architectural firms, R&D is specific to projects and very informal. No budget assigned but investigations into building types and trends are undertaken'.

This finding is specifically relevant to consulting engineering firms and knowledge-based firms in general as it can help in prioritising their investment into innovation activities. It echoes the concerns of some of the industry leaders in Queensland who feel that investing into R&D may have a positive impact on their profile in the market and their staff development. But is not trickling down to have a significant direct impact on the performance of their projects especially not as significant impact on client or design team satisfaction as you would expect from other innovation activities. The direct impact on delivering projects within project budgets or project timelines are also not as significant. There is a need for tertiary institutions and R&D firms to look at tailoring their research topics and identifying innovation focussed R&D activities that are tailored to the projects of these organisations and can have better results on project performance for knowledge-based firms. It is important to note that 'Total R&D investment as a percentage of turnover' is more of a measure than an activity but it is not hard to establish that the intent of experts is for consulting firms to invest into innovation activities that directly contribute towards measuring and improving their performance towards this metric. It is also important to align the investment should be specifically to realising real business drivers and look at optimising performance improvement. It might be valuable for large engineering houses to identify specific activities to support this measure as part of future research.

Innovation activities related to staff development: All these activities were consistently ranked higher by experts as compared to the other innovation activities. Three out of four were ranked lower than 12 with one of the activity ranked 6. There was a consensus that motivated staff can bring improved performance on projects. Hence, careful consideration needs to be given to activities that add to staff motivation in areas such career development, financial reward, fun and challenge. It is interesting to note that that this area was not explicitly identified in the work done on innovation by previous researchers and was not included in the developed model which was based on a literature review. This is an addition to the existing body of knowledge for consulting engineering firms. The validation process through Delphi resulted in enhancing the robustness and relevance of the conceptual model. This theme comprised of the following activities:



It is quite evident that most of these have a direct impact on project performance and delivery e.g. a lack of knowledge management and the inability of staff to use it will have a direct impact on effectiveness and efficiencies of knowledge shared across projects and within multiple stakeholders working on a single project. The consistently higher relative significance and rating across all the above innovation activities is a testament of the importance of the human assets that are the building blocks of consulting engineering firms. It echoes the observations by Grant (1996) who defines KBFs as those where vital input in production and the key source of value is knowledge, where employees embody this knowledge. This view is further strengthened by the research from Herling et al (2000) who notes that the human resource is of utmost importance as it epitomises knowledge which is the point of different for the organisation. It is recommended that top management within consulting engineering firms looks at ongoing investment across the in innovative activities that enhances staff development, training and development which as established by this research model, will in turn have a significant impact on improving project performance. ‘Introducing incentive mechanisms to help development of new capability / staff motivation’ and ‘Increased opportunity for staff development’ are very similar but the former focusses on development of new capability specifically tailored to specific people which is over and above the standard and generic development available to that staff. The tailored development may require a substantial investment but can be easily retrieved back by the business opportunities created by acquiring the new skill set.

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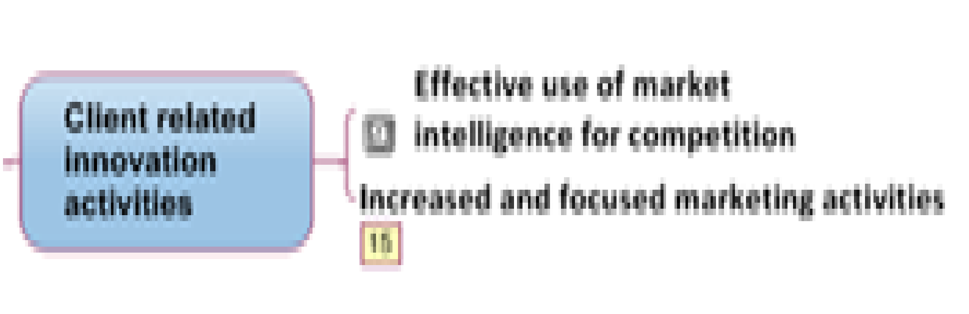

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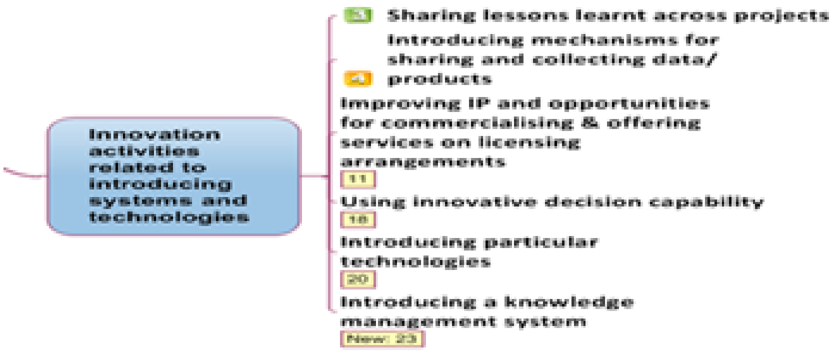
'Past innovation is often the basis for further development where new concepts feed from older ones'. The innovation activities associated with this theme are as under:



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  - Design team satisfaction.
  - Meeting design fee/project budget & program

Consider the example of 'Communication between individuals'. The Delphi experts have validated the work of the previous workers that this activity as a positive impact on achieving Client satisfaction with time, design quality and budget and Design team satisfaction. It will also help in Meeting design fee/project budget & program. The Delphi process has also established that this activity has the most positive impact (rank 1) on the above performance measures. Although, this research has not prioritised the performance measures, some experts were of the view that some of the measures more important from the others e.g. one of the experts reconfirmed through the final Delphi workshop that:

> 'Project profitability is always an aim and often innovative solutions dictate an increase in design time and cost'.
>
> A Delphi expert who was a director at one of the leading global consulting engineering firm mentioned *'that for them innovation activities that have a direct impact on achieving client satisfaction with quality were the most important. According to them 'innovation activity is driven by the desires of staff to do things mainly in response to perceived market need and secondly to make systems and processes more efficient and effective for staff to use' (details kept anonymous).*

The Delphi experts through their feedback validated the approach which was the basis of the development of the conceptual model. They noted that some of the innovation activities were generic or high level. In their view the open-endedness provides a huge opportunity for the organisation when implementing these activities to specifically look at enablers or solutions that are tailored to the make-up of that organisation. This will help in putting in place an innovative solution that is tailored, cost effective and efficient.

5.4 IMPLEMENTATION OF THE PRIORITISED MODEL

It is important to note that when an organisation decides to implement the innovation activities identified as part of this conceptual model, it will be hard to implement all 23 in in one go due to the limitations and constraints with availability of resources. It will also be important to consider the risk profile of the organisation and its projects and if the innovation activities don't directly worsen it. This will be tougher to achieve in the current financial market where the organisations have limited project activity and limited knowledge workers to cover the work let alone focus on any other activity. To deal with this situation, a staged approach is being proposed where the consulting engineering firm can further prioritise and stager the implementation of the innovation activities. A plan with a high-level estimate of timeline for implementing the innovation activities (cross-referenced to Figure 4.6) is outlined in Table 5.1.

Table 5.1 *Implementation Plan*

Innovation Activities	**Duration by which implemented**
1-5	Over a duration of 6 months
6-12	Over a duration of 12 months from the complete implementation of activities 6-12.
13-20	Over a duration 24 months from the implementation of 6-12.
21-23	Over a duration of 3-6 months from the implementation of 1ctivities 13-20

The implementation will depend upon the size and uptake within an organisation of these activities. It will also depend upon the skill set and experience of the team responsible for the implementation and cultural change program. The implementation durations are a reference point and may vary because of the above factors.

5.5 SIGNIFICANCE AND APPLICATIONS OF THIS RESEARCH

This research model will be particularly useful to consulting engineering firms where innovation activities and their implementation are still in the infancy stages. Some of the concepts that formed the basis of the model were extrapolated from the manufacturing or other services industry where this concept is much more advanced. The research helped in validating and contextualising innovation activities to consulting engineering firms. The model will not only be useful to reform the internal organisational policies and systems but also can be offered as a commercially viable stand-alone health check service to consulting engineering organisations.

Some of the additions that this research brings to the existing body of knowledge are:

- The literature on innovation is not advanced for consulting engineering firm. This research uses some of the concepts from manufacturing, knowledge-based firms in general and other project-based firms to extend to consulting engineering firms. Delphi analysis is used to specifically tailor the research model to consulting engineering firms and based on experts feedback and consensus.
- Most of the existing body of knowledge is focussed on a specific aspect of innovation. This research draws upon the individual aspects and collates the information into a holistic model that covers the perspective of multiple internal and external stakeholders and is focussed on:
  - R&D activities
  - Communication activities on projects
  - Introducing innovative systems
  - Client related activities
  - Staff related activities.

  The model considers a more holistic view of innovation and captures the innovation related activities associated with stakeholders involved in a project environment i.e. clients, internal organisational team members and project team members. It also encapsulates innovation activities associated with technology, use of process and tools and research and development. This is a major shift from the work of previous researchers on innovation which only considered innovation as a cost cutting activity.
- Among the above themes, staff related activities in particular were not covered in greater detail by existing literature. This was mainly introduced by the Delphi experts who thought that while considering consulting engineering firms, staff related innovation activities were an important consideration. This will particularly provide guidance for staff development in areas of specific interest and relevance to consulting engineering firms.

- The people related innovation activities such as investment into staff development that have a positive impact on project performance may assist in increasing employee commitment and in turn influences staff turnover.
- Client focussed innovation activities will help in identifying market and client sector focussed strategies which in turn will help in generating new business and also improve the probability of repeat business and project opportunities.
- Improving systems and processes and technical excellence will drive efficiency in delivery projects and also securing new clients.
- Improving communication strategy across multiple external stakeholders and design team members will positively impact all the above outcomes. The need is to also implement communication channels that support the weaving of innovations through the fabric of the organisation.
- This research also extends the concept of innovation management to project performance which is currently more focussed on organisational performance.
- The research also provides a comprehensive insight into some of the impediments to implementation of innovation activities in consulting engineering firms which can be used by consulting engineering firms to develop incremental steps to better overcome them.

Some of the other expected benefits to consulting firms and industry in general:

- Some of the first tier large consulting engineering firms and knowledge-based firms in general can use the research model to validate their investment into innovation activities. They can establish if they are putting investment into the right area of innovation and if not, install immediate steps to get it working for them. They can also use the model to draw the linkages between innovation and project performance which in the past has not trickled down to realising tangible benefits on projects. The prioritisation process can help them channel the savings into other optimisation activities. They can also reinvest the savings into improving the capability of their knowledge works. They can also invest in community or cyclone relief or flood rehabilitation programs.

- The model can also be used by smaller firms to start investing into innovation activities and use a credible decision making model based on credible research rather than 'adhocly' investing into innovation activities through a ‘hit’ and ‘miss’ process. Growing firms using the model can prioritise their commitment towards investing into enhancing employee’s commitment which positively influences staff turnover which can help them further grow the firm to a sustainable size. Proactive and innovative companies need to be continually looking into the future to have a sense where new opportunities might lie, being able to anticipate change and investing in building new competencies. Once core competencies are accumulated and established they must be exploited by matching them to market opportunities (Hamel and Prahalad 1991, Hamel and Prahalad 1994).
- The model can be used by consulting engineering firms and knowledge-based firms to develop point of differences that can help them develop a competitive edge in the market. Innovation is seen by many key clients especially in the federal government as a differentiation factor and now being used as a key selection criteria as part of government procurement and contestability models. Engineers can focus on improving systems and processes and expanding their technical excellence to strengthen their position as a market leader. Some of the themes identified by this research are consistent with the work of other researchers. Kak and Sushil (2002) note that there are four key sources of core competence which defines an organisations ability to create and maintain competitive advantage – organisational learning and flexibility, management of technology, individuals within an organisation and business strategy & planning.
- Consulting firms have in the past not paid as much heed to improving communication between their team members and other stakeholder strategy. The onus put by this research on this area will pave the way for firms to ensure that it is effectively woven through a consulting firm’s

fabric. It is a matter of time when these firms will understand that change will be ongoing and timely adoption will be fundamental to their success. This research will help them realise success through a systemic approach. The mind-set of the senior leadership within engineering firms will have to change so that they don't see investment as an additional overhead or a stand-alone activity. There has to be willingness to integrate innovation into the business to make it commercially viable and sustainable in the long-term rather than considering it as an immediate financial burden. This will need to be championed at strategic and operational levels. At strategic levels it will need to be recognised by CEO's, directors, principals and at the operations level by technical leaders, project managers and senior engineers.

This research will also be useful for Queensland Government so they can benchmark some of their policy, procurement and delivery models. This will also help in longer term budget allocation and provide them the opportunity to implement priority innovation activities and stager the remaining over an extended period. There will be need to contextualise this model to make it relevant to their business and project delivery requirements.

- This research can facilitate cross-industry knowledge transfer. Albeit, the manufacturing sector is much more advanced in innovation and its integration into their everyday processes, this research will help in cross fertilise the understanding of knowledge-based firms in the manufacturing industry. Likewise, people in the manufacturing industry will understand how consulting engineering firms and knowledge-based firms in particular operate and their key drivers of innovation.
- As part of the validation of this model, a strong consensus was reached among the Delphi experts who have senior roles in bigger construction and consulting firms in the industry. It will not be difficult to convince leaders of other consulting firms to implement and commercialise this model as they may relate to these issues, originating from experts from the same industry.

- The benefits reaped from the industry success will also attract more investment into developing in-house training models (which are endorsed and partnered by leading international executive education programs). There will be a huge opportunity to learn from subject matter experts and academics from leading international and local tertiary institutions who can be involved in delivering the in-house programs.

Some of the other expected benefits to academia in general:

- The application of innovation to consulting engineering is still under researched. The intellectual property produced by this research will also help in it being used as lessons learnt by other researchers to expand the subject matter to other domains. A few examples of how this research can be used and developed for future research are outlined in the next section. The extension of the innovation concept to projects due to its scarcity in the past will be of great interest to project management researchers and industry practitioners
- Due to the paucity of literature in this area, it might be useful to incorporate the learnings from this model into teaching and learning programs for engineering and project management students.

Due to the relevance of this research model and tailoring to consulting engineering firms which in the past has been an under tapped area, it is quite appropriate to contemplate that there will be sufficient interest by the industry into using this model. It is important to develop an appropriate communication strategy to market and present at relevant technical and project management forums. The confidence of consulting engineering firms can also be built by establishing that the model has been developed through a robust research method developed under the banner of a credible research institution. The branding will certainly stimulate immediate interest as there are currently a number of on-shelf and services based tools flooding the Australian market which have been delivered on the basis of very little rigour and research.

It is the intention of this study to communicate a set of recommendations/value proposition in relation to the above outcomes, for consideration to a broader audience by presenting at industry forums such as Australian Institution of Project Management, Engineers Australia, Property Council and Queensland Government innovation focussed platforms. The presentations to a wider audience will also help in invigorating interest from individual clients. Individual presentations will be held for clients who show specific interest into this research. To add credibility and research rigour, a paper based on this research was presented at the Australian Institute of Project Management conference in 2009 and received the best paper award. It is anticipated that further publications based on this research will be written for academic and industry journals. However, the confidentiality protocols relating to all stakeholders involved with the project, will be strictly followed. The conceptual model developed as part of this research which is mainly based on a robust review of literature, provides a continuation of knowledge and taps into the work of by previous researchers. Some of this work will also provide a foundation for future research work which is discussed next.

5.6 RECOMMENDATION FOR FUTURE RESEARCH

It is important to note that the model developed through this research is not valid and useful to all applications and will need to be tailored when applied to projects outside of a consulting context. Considering some of the challenges and observations made by the Delphi experts I came across while conducting this research, some recommendations for future research are as follows:

- This study focusses on consulting engineering. The aspiration to develop a focussed model that has only a consulting engineering focus may have excluded the opportunity to capture aspects of other knowledge-based firms. It might be advantageous for future researchers to extend and contextualise the model to other type of knowledge-based firms such as law and accounting firms, management consulting, I.T consultancies, advertising agencies, research & development units and high tech companies.
- There is also lack of support of innovation in contracting especially larger contractors have not adopted it, as much as there is need in that sector due to the complexity of projects most of the managing contractors deliver. This was also noted by the Delphi experts. Miozzo and Dewick (2002, p-1)

note that that the construction industry has a record of very low identifiable innovation and has thus been viewed as a technological laggard. This industry has a very slow and lower adoption of innovations as compared to other industries. Future researchers could consider extending the research model to larger contracting firms using larger infrastructure or building projects as case studies.

- Consulting engineering firms might benefit from further research that focusses on narrowing the list of innovation activities so that instead of 23 activities an organisation only has to implement 5 or 6. This will have lesser pressure on the organisational resources and more buy-in from senior management to use the model.
- Researchers' who are interested in working in the organisational culture area may be able to extend the research to local consulting firms in other countries. This will help in enriching this model with attributes which are 'culture' dependent. The lessons learnt from this research can be brought back to share with consulting engineering firms in Australia. This can very useful in the current time and environment where there has been a significant influx of skilled migrants to Australia mainly from Asia and the Middle East who are being inducted into the Australian work force for consulting engineering firms. The lessons learnt from this research maybe useful to develop organisational and HR strategies to successfully and quickly assimilate them into the work force.
- The outcomes of this research can feed into future research on identifying obstacles to innovation activity in large contractors. This research and work previously done by European Federation of Engineering Consultancy Associations (EFCA) (2008) will be a good start to cover themes such as:
    - Identifying strategies to convince top management of the importance of innovation and its long term benefits.
    - Strengthening the relations between the Federal and State Government and large contractors to introduce legislation that support innovation. The Construction Q initiative recently organised by Queensland Government was a positive step towards overcoming it.

- Develop technical training programmes which are tailored to trades and managerial staff within contractors. Focus on improving the links to research organisations, and valorise training through research within companies.

  The above can also be extended to State, Territory and Federal Governments.

- It might be valuable in extending the model to include the impact of 'contingency factors' on consulting engineering firms. Contingency theory was introduced in 1961 by Burns and Stalker who pioneered the traditional distinction between incremental and radical innovation, and between organic and mechanistic organisations. There are three main bodies of literature within contingency theory literature including organisational, leadership and decision making theories. The three bodies of literature are founded on the notion that there is no best method to manage an organisation, its leadership or decision-making. Previous theories had neglected the influence of external environment also called the contingency factors, on the management style and organisational structure. Contingency Leadership Theory attempts to explain how a leader behaviour typically varies from one situation to another. The contingency model of leadership behaviour is important to managers because it was introduced as a model of how leaders should make decisions if they are to be effective (Field, 1979).

  External environment is one of the main factors influencing project success and may also determine the type of innovation activity required to improve it. Chun (1996) identifies the physical location of the project, socio-political influence and economic environment as the main contingency factors affecting project success. Some of the contingency factor which impact project performance are discussed next.

  Project location

  It is evident from the above discussion that project success is also contingent on a number of factors including the particular stakeholders and their interests. Many researchers (Sidwell 1983, Ireland 1983, Walker

1995) believe that project characteristics affect project success. The physical location of the project will pose unique planning and organisational problems (Chan, 1991). Geographical location and proximity from transport facilities will also affect project performance. A useful area of research for future academics will be to contemplate innovation activities that are best suited for a specific location.

Economic Environment

The economic environment directly affects individual projects due to lack of sufficient and quality resources (Chan, 1996). In Australia similar to the rest of the world, public projects are financed from capital investment or loans. Signs of recession see reduced investment due to expected reduction in revenue. Construction projects may be halted by company insolvency affecting builders getting involved with projects or about to take a new project. (Walker, 1995). With the impact of GFC at its peak in Australia there is a growing emphasis on using performance models that considers external environmental factors while assessing project success. Investment in innovation is crucial in the existing financial environment but might not be seen as important by some of the senior leadership who are more focussed on the immediate bottom-line rather than the long term benefits realised from it. The market economics might have a direct impact on the make-up of the innovation management model and should be explored as part of further research.

Socio-political Environment

Political instability or community dissatisfaction can have catastrophic impact on project success and as a result on innovation activity. Sidwell (1982) suggests that decisions on the priorities of government investment will affect projects directly and the community needs will also increase and decrease project demand. Some researchers argue that we need to consider aspects other than economic factors. Sanders (2004) suggests that the popular model of sustainable development proposed by Brundland is flawed as it emphasises on achieving sustainable development through economic growth and reliance on market forces- the very forces that are driving unsustainability. He thinks that there is even problem with seeing the ecological, social and economic states as being of equal importance. Sanders (2004) identifies that none of these models reflects the current reality that humanity finds itself in. 'Society is a totally dependent subsystem of the planet's ecosystems and the human economy is one of the many subsystems of society. Therefore, there is a need to adopt a systems view and see economy within society and society within ecology'. This view is also supported by Lowe (2002a) as shown in the Figure 5.1 below:

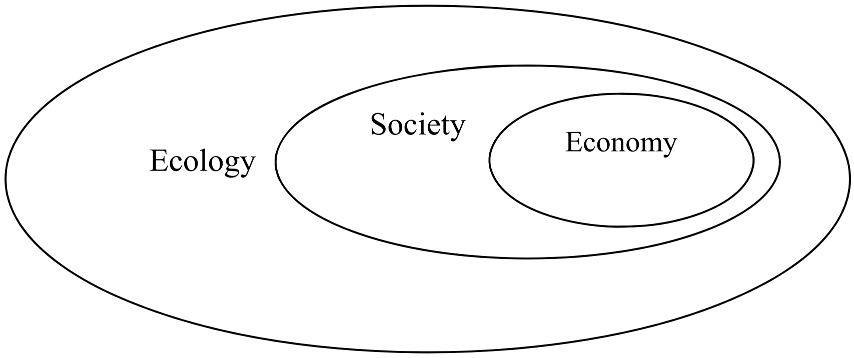

Figure 5.1. System Approach for Sustainable Development

The above concept can be conveniently extended to projects for consulting engineering firms where achieving the financial bottom line is important but at the same time it is equally, if not more important, to cater for the social needs of community and stakeholders. It might be useful to consider this area as part of the future development of the innovation model.

The above recommendations are captured in Figure 5.2 and act as a credible starting point for the consideration of researchers aspiring to expand on the work done as part of this research.

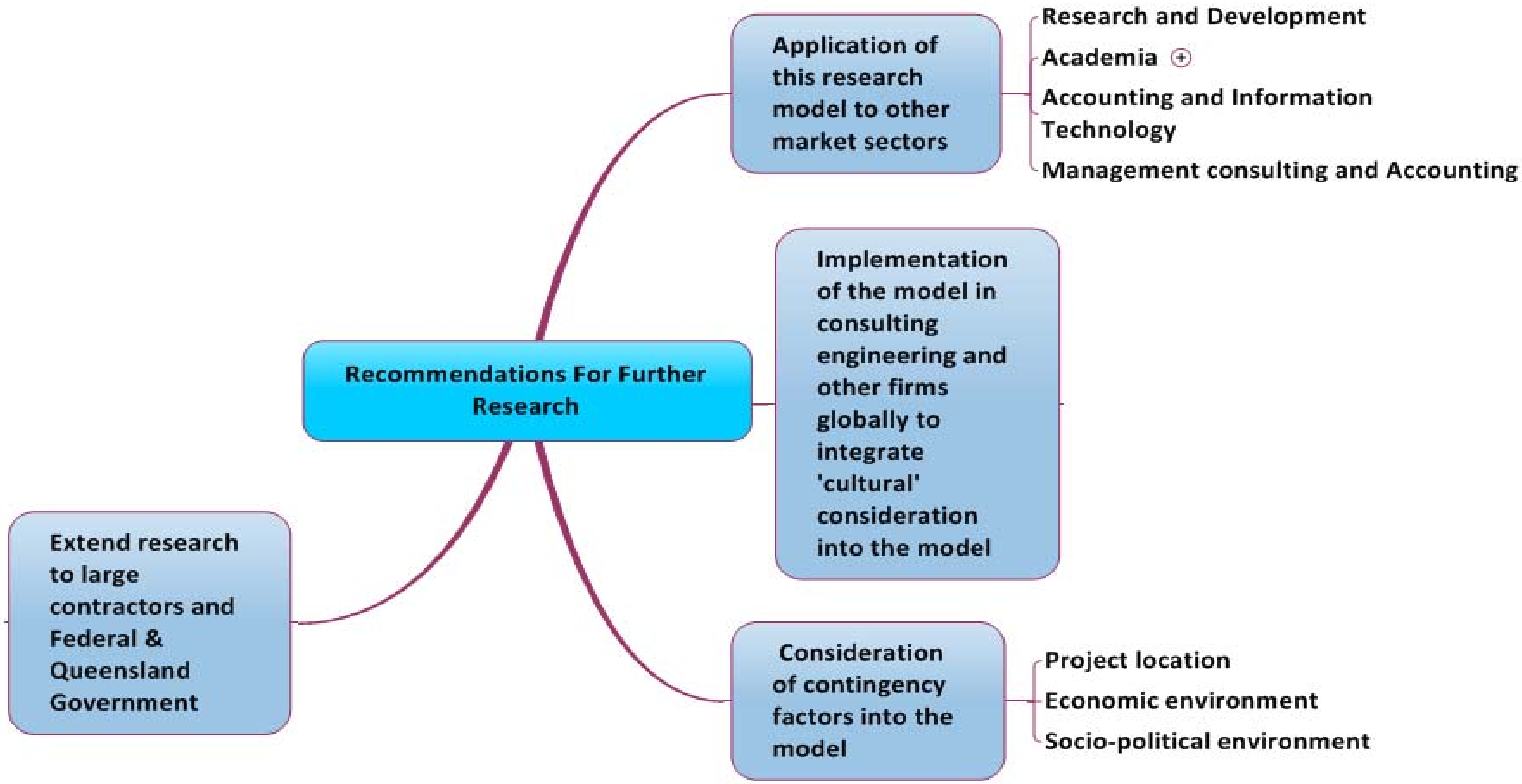

Figure 5.2. Considerations for Future Research

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APENDECIES

Appendix A- Delphi Round 1 Questionnaire

Impact of Innovation Activity on Project Performance for Knowledge-based Firms

Preamble

This questionnaire is the first round of a Delphi Study which aims to determine the most important issues and challenges that Knowledge-based Firms (KBFs) are facing in the current financial crisis. Grant (1996) states that KBFs are those where vital input in production and key source of value is knowledge, where employees embody this knowledge. It is also important to clarify that this study revolves around KBFs and will specifically limit the research to consulting engineering and architecture firms. The main aim of the study is to test he perceived view that innovation activities have a positive impact on project performance. A Delphi study consists of several rounds of questionnaires submitted to experts in a particular field of endeavour, in order to determine if any consensus exists as to future trends in the field. People with experience in such fields are asked to rank the most significant issues.

The first round of questions in this study is intended to provide expert confirmation of the innovation activity within the organisation which directly impacts project performance. This research intends to use the innovation activities identified from the literature, which have been identified through a review of the innovation related literature. It is intended that the information collected from this first round be analysed and reported back to the survey participants for further comment. Participants will not be identified in the feedback, only their priorities and comments will be forwarded to the other participants. Comments on the results of the first round will then be invited and more specific questions may be asked. Participants will come from several disciplines involved in the delivery of commercial refurbishment projects and so not all areas of the study will be relevant to all participants. The study will be carried out under five general headings: Research and Development activities, Communication activities on projects, introducing systems, staff related innovation activity and client related activities. Participants should feel free to omit those items or headings that are not relevant to their own particular experience.

For the purposes of data collection, could you please fill out the following details of your experience and expertise?

Name (optional)

Organisation (optional)

Organisation type

Position

Areas of expertise

Instructions on completing the questionnaire

Could you please indicate your opinion of the relative importance and relevance (to impacting project performance) of each innovation activity in reference to consulting engineering firms? While considering project performance, please consider measures such as client satisfaction with budget, time and quality, design team satisfaction and construction time and budget.

Please let us know in the comments section what your priorities are. Please also add and rank any other criterion that you think is important.

1= Not relevant

2= Little relevance

3= Quite relevant

4= Very relevant

5= Most relevant

Space is provided at the end of each subsection for your general comments on this area. In addition, any feedback you may care to give on the content of the questionnaire would be welcome.

ISSUES/CRITERIA	1= NOT RELEVANT	2= LITTLE RELEVANCE	3= QUITE RELEVANT	4= VERY RELEVANT	5= MOST RELEVANT
Research and Development Activity					
Improving annual R & D budget					
No of patents filled in the past year					
No of active R&D projects					
Total R&D as percentage of turnover					
Partnerships with R&D organisations and tertiary institutions					
Acquisition of new initiatives and technology options to facilitate business					

Comments

ISSUES/CRITERIA	1= NOT RELEVANT	2= LITTLE RELEVANCE	3= QUITE RELEVANT	4= VERY RELEVANT	5= MOST RELEVANT
Communication activities on projects					
Increasing the number of ideas put forward by team member to leaders					
Reducing the average time from idea evolution to full implementation					
Resources made available for continuous innovation					
Cooperation between individuals					
Using more opportunities to discuss innovation and reward smart ideas and reward smart ideas					

ISSUES/CRITERIA	1= NOT RELEVANT	2= LITTLE RELEVANCE	3= QUITE RELEVANT	4= VERY RELEVANT	5= MOST RELEVANT
Comments					
Client related activities					
Increased and focussed marketing activities					
Effective use of market intelligence to achieve a competitive edge					
Optimising the savings achieved through successful operation efficiency ideas					
Introduction of client management tools					
Broadening the client portfolio					

ISSUES/CRITERIA	1= NOT RELEVANT	2= LITTLE RELEVANCE	3= QUITE RELEVANT	4= VERY RELEVANT	5= MOST RELEVANT
Comments					
Introducing systems					
Improving the percentage sales from products introduced in the past X years					
Improving IP and opportunities for commercialising & offering services on licencing arrangements					
Introducing mechanisms for sharing and collecting data/products					
Introducing a Knowledge Management System					
Using innovative					

ISSUES/CRITERIA	1= NOT RELEVANT	2= LITTLE RELEVANCE	3= QUITE RELEVANT	4= VERY RELEVANT	5= MOST RELEVANT
decision capability					
Introducing particular technologies for staff training					
Comments					
Others					
Comments					

Please return the completed questionnaire and email to d.mian@qut.edu.au. If you have any queries call Daniyal Mian on ++61 4 02395568.

Confidentiality Protocol

We respect your privacy and to ensure confidentiality the data obtained from this questionnaire will be kept strictly confidential and the name of the respondent will not be included in the reference list when the results of this research are published.

Voluntary participation

Your participation in this project is voluntary. If you do agree to participate, you can withdraw from participation at any time during the study without comment or penalty. Your decision to participate will in no way impact upon your current or future relationships with QUT, Robert Bird Group or any other organisation associated with the study.

Consent

The return of the completed questionnaire is accepted as an indication to participate in this project. Thank you for your time in completing this questionnaire

Appendix B- Delphi Round 1 Data Analysis

Average and Standard Deviation Data Analysis from Round 1

	A	B	C	D	E	F	G	H	Total	Average	Std.Dev
1	4	4	4	4	2	4	2	3	27	3.25	0.88641
2	2	1	1	1	2	3	1	3	14	1.75	0.88641
3	3	3	3	3	3	3	4	3	25	3	0.53452
4	5	3	3	3	4	5	3	3	29	3.375	1.30247
5	4	5	5	5	4	4	3	4	34	4	0.75593
6	2	4	4	4	2	4	1	2	23	2.625	1.18773
7	2	4	4	4	3	3	3	4	27	3.375	0.74402
8	2	4	5	4	4	2	4	4	29	3.625	1.06066
9	4	3	4	4	4	4	4	4	31	3.875	0.35355
10	5	4	5	5	4	5	4	4	36	4.5	0.53452
11	4	4	4	3	3	5	4	4	31	3.875	0.64087
12	3	3	3	4	3	2	2	5	25	3.125	0.99103
13	4	4	5	5	2	4	2	5	31	3.875	1.24642
14	5	5	4	3	2	3	4	5	31	3.875	1.12599
15	2	4	4	2	3	1	4	4	24	3	1.19523
16	3	4	4	5	2	2	3	5	28	3.5	1.19523
17	3	2	2	2	2	2	2	2	17	2.125	0.35355
18	2	2	2	3	3	2	3	2	19	2.375	0.51755
19	4	3	4	3	3	2	4	2	25	3.125	0.83452
20	4	3	4	1	4	3	4	4	27	3.375	1.06066
21	2	3	4	2	3	3	4	2	23	2.875	0.83452
22	5	2	4	2	2	2	4	4	25	3.125	1.24642
Sum²	5476	5476	6724	5184	4096	4624	4761	6084			

Appendix C- Delphi Round Questionnaire

Impact of Innovation Activity on Project Performance for Consulting Engineering Firms

Instructions on completing the questionnaire

The total scores from a maximum possible score of 40 (based on scores from 8 respondents) are given for each criterion as shown in table 1. Please rank the criteria in table 1 using a ranking scale from 1 to 22? If you have difficulty in ranking one criterion over the other, can you please still do so, but also pre-qualify your selection with comments.

The additional nine criteria identified from Round 1 are also listed in table 2. Could you please also indicate your opinion of the relative importance and relevance (to impacting project performance) of each innovation activity in table 2 in reference to Consulting Engineering Firms which is type of a Knowledge-based Firms? While considering project performance, please consider measures such as client satisfaction with budget, time and quality, design team satisfaction and construction time and budget.

Please note that round 3 questionnaire will explore these criteria and your feedback in relevance to their importance in more detail.

Table1 ISSUES/CRITERIA	Round 1 total scores	Comments
Research and Development Activity		
Improving annual R & D budget	27	
No of patents filled in the past year	14	
No of active R&D projects	25	
Total R&D as percentage of turnover	29	
Partnerships with R&D organisations and tertiary institutions	34	
Acquisition of new initiatives and technology options to facilitate business	23	
Communication activities on projects		
Increasing the number of ideas put forward by team member to leaders	27	
Reducing the average time from idea evolution to full implementation	29	
Resources made available for continuous innovation	31	
Cooperation between individuals	36	
Using more opportunities to discuss innovation and reward smart ideas	31	
Client related activities		
Increased and focussed marketing activities	25	
Effective use of market intelligence to achieve a competitive edge	31	
Optimising the savings achieved through successful operation efficiency ideas	31	
Introduction of client management tools	24	
Broadening the client portfolio	28	
Introducing systems		
Improving the percentage sales from products introduced in the past X years	17	
Improving IP and opportunities for commercialising & offering services on licencing arrangements	19	

Table1 ISSUES/CRITERIA	Round 1 total scores	Comments
Introducing mechanisms for sharing and collecting data/products	25	
Introducing a Knowledge Management System in SME's	27	
Using innovative decision capability	23	
Introducing particular technologies	25	

Table 2 ISSUES/CRITERIA	1= NOT RELEVANT	2= LITTLE RELEVANCE	3= QUITE RELEVANT	4= VERY RELEVANT	5= MOST RELEVANT
Staff related innovation activity					
Increased opportunity for staff development					
Introducing useful organisational change					
Improving staff training on knowledge sharing					
Introducing incentive mechanisms to help development of new abilities/motivation					
Comments					

Table 2 ISSUES/CRITERIA	1= NOT RELEVANT	2= LITTLE RELEVANCE	3= QUITE RELEVANT	4= VERY RELEVANT	5= MOST RELEVANT
Communication activities on projects					
Selection of the ideas that bring the best return					
Involvement of all stakeholders/key personal in the design process					
Comments					
Introducing systems					
Share lessons learnt across projects					
Comments					
Research and Development activity					
Investment into research that optimises project outcomes					
Rate at which innovation is disseminated throughout a firm					
Comments					

Table 2 ISSUES/CRITERIA	1= NOT RELEVANT	2= LITTLE RELEVANCE	3= QUITE RELEVANT	4= VERY RELEVANT	5= MOST RELEVANT

Please return the completed questionnaire and email to d.mian@qut.edu.au. If you have any queries call Daniyal Mian on ++61 4 02395568.

Confidentiality Protocol

We respect your privacy and to ensure confidentiality the data obtained from this questionnaire will be kept strictly confidential and the name of the respondent will not be included in the reference list when the results of this research are published.

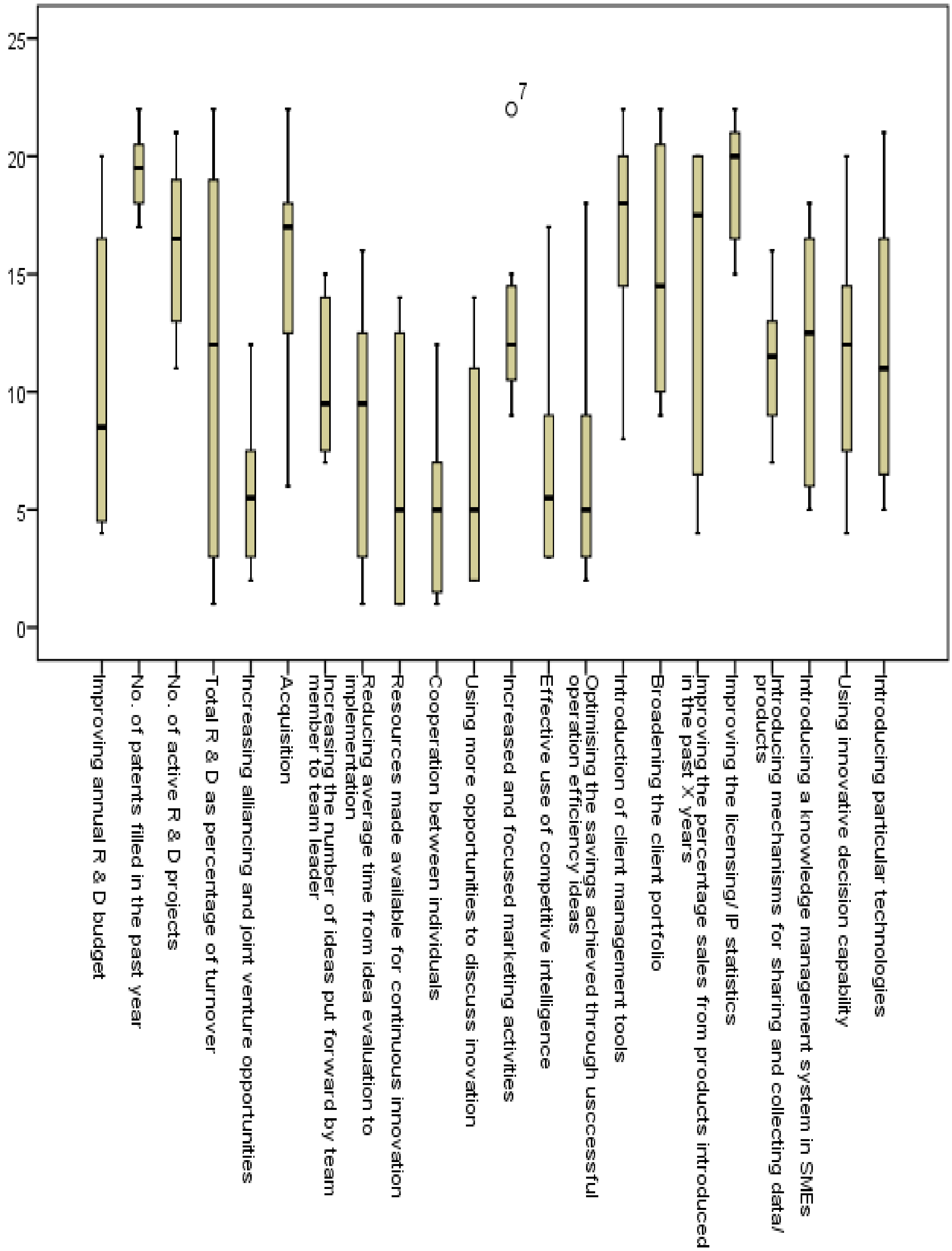
Voluntary participation

The research team does not believe that there are any risks for you to participate in this research, or where risks exist they have been reviewed and suitable plans put in place. However your participation in this project is voluntary. If you don't agree to participate, you can withdraw from participation at any time during the study without comment or penalty. Your decision to participate will in no way impact upon your current or future relationships with QUT or any other organisation associated with the study.

Consent

The return of the completed questionnaire is accepted as an indication to participate in this project. Thank you for your time in completing this questionnaire

Box Plots- Round 2



Multiple comparison analysis: ANOVA – Tuckey's test

ANOVA

Innovation Activities		Sum of Squares	df	Mean Square	F	Sig.
Improving annual R & D budget	Between Groups	148.875	4	37.219	.604	.688
	Within Groups	185.000	3	61.667		
	Total	333.875	7			
No. of active R & D projects	Between Groups	18.375	4	4.594	.185	.932
	Within Groups	74.500	3	24.833		
	Total	92.875	7			
Total R & D as percentage of turnover	Between Groups	168.875	4	42.219	.380	.813
	Within Groups	333.000	3	111.000		
	Total	501.875	7			
Partnerships with R&D organisations and tertiary institutions	Between Groups	22.500	4	5.625	.307	.858
	Within Groups	55.000	3	18.333		
	Total	77.500	7			
Acquisition of new initiatives and technology options to facilitate business	Between Groups	187.375	4	46.844	21.620	.015
	Within Groups	6.500	3	2.167		
	Total	193.875	7			
Increasing the number of ideas put forward by team member to team leader	Between Groups	38.000	4	9.500	.679	.651
	Within Groups	42.000	3	14.000		
	Total	80.000	7			
Reducing average time from idea evaluation to implementation	Between Groups	124.875	4	31.219	1.077	.496
	Within Groups	87.000	3	29.000		
	Total	211.875	7			
Resources made available for continuous innovation	Between Groups	93.500	4	23.375	.492	.748
	Within Groups	142.500	3	47.500		
	Total	236.000	7			
Cooperation between individuals	Between Groups	77.000	4	19.250	2.511	.238
	Within Groups	23.000	3	7.667		
	Total	100.000	7			
Using more opportunities to discuss innovation and reward smart ideas	Between Groups	162.000	4	40.500	6.075	.085
	Within Groups	20.000	3	6.667		
	Total	182.000	7			
Increased and focused marketing activities	Between Groups	34.375	4	8.594	.305	.859
	Within Groups	84.500	3	28.167		
	Total	118.875	7			
Effective use of market intelligence to achieve a competitive edge	Between Groups	115.875	4	28.969	1.849	.320
	Within Groups	47.000	3	15.667		
	Total	162.875	7			
Optimising the savings achieved through successful operation efficiency ideas	Between Groups	178.000	4	44.500	5.235	.103
	Within Groups	25.500	3	8.500		
	Total	203.500	7			
Introduction of client management tools	Between Groups	117.875	4	29.469	2.389	.250
	Within Groups	37.000	3	12.333		
	Total	154.875	7			
Broadening the client portfolio	Between Groups	148.375	4	37.094	2.042	.292
	Within Groups	54.500	3	18.167		
	Total	202.875	7			
Improving the percentage sales from products introduced in the past X years	Between Groups	221.500	4	55.375	1.182	.464
	Within Groups	140.500	3	46.833		
	Total	362.000	7			
Improving the licensing/	Between Groups	27.000	4	6.750	.880	.565

IP statistics	Within Groups	23.000	3	7.667		
	Total	50.000	7			
Introducing mechanisms for sharing and collecting data/ products	Between Groups	28.500	4	7.125	.611	.685
	Within Groups	35.000	3	11.667		
	Total	63.500	7			
Introducing a knowledge management system in SMEs	Between Groups	196.375	4	49.094	5.776	.091
	Within Groups	25.500	3	8.500		
	Total	221.875	7			
Using innovative decision capability	Between Groups	138.000	4	34.500	2.156	.277
	Within Groups	48.000	3	16.000		
	Total	186.000	7			
Introducing particular technologies	Between Groups	139.000	4	34.750	.998	.522
	Within Groups	104.500	3	34.833		
	Total	243.500	7			

The priority factor selected for the first ANOVA was the variable with the highest score. The priority factor was RDA_2 (No. Of patents filled in the past year). The results from the ANOVA highlight only one variable that varied significantly from the priority factor (Acquisition of new initiatives and technology options to facilitate business, p = 0.015). As such, all of the other variables can be added to the list of variables to be included in round three.

ANOVA

Innovation Activities		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Improving annual R & D budget	Between Groups	308.875	5	61.775	4.942	.177
	Within Groups	25.000	2	12.500		
	Total	333.875	7			
No. of active R & D projects	Between Groups	74.375	5	14.875	1.608	.426
	Within Groups	18.500	2	9.250		
	Total	92.875	7			
Total R & D as percentage of turnover	Between Groups	429.375	5	85.875	2.369	.323
	Within Groups	72.500	2	36.250		
	Total	501.875	7			
Partnerships with R&D organisations and tertiary institutions	Between Groups	67.500	5	13.500	2.700	.292
	Within Groups	10.000	2	5.000		
	Total	77.500	7			
Acquisition of new initiatives and technology options to facilitate business	Between Groups	167.375	5	33.475	2.526	.307
	Within Groups	26.500	2	13.250		
	Total	193.875	7			
Increasing the number of ideas put forward by team member to team leader	Between Groups	75.500	5	15.100	6.711	.135
	Within Groups	4.500	2	2.250		
	Total	80.000	7			
Reducing average time from idea evaluation to	Between Groups	149.375	5	29.875	.956	.583
	Within Groups	62.500	2	31.250		

implementation	Total	211.875	7			
Resources made available for continuous innovation	Between Groups	184.000	5	36.800	1.415	.463
	Within Groups	52.000	2	26.000		
	Total	236.000	7			
Cooperation between individuals	Between Groups	83.000	5	16.600	1.953	.372
	Within Groups	17.000	2	8.500		
	Total	100.000	7			
Using more opportunities to discuss innovation and reward smart ideas	Between Groups	110.000	5	22.000	.611	.716
	Within Groups	72.000	2	36.000		
	Total	182.000	7			
Increased and focused marketing activities	Between Groups	68.875	5	13.775	.551	.744
	Within Groups	50.000	2	25.000		
	Total	118.875	7			
Effective use of market intelligence to achieve a competitive edge	Between Groups	160.375	5	32.075	25.660	.038
	Within Groups	2.500	2	1.250		
	Total	162.875	7			
Optimising the savings achieved through successful operation efficiency ideas	Between Groups	195.000	5	39.000	9.176	.101
	Within Groups	8.500	2	4.250		
	Total	203.500	7			
Broadening the client portfolio	Between Groups	170.375	5	34.075	2.097	.354
	Within Groups	32.500	2	16.250		
	Total	202.875	7			
Improving the percentage sales from products introduced in the past X years	Between Groups	249.500	5	49.900	.887	.606
	Within Groups	112.500	2	56.250		
	Total	362.000	7			
Improving the licensing/ IP statistics	Between Groups	37.000	5	7.400	1.138	.529
	Within Groups	13.000	2	6.500		
	Total	50.000	7			
Introducing mechanisms for sharing and collecting data/ products	Between Groups	31.500	5	6.300	.394	.827
	Within Groups	32.000	2	16.000		
	Total	63.500	7			
Introducing a knowledge management system in SMEs	Between Groups	105.375	5	21.075	.362	.845
	Within Groups	116.500	2	58.250		
	Total	221.875	7			
Using innovative decision capability	Between Groups	85.000	5	17.000	.337	.859
	Within Groups	101.000	2	50.500		
	Total	186.000	7			
Introducing particular technologies	Between Groups	237.000	5	47.400	14.585	.065
	Within Groups	6.500	2	3.250		
	Total	243.500	7			
No. of patents filled in	Between Groups	17.875	5	3.575	1.788	.396

the past year	Within Groups	4.000	2	2.000
	Total	21.875	7	

Appendix D- Delphi Round 3 Questionnaire

Impact of Innovation Activity on Project Performance for Consulting Engineering Firms

Introduction and guidance on completing the questionnaire

The total scores for each criterion from Round 1 and Round 2 with a maximum possible score of 40 (based on scores from 8 respondents) are shown in table 1. There were additional criteria added to the list as we progressed from Round 1 to Round 2. Please be reminded that the total scoring for each criterion was based on a 1 to 5 (most relevant) rating system used in these rounds. The results from Round 2 analysis shows that there was weak to moderate agreement among the group members on the relative ranking of the criteria. This study is focussed specifically on consulting engineering firms and while considering project performance, please consider measures such as client satisfaction with budget, time and quality, design team satisfaction and construction time and budget.

For Round 3, please rank the criteria in table 1 using a ranking scale in order of importance from 1 (most relevant) to 31 (least relevant). If you have difficulty in ranking one criterion over the other, can you please still do so, but also pre-qualify your selection with comments.

Kindly, complete and return the questionnaire in 7 days of receipt. Many thanks in advance for your contribution to this research. Please contact me directly, if you have any questions.

Kind Regards,

Daniyal Mian

Mobile 0413 716 510

d.mian@qut.edu.au

Table1 ISSUES/CRITERIA	Round 1 and 2 total scores	Your Rank in order of importance (1 being most relevant and 31 being the least relevant))	Comments
Research and Development Activity			
Improving annual R & D budget	27		
No of patents filled in the past year	14		
No of active R&D projects	25		
Total R&D as percentage of turnover	29		
Partnerships with R&D organisations and tertiary institutions	34		
Acquisition of new initiatives and technology options to facilitate business	23 23		
Investment into research that optimises project outcomes	23		
Rate at which innovation is disseminated throughout a firm			
Communication activities on projects			
Increasing the number of ideas put forward by team member to leaders	27		
Reducing the average time from idea evolution to full implementation	29		
Resources made available for	31		

Table1 ISSUES/CRITERIA	Round 1 and 2 total scores	Your Rank in order of importance (1 being most relevant and 31 being the least relevant))	Comments
continuous innovation			
Cooperation between individuals	36		
Using more opportunities to discuss innovation and reward smart ideas	31		
Selection of ideas that bring the best return	30		
Involvement of all stakeholders /key personal in the design process	30		
Client related activities			
Increased and focussed marketing activities	25		
Effective use of market intelligence to achieve a competitive edge	31		
Optimising the savings achieved through successful operation efficiency ideas	31		
Introduction of client management tools	24		
Broadening the client portfolio	28		
Introducing systems			
Improving the percentage sales from products introduced in the past X years	17		
Improving IP and opportunities for commercialising & offering services on licencing arrangements	19		
Introducing mechanisms for sharing and collecting data/products	25		

Table1 ISSUES/CRITERIA	Round 1 and 2 total scores	Your Rank in order of importance (1 being most relevant and 31 being the least relevant))	Comments
Introducing a Knowledge Management System in SME's	27		
Using innovative decision capability	23		
Introducing particular technologies	25		
Share lessons learnt across projects	28		
Staff related innovation activity			
Increased opportunity for staff development	29		
Introducing useful organisational change	30		
Improving staff training on knowledge sharing	30		
Introducing incentive mechanisms to help development of new abilities/motivation	29		

Thank you for completing the Round 3 questionnaire. Please return the completed questionnaire to d.mian@qut.edu.au. If you have any queries call Daniyal Mian on ++61 413 716 510.

Confidentiality Protocol

We respect your privacy and to ensure confidentiality the data obtained from this questionnaire will be kept strictly confidential and the name of the respondent will not be included in the reference list when the results of this research are published.

Voluntary participation

The research team does not believe that there are any risks for you to participate in this research, or where risks exist they have been reviewed and suitable plans put in place. However your participation in this project is voluntary. If you don't agree to participate, you can withdraw from participation at any time during the study without comment or penalty. Your decision to participate will in no way impact upon your current or future relationships with QUT or any other organisation associated with the study.

Consent

The return of the completed questionnaire is accepted as an indication to participate in this project. Thank you for your time in completing this questionnaire.

Appendix E- Delphi Round 3 Data Analysis

Detailed Analysis for Calculating Overall Index

Innovation Activities	E	D	F	C	A	H	B	G	O.R	Rank
Total R&D as a percentage of turnover	19	15	13	14	18	19	13	16	15.875	15
Acquisition of new initiatives and technology options to facilitate business of other companies/innovation initiatives	22	16	12	27	13	26	12	26	19.25	19
Investment into research that optimised project outcomes	8	14	8	12	11	23	21	17	14.25	14
Rate at which innovation is disseminated throughout a firm	31	11	26	24	10	28	20	18	21	21
Increasing the opportunity for idea generation by design team members	7	8	10	11	7	10	11	8	9	8
Reducing average time from idea generation to implementation	6	3	9	10	4	13	7	9	7.625	5
Resources made available for continuous innovation	1	1	4	2	1	8	1	1	2.375	2
Cooperation between team members	3	1	1	1	2	1	2	6	2.125	1
Using opportunities to discuss innovation	13	2	11	13	3	12	6	11	8.875	7
Selection of ideas that bring the best return	17	12	14	23	6	9	19	12	14	13
Involvement of all stakeholders/key project person in the design process	28	21	30	28	17	22	18	23	23.375	22
Increased and focussed marketing activities	27	9	15	25	9	7	14	21	15.875	15
Effective use of market intelligence to achieve a competitive edge	12	17	7	7	5	14	3	7	9	8
Improving licencing and IP metrics	4	10	2	8	8	18	15	30	11.875	11
Introducing mechanisms for sharing and collecting data/products	2	6	3	4	15	5	16	3	6.75	4
Introducing a knowledge management system	14	27	23	21	27	17	31	29	23.625	23
Using innovative decision making tools	18	13	21	20	19	16	24	14	18.125	18
Introducing particular technologies for training staff	20	25	20	20	18	31	17	15	20.75	20

Innovation Activities	A	B	C	D	D	E	F	G	O.R	Rank
Increased opportunity for staff development	16	18	16	6	22	6	9	5	12.25	12
Introducing change programs	5	7	17	3	14	3	8	4	7.625	5
Improving staff training on knowledge sharing	10	23	22	15	28	11	10	13	16.5	17
Introducing incentive mechanisms to help development of new capability and encouraging motivation.	15	19	5	9	20	2	5	10	10.625	10
Total R&D as a percentage of turnover	19	15	13	14	18	19	13	16	15.875	15
Acquisition of new initiatives and technology options to facilitate business of other companies/innovation initiatives	22	16	12	27	13	26	12	26	19.25	19
Investment into research that optimised project outcomes	8	14	8	12	11	23	21	17	14.25	14
Rate at which innovation is disseminated throughout a firm	31	11	26	24	10	28	20	18	21	21
Increasing the opportunity for idea generation by design team members	7	8	10	11	7	10	11	8	9	8
Reducing average time from idea generation to implementation	6	3	9	10	4	13	7	9	7.625	5
Resources made available for continuous innovation	1	1	4	2	1	8	1	1	2.375	2
Cooperation between team members	3	1	1	1	2	1	2	6	2.125	1
Using opportunities to discuss innovation	13	2	11	13	3	12	6	11	8.875	7
Selection of ideas that bring the best return	17	12	14	23	6	9	19	12	14	13
Involvement of all stakeholders/key project person in the design process	28	21	30	28	17	22	18	23	23.375	22
Increased and focussed marketing activities	27	9	15	25	9	7	14	21	15.875	15
Effective use of market intelligence to achieve a competitive edge	12	17	7	7	5	14	3	7	9	8
Improving licencing and IP metrics	4	10	2	8	8	18	15	30	11.875	11

Introducing mechanisms for sharing and collecting data/products	2	6	3	4	15	5	16	3	6.75	4
Introducing a knowledge management system	14	27	23	21	27	17	31	29	23.625	23
Using innovative decision making tools	18	13	21	20	19	16	24	14	18.125	18
Introducing particular technologies for training staff	20	25	20	20	18	31	17	15	20.75	20
Sharing lessons learnt from projects	9	5	6	5	12	4	4	2	5.875	3
Increased opportunity for staff development	16	18	16	6	22	6	9	5	12.25	12
Introducing change programs	5	7	17	3	14	3	8	4	7.625	5
Improving staff training on knowledge sharing	10	23	22	15	28	11	10	13	16.5	17
Introducing incentive mechanisms to help development of new capability and encouraging motivation.	15	19	5	9	20	2	5	10	10.625	10

Stem-and-Leaf Plots- Typical Example

No. of patents filled in the past year Stem-and-Leaf Plot

Frequency Stem & Leaf

1.00 Extremes (=<1)

1.00 2. 0

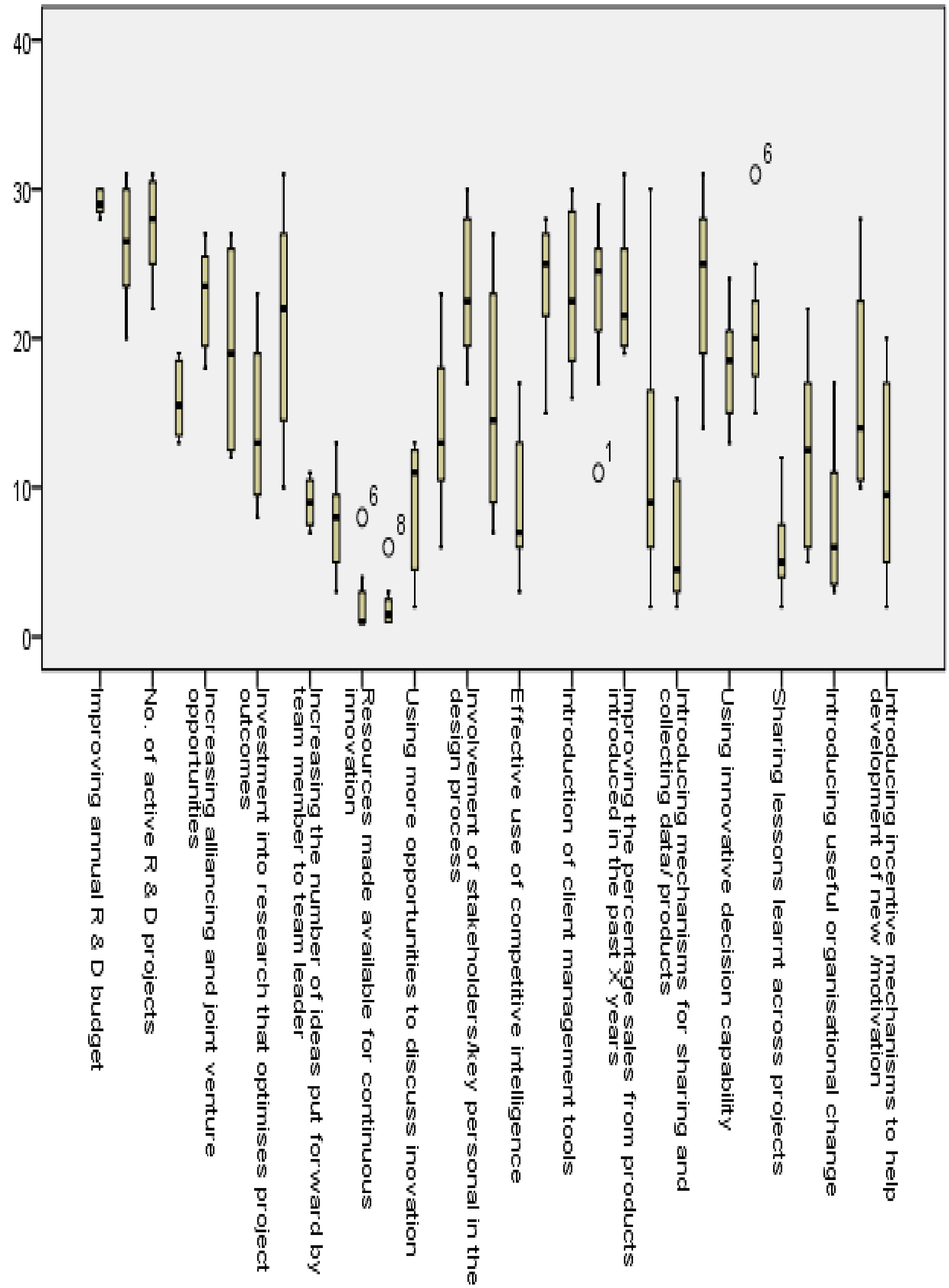
4.00 2. 8999

2.00 3. 01

Stem width: 10.00

Each leaf: 1 case(s)

Box Plot from Round 3



Kendall's W Coefficient Calculation-Ranks

Ranks

	Mean Rank
Improving annual R & D budget	29.13
No. of patents filled in the past year	26.38
No. of active R & D projects	27.50
Total R & D as percentage of turnover	15.94
Partnerships with R&D organisations and tertiary institutions	22.75
Acquisition of new initiatives and technology options to facilitate business	19.25
Investment into research that optimises project outcomes	14.25
Rate at which innovation is disseminated through a firm	21.00
Increasing the number of ideas put forward by team member to team leader	9.00
Reducing average time from idea evaluation to implementation	7.75
Resources made available for continuous innovation	2.44
Cooperation between individuals	2.19
Using more opportunities to discuss innovation and reward smart ideas	9.00
Selection of ideas that bring the best return	14.00
Involvement of stakeholders/key personal in the design process	23.38
Increased and focused marketing activities	15.88
Effective use of market intelligence to achieve a competitive edge	9.00
Optimising the savings achieved through successful operation efficiency ideas	23.75
Introduction of client management tools	23.13
Broadening the client portfolio	22.75
Improving the percentage sales from products introduced in the past X years	23.00
Improving the licensing/ IP statistics	11.88
Introducing mechanisms for sharing and collecting data/ products	6.75
Introducing a knowledge management system in SMEs	23.75
Using innovative decision capability	18.31
Introducing particular technologies	20.88
Sharing lessons learnt across projects	5.88
Increased opportunity for staff development	12.25
Introducing useful organisational change	7.63
Introducing staff training on knowledge sharing	16.50
Introducing incentive mechanisms to help development of new /motivation	10.75

Detailed Analysis for Calculating Overall Index

Appendix F- Sample Email Imitation to Delphi Experts

RE: Invitation to Participate in a QUT Research Project

My name is Daniyal Mian. I am a Senior Project Manager with Arup and currently undertaking my PhD from Queensland University of Technology. I am writing to request your participation in my research project. Based on my initial has suggested that your experience and expertise would be beneficial to this research.

The Delphi study which aims to determine the most important issues and challenges that Knowledge-based Firms (KBFs) are facing in the current financial crisis.

'Grant (1996) states that KBFs are those where vital input in production and key source of value is knowledge, where employees embody this knowledge.'

It is also important to clarify that this study revolves around consulting engineering firms. The main aim of the study is to test he perceived view that innovation activities have a positive impact on project performance. A Delphi study consists of several rounds of questionnaires submitted to experts in a particular field of endeavour, in order to determine if any consensus exists as to future trends in the field. People with experience in such fields are asked to rank the most significant issues.

Your participation would involve completing three rounds of questionnaires, which will be conducted anonymously and confidentially. It is expected that this research will benefit you. By participating in this research, you will help generate new knowledge about innovation management in consulting engineering firms that will have practical applications in the industry. Further, the results of all the questionnaires will be reported back to you after each round.

Please refer to the attached participant information and consent forms for more details on the research project and how you can participate.

If you agree to participate in this research, please sign the attached consent form for QUT research and return it to me by mail or email (contact details below).

I look forward to your agreement to participate in this research. Please do not hesitate to contact me should you have any questions.

Kind regards,

Daniyal Mian

Address: [details withheld]

Phone: [details withheld]

Email: [details withheld]

Appendix G- Participant Information

PARTICIPANT INFORMATION for QUT RESEARCH PROJECT

A model to assess the impact of innovation activity on project performance in Knowledge-based Firms (KBFs)

Research Team Contacts	
Daniyal Mian	Stephen Kajewski – HOS UD
0402 395 568	07 3138 2676
d.mian@qut.edu.au	s.kajewski@qut.edu.au

Description

This project is being undertaken as part of PhD for Daniyal Mian. The project is funded by RTS. The funding body will not have access to the data obtained during the project.

The purpose of this research is to develop a model that uses a structured and systematic approach to assess the impact of innovation activity on project performance, for Knowledge-based Firms.

It is proposed to use Delphi technique (expert advice) to collect data from the experts working in/with Knowledge-based Firms.

Participation

Your participation in this project is voluntary. If you do agree to participate, you can withdraw from participation at any time during the project without comment or penalty. Your decision to participate will in no way impact upon your current or future relationship with QUT (for example your grades).

Your participation will involve completing a questionnaire which will not take more than 15-20 minutes. The questionnaire will be sent to you through email.

Expected benefits

It is expected that the lessons learnt will be useful for the reviewing process within your own practice especially if you are associated with a Knowledge-based Firm.

Risks

The research team does not believe there are any risks for you if you choose to participate in this research, or where risks exist they have been reviewed and suitable plans put in place.

The research team has identified the following possible risks in relation to participating in this study - confidentiality may be an issue for some respondents. However the research team will ensure that the information provided is kept confidential and not divulged to a third party without the approval of each respondent.

Strategies are in place to manage these risks and full details will be provided should you choose to participate.

QUT provides for limited free counselling for research participants of QUT projects, who may experience some distress as a result of their participation in the research. Should you wish to access this service please contact the Clinic Receptionist of the QUT Psychology Clinic on 3138 0999. Please indicate to the receptionist that you are a research participant.

Confidentiality

There is no need for verifying the answers as they are been sent through email and are recognisable.

Consent to Participate

The return of the completed questionnaire is accepted as an indication of your consent to participate in this project.

Questions / further information about the project

Please contact the researcher team members named above to have any questions answered or if you require further information about the project.

Concerns / complaints regarding the conduct of the project

QUT is committed to researcher integrity and the ethical conduct of research projects. However, if you do have any concerns or complaints about the ethical conduct of the project you may contact the QUT Research Ethics Officer on 3138 2340 or ethicscontact@qut.edu.au. The Research Ethics Officer is not connected with the research project and can facilitate a resolution to your concern in an impartial manner.

CONSENT FORM for QUT RESEARCH PROJECT

A model to assess the impact of innovation activity on project performance in Knowledge-based Firms (KBFs)

Statement of consent

By signing below, you are indicating that you:

- have read and understood the information document regarding this project
- have had any questions answered to your satisfaction
- understand that if you have any additional questions you can contact the research team
- understand that you are free to withdraw at any time, without comment or penalty
- understand that you can contact the Research Ethics Officer on 3138 2340 or ethicscontact@qut.edu.au if you have concerns about the ethical conduct of the project
- agree to participate in the project

Name ______________________________

Signature ______________________________

Date ________ / ________ / ________

Extract from Ethics Approval

Re: Innovation management program

'This email is to advise that your application has been reviewed and confirmed as meeting the requirements of the National Statement on Ethical Conduct in Human Research. Your ethics approval number is 0900000479.
Please quote this number in all future correspondence.

Whilst the data collection of your project has received ethical clearance, the decision to commence and authority to commence may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or permissions from other organisations to access staff. Therefore the proposed data collection should not commence until you have satisfied these requirements.

If you require a formal approval certificate, please respond via reply email and one will be issued'