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IMPROVING INNOVATION MANAGEMENT IN CONSTRUCTION

By
Nicholas Shaw

A dissertation thesis submitted in partial fulfilment of the requirements for the award of the degree Doctor of Engineering (EngD), at Loughborough University

[December 2010]
ACKNOWLEDGEMENTS

This research would not have been possible without the support, time and energy that so many people have selflessly provided me along the way. I would particularly like to thank my supervisors; Dino Bouchlaghem, Peter Demian, Rennie Chadwick, David Kerr and my previous supervisor Chimay Anumba. Their guidance and encouragement throughout this project has been invaluable. I would also like to thank my former team members Chris Denison and Gary Codling for their inspiration and feedback, and Kelly McGall for keeping us all in order. I am also very grateful for the assistance provided by the CICE staff and the motivation provided by my fellow EngD research engineers, especially Paul Fuller and Abdullahi Sheriff who helped to keep me smiling. I would like to thank my family and friends for their ongoing support in all that I do. Finally, I would like to thank Martina for believing in me.
The need for change and improvement in the construction sector has been well documented. The recent economic downturn, greater levels of competition, increasing product complexity, regulatory requirements and tougher environmental targets are all examples of current challenges that continue to add weight to this requirement and accelerate the pace in which the sector must respond. It is widely agreed that it is through innovation, which can be defined as the successful exploitation of an idea, that construction firms will be able to create and exploit solutions in response to many of these challenges.

In response, more and more construction firms are seeking ways to manage innovation in a more strategic and conscientious manner. However, there is little practical guidance for construction professionals on how this can be achieved and progress towards the optimisation of intra-organisational innovation in construction is widely considered to have been slow. Progress has been hindered by a lack of research and understanding of innovation in the construction context. There is an urgent need to address this and equip construction firms with practical and effective approaches for improved innovation management.

This thesis presents an action research project that has developed and tested two interventions aimed at improving the management of innovation at the intra-organisational level within a major construction, engineering and associated services firm. The first intervention comprised of a stage-gate idea management process, a support network of ‘innovation champions’ and a web-based tool for capturing, storing and reporting on ideas, with the purpose of providing a new platform for innovation outside the normal scope and boundaries of a single project. The second intervention included an online resource that provided tools and guidance for innovation with the purpose of promoting and providing practical support for those seeking to facilitate innovation in their projects or teams.

Evaluation of the first intervention has revealed a number of important results, including the improved performance of budgets for innovation, increased employee satisfaction with levels of support for innovation, improvement in self-reported innovation performance and an increased portfolio of innovation projects. Usability testing of the second intervention suggests that it is a valuable tool that encourages and supports innovation at the project level. The thesis concludes by outlining a number of recommendations for consideration by the industry, along with suggestions for future research.

KEY WORDS

Innovation Management, Action Research, Construction Industry, Organisational Climate, Measurement
ACRONYMS AND ABBREVIATIONS

- CICE  Centre for Innovative and Collaborative Engineering
- CPD  Collaborative Product Development
- EngD  Engineering Doctorate
- GDP  Gross Domestic Product
- ICT  Information and Communication Technology
- IVM  Institute of Value Management
- KPI  Key Performance Indicators
- NESTA National Endowment for Science, Technology & the Arts
- NPD  New Product Development
- OECD Organisation for Economic Co-operation & Development
- OGC  Office of Government Commerce
- ONS  Office for National Statistics
- PCA  Principal Component Analysis
- PDMA  Product Development & Management Association
- R&D  Research and Development
- RE  Research Engineer
- ROI  Return on Investment
- SUS  System Usability Scale
- TCI  Team Climate Inventory
- TSB  Technology Strategy Board
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1 INTRODUCTION

1.1 Introduction

This chapter provides an introduction to this thesis on the subject of innovation management within the construction industry. It sets out the context of the research both within the construction industry and the industrial sponsor, and highlights the novelty and need for such a project. The main aim and objectives of the project are defined, before the remaining structure of the thesis is described.

1.2 Background

The need for change and improvement in the construction industry has been well documented (Egan, 1998; Fairclough, 2002; Latham, 1994). The industry has been consistently shown to be risk averse, slow to develop and adopt new products and processes and poor at managing knowledge and innovation in order to improve its performance.

Evidence on the level of activity in the traditional measures of innovation, such as investment in formal research and development (R&D) and number of patents awarded, lend support to these assertions. Recent figures show that R&D investment in construction is very low in comparison to other industry sectors and is in decline (BERR, 2008). As a result many believe the construction industry to be a low innovation sector and have highlighted the case for the industry to find new and improved ways to manage and exploit innovation in order to better its image and performance. The UK construction industry accounts for approximately six per cent of gross domestic product (GDP) and research has indicated that every £1 spent on construction leads to an increase in GDP of £2.84, as the spending not only creates construction output worth £1, but also stimulates growth elsewhere in the economy worth £1.84 (LEK, 2009; ONS, 2010). Therefore it is argued that an improvement in performance is not only imperative for the sector itself, but would also significantly contribute to the health of the wider economy.

The impact of the recession, the worst since World War Two, has also elevated the need and urgency for improved innovation performance in construction. Dramatic reductions in public and private sector investment in the built environment has forced many construction firms to find new efficiency savings in existing processes, rethink business models and seek differentiation for competitive advantage to survive and prepare for the anticipated upturn (NESTA, 2008). Increases in competition, complexity, regulations, customer expectations and the growing need to minimise environmental impact all add to the challenge, and to the assertion that this need for change and improvement has never been greater.

Innovation has been defined as the successful exploitation of an idea (DTI, 2003). It is widely agreed that it is through innovation that construction firms will be able to create and exploit solutions in response to many of the challenges previously discussed. As a result, innovation is becoming an ever more essential ingredient for winning work and increasing profitability in the sector (Seaden et al, 2003; Tatum, 1991), with more and more construction firms seeking ways to manage innovation in a more strategic and conscientious manner (Hartmann, 2006a; Wamuziri & Madan, 2009).
Other industry sectors have demonstrated some of the advantages associated with the active management of innovation. In particular, firms in the manufacturing sector often make extensive use of formalised processes, roles and responsibilities, information communication technology (ICT), and strategic planning in order to drive innovation performance (Cooper, 1994). Innovation management as a field of study has existed for several decades, focusing primarily on the manufacturing sector (Slaughter, 1998).

However, there is little practical guidance for construction professionals on how to make innovation flourish within their firms and research on innovation management specifically for the construction sector is limited (Gann & Salter, 2000). Innovation potential in construction continues to be dampened by this lack of understanding and further complicated by the highly regulated, project orientated and contractual nature of the industry (Ozorhon et al, 2009; Reichstein et al, 2008). Those who aspire to improve innovation performance in the construction firm will need to address this and develop a better understanding of innovation process and outcomes in construction, including how and when it occurs, what organisational forces influence it and what management interventions can support it (Blayse & Manley, 2004; Hartmann, 2006a; Reichstein et al, 2005).

1.3 The Research Context

The requirements for this research originated in 2006 from a need identified by Taylor Woodrow Construction to better understand the process of innovation and improve its management within the context of a construction firm. This need in turn stemmed from a desire to continue to reflect and reinforce the company’s innovation values and to simultaneously better utilise resources for innovation in order to help meet and exceed the increasing expectations and demands of expert construction customers.

Taylor Woodrow Construction provided construction services, project and facilities management across mixed-use, transport, retail, education and health sectors, with operations primarily based in the UK at that time. In September 2008, the mid-point of the research project and the beginning of the economic downturn, Taylor Woodrow Construction was acquired by VINCI PLC. This was closely followed by the formation of VINCI Construction UK, a wholly owned subsidiary of VINCI PLC, in December 2008 with the objective of integrating its principal construction subsidiaries. Prior to the acquisition of Taylor Woodrow Construction, Norwest Holst had been the principal contracting entity; now Norwest Holst, Taylor Woodrow Construction and a number of regional contracting companies have been consolidated into a single coherent contracting entity.

Despite some inevitable disruption during the initial stages of this re-organisation, the original aspirations of Taylor Woodrow Construction for improved innovation management were shared by the newly formed company and the research project aim and objectives remained unchanged. Indeed, innovation forms one of VINCI Construction UK’s core company values and was recognised as a key factor for improving the strength and position of the business during the recession and beyond.

Today, VINCI Construction UK has a turnover exceeding £1 billion and employs over 4000 people across the UK. The company provides construction, facilities and associated services to a wide range of sectors and is formed of five operational divisions; air, building, civil engineering, facilities management, and technology. The air division provides programme
management, engineering and construction services to customers with air-related infrastructure requirements such as airport operators, airlines and associated stakeholders. The building division has longstanding expertise in the provision of schools, hospitals, residential and student accommodation throughout the country. The civil engineering division specialises in the delivery of technically demanding, multi-disciplinary and logistically complex projects for a variety of customers, including Transport for London, Highways Agency and Network Rail. VINCI facilities provides an extensive range of property and facilities management services to both public and private sector clients, enabling them to maximise the value of their assets. The technology division comprises of a team of engineers, consultants and scientists dedicated to providing associated support services and innovative solutions for the construction industry.

During the project, the Research Engineer (RE) worked as a member of the team responsible for innovation and knowledge management and reported to the director responsible for innovation. The industrial supervisors for the project remained the same throughout the research.

1.4 Aims and Objectives

A core element of the EngD degree is the solution of one or more significant and challenging problems within industry (CICE, 2010). The industrial sponsor presented two significant challenges; firstly to assess innovation performance and secondly, to develop and implement an intervention to improve performance. These challenges were addressed in the primary aim of the project, to improve the management of innovation within the context of a construction, facilities and associated services firm. In order to achieve the primary aim a total of three objectives were defined. The aim and three objectives are shown in Figure 1-1, including how they relate to the papers published during the research project and this thesis.
1.5 Justification for the Research

In addition to the general call for improvement from the construction industry and the need for further research in the field of innovation management highlighted earlier in the chapter, this research is justified through the need to:

- Assist the sponsor in developing and applying appropriate methods to assess innovation performance, whilst supporting the call for new and appropriate measures of innovation specifically for the construction industry;
- Develop, implement and evaluate suitable interventions to improve innovation performance across the sponsoring firm and demonstrate how the industry may meet the demands and targets set for increased innovation;
- Contribute to and expand upon the existing body of knowledge relating to innovation in construction, including knowledge gaps concerning the influencing factors of innovation and their relationships in the context of the construction firm;
- Contribute to the collection and dissemination of state of the art innovation management practice in the construction industry.
1.6 Novelty of the Research

This project provides a unique insight into the role, performance and management of innovation within a major construction, facilities and associated services firm. The RE’s position within the firm has enabled detailed assessment of the subject area, access to the opinions of key stakeholders, the implementation of changes and subsequent evaluation in a real industry setting. More specifically, it is hoped that the research has made the following contributions to the field:

- A methodology for the measurement of innovation performance in the construction firm;
- A review of the influencing factors of innovation and their relationships in the construction firm;
- A practical methodology for diagnosing, planning, implementing and evaluating interventions for improved innovation management in the context of a construction firm;
- An example of two practical solutions for improved innovation performance in the construction firm, including evaluation of the resulting impact;
- A number of key recommendations for the wider industry and direction for further work.

1.7 Scope of the Research

Innovation in construction is a broad and complex subject area. In order to achieve the aim and objectives of the project and deliver an improvement within the four year project timeframe there was a need to carefully define the scope of the research. The logical conclusion was to focus on innovation and its management within the sponsor and its Strategic Alliance Partnership (SAP). Limiting the scope in this way ensured that the RE could maintain the control and influence required to deliver change and improvement within the project constraints. The application of triangulation and critical evaluation of research findings enables recommendations to be drawn for the wider industry. Changes in the sponsoring company during the period of research required the scope to be adjusted. One significant change was the dismantlement of the SAP and the team responsible for its management shortly after the acquisition and merger. As a result, the line of enquiry into improving the conditions for innovation within the SAP was not pursued beyond the initial performance assessment. From this point forward the project focused exclusively on improving the management of innovation within the boundaries of the firm. The role and importance of inter-firm and sector level innovation is duly acknowledged, but is not the primary focus of this work.

1.8 Thesis Structure

The remainder of this thesis is organised into five chapters, structured as follows:

- Chapter Two – Related Work (page 7). This chapter provides the findings of a literature review on the subject of innovation and its management in construction and acknowledges previous and parallel research efforts within the field. Topics covered include innovation process, performance, influences, management and current limitations in construction.
- Chapter Three – Research Methodology (page 19). This chapter presents the research methodology adopted and specific methods applied for the project, including justification for their use.
Chapter Four – Research Undertaken (page 29). This chapter describes the research undertaken to meet the aim and objectives of the project. This includes details of the innovation performance assessment within the sponsor and the development, implementation and evaluation of two complimentary interventions to improve performance.

Chapter Five - Findings and Implications (page 55). This chapter provides the main findings from the research, including the impact of the research within the sponsor and the implications for the wider industry.

Chapter Six – Conclusions (page 67). This chapter presents the final conclusions, including critical evaluation of the research, recommendations and suggestions for future research.

1.9 Summary

This chapter has provided an introduction to the thesis, including the background, context, primary aim, objectives, and justification for the project. The current state and call for improved innovation management in the both the industrial sponsor and the wider construction industry have been presented. The aim of the project, to investigate and improve innovation management in the context of a construction firm, and the three supporting objectives have been outlined in Figure 1-1. The project is justified through the need to address poor innovation performance in the industry and contribute to a field of research that has so far not received enough attention. Finally the thesis structure has been provided, including an overview of each of the remaining five chapters of this thesis.
2 RELATED WORK

2.1 Introduction

This chapter provides an overview of previous research in the general subject domain. The initial literature review was conducted in order to establish a sound foundation from which this research project could build upon and contribute to knowledge. First, the definition of innovation is explored and the principal motivation and benefits of innovation are highlighted. Then the review converges towards the process and performance of innovation specifically in the construction industry, including an overview of innovation management and acknowledgement of other existing management practices which can influence and bring about innovation in the construction firm. Finally, the chapter concludes by highlighting the gaps in the existing body of research, which was used to help justify and shape the direction of the project during its inception.

2.2 Innovation

There are many definitions of innovation, most of which play on identical themes. In simple terms innovation can be defined as the successful exploitation of new ideas (DTI, 2003). To be more unequivocal, it can also be described as the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the firm developing the change (Slaughter, 1998), where the improvement may relate to an increase in efficiency and/or effectiveness (Seaden et al, 2003). In this project innovation was defined as the successful exploitation of new ideas, on the basis that this broader definition better reflects the many ways in which innovation may be achieved in practice.

An area of frequent terminological confusion is that innovation is both an outcome and a process (Dodgson et al, 2005). The process of innovation involves the generation, development, diffusion and exploitation of ideas (Dulaimi et al, 2005). The outcome of this process, when successful, is an innovation. It is all about the management of ideas into good currency (Van de Ven, 1986) and it is the process that this project aims to understand, assess and ultimately improve. The process of innovation in the construction firm is poorly understood and takes place in different levels of the firm, in different ways (Winch, 1998). This subject is discussed in more detail later in this chapter.

The outcomes of innovation also come in a variety of forms (DTI, 2003; Ozorhon et al, 2010). It is common to describe an innovation in terms of its type (is it a product, service or process innovation?), extent (is it an incremental, semi-radical or radical improvement?), and novelty (is it new to the firm, industry, or world?) which serves to illustrate the point (Dodgson et al, 2005).

There has been considerable debate about the fundamental driving forces of innovation. Although previous efforts, both theoretical and empirical, have significantly improved understanding of innovation, there is no single and unifying theory of innovation to date (Saad & Jones, 2003; Dodgson et al 2005). However, it is useful to provide a brief overview of the more prominent theories. The first, emerging during the 1950s and 1960s, described innovation as simple linear models, according to which innovation is a sequence of events triggered from scientific research, known as technology-push, or from a perceived market
The need for innovation is well established and has a central role in explanations of economic growth, industry productivity and international trade (Reichstein et al, 2005; Slaughter, 1998). The construction industry is one of the most important in modern economies (Blayse & Manley, 2004), accounting for approximately six per cent of GDP in the UK (ONS, 2010). Greater levels of innovation from the construction industry would be of significant benefit to the economy (Blayse & Manley, 2004) and society in general (Slaughter, 1998).

The notion of sustainable competitive advantage is increasingly interwoven with the ability of nations and firms to innovate (Barrett & Sexton, 2006). Innovation can contribute to competitiveness through the creation of new value propositions, offering novel or unique products or services and by continuously redefining the cost/performance frontier (Dodgson et al, 2005; Tidd, 2001). It provides an important alternative to cost based competition that has plagued the industry (Dulaimi et al, 2005; Slaughter, 1998).

The bottom line is that innovation is required to win projects, meet client goals and deliver healthier profits (Dulaimi et al, 2005; Seaden et al, 2003; Tatum, 1991), and has been shown to support profits during economic recessions (Reichstein et al, 2005). Reassuringly, most senior construction executives recognise the need to innovate (CIOB, 2007; Findlay, 2009) and consider it to be the principal competitive tool to achieve greater market penetration and increased profits (Seaden et al, 2003). It should be of no surprise that a growing number of construction firms are seeking ways to manage innovation in a more effective manner (Gann & Salter, 2000; Hartmann, 2006a; Wamuziri & Madan, 2009).

### 2.4 Innovation in Construction

There has been little research on innovation in construction, or even in project-based firms in general (Keegan & Turner, 2002), and a deeper understanding and analysis has been widely called for (Dulaimi et al, 2005; Ozorhon et al, 2009; Winch, 1998). What is understood is that the project-based and fragmented nature of construction exerts considerable influence over the processes by which innovation is achieved.
Winch (1998) asserts that there are two primary processes of innovation in the construction firm. The first process involves the identification of a performance gap, the decision to adopt a new idea and its subsequent implementation and diffusion across projects to achieve the anticipated performance benefits (Winch, 1998). These new ideas may be from a wide variety of sources, but often emanate from outside the firm (Koskela & Vrijhoef, 2001). The second process involves the identification of a problem on a project and the development of a solution. Problem solutions that are successfully learned, codified and applied to future projects can be considered innovations and provide a rich, internal source of new ideas to the firm (Slaughter, 1998; Winch, 1998). These two processes are captured in a two-moment model, which comprises of a top-down process of adoption and implementation and a bottom-up process of problem solving and learning that broadly describes the different ways in which a construction firm innovates, see Figure 2-1.

![Figure 2-1 - Two-moment Model of Construction Innovation (Winch, 1998)](image)

The principal of top-down innovation is also often referred to as strategic, firm-level and formal innovation in the literature, and descriptions such as day-to-day, project-level and informal innovation are often used to describe bottom-up processes of innovation. For purposes of clarity the terms top-down and bottom-up have been adopted for this project and are considered to also encompass the alternatives offered by others, as listed above.

This distinction between top-down and bottom-up processes is compatible with the arguments of other research in the field (Koskela & Vrijhoef, 2001). Gann and Salter (2000) assert that innovation in the construction firm is often the result of practitioner research (problem solving) at the project level and is not exclusively delivered by traditional R&D and technical support functions, maintaining the top-down and bottom-up processes of innovation proposed by Winch (1998). Indeed, the role of practitioner-research and project based problem solving are consistently highlighted in the research as an important source of innovation in construction (Dulaimi et al, 2005; Hartmann; 2006b; Ozorhon et al, 2009; Tidd, 2001). The major challenge for construction firms is the relationship between business processes (in the firm) and project processes (Gann & Salter, 2000), which is essential for codification, learning and diffusion onto future projects, as shown in Figure 2-2.
In addition to the various processes of innovation in the construction firm, previous research has also explored the various outcomes of innovation that may result. Slaughter (1998) identified five typologies of innovation that reflect the special conditions associated with construction. These are organised on the basis of two key attributes: the magnitude of change associated with the innovation, and the linkages of the innovation to other components and systems, see Table 2-1:

<table>
<thead>
<tr>
<th>Form</th>
<th>Attributes</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incremental</td>
<td>A small change, with limited impacts on surrounding elements</td>
<td>Full-body safety harness</td>
</tr>
<tr>
<td>Modular</td>
<td>A more significant change in the basic concept, but also with limited impacts on surrounding elements</td>
<td>Post-tensioned concrete</td>
</tr>
<tr>
<td>Architectural</td>
<td>May entail only a small change within a concept, but strongly linked and interactive with other components</td>
<td>Self-compacting concrete</td>
</tr>
<tr>
<td>System</td>
<td>Multiple and linked innovations that must be integrated together and may require significant changes in other components</td>
<td>Pre-fabricated bathroom pods</td>
</tr>
<tr>
<td>Radical</td>
<td>A entirely new approach and causes major changes in the nature of the industry itself</td>
<td>Introduction of structural steel</td>
</tr>
</tbody>
</table>

Table 2-1 - Innovation Typologies (Slaughter, 1998)

Incremental and modular innovation are the most frequent in construction (Koskela & Vrijhoef, 2001) and often originate from within the firm or entity that has control over the relevant components and linkages (Slaughter, 1998). Conversely, radical innovation is
uncommon and more likely to appear from outside an existing industry, often based on scientific or engineering research (Slaughter, 1998).

These distinct processes and outcomes of innovation in construction require different methods and levels of management (Koskela & Vrijhoef, 2001; Slaughter, 1998; Winch, 1998) and are influenced by a range of context specific factors (Blayse & Manley, 2004; Hartmann, 2006a; Tidd, 2001).

2.5 Influencing Factors of Innovation in Construction

The research highlights a number of key factors that influence construction innovation, some of which a firm may be able to directly or indirectly control. Blayse and Manley (2004) identified six primary influences, including: customers and manufacturers, the structure of production, relationships between firms, procurement systems, regulations and standards, and the nature and quality of organisational resources.

Customers of the construction industry play an active and integrated role throughout the project lifecycle and are considered to be highly influential in the delivery of innovation (Barlow, 2000; Gann & Salter, 2000; Kumaraswamy & Dulaimi, 2001; Nam & Tatum, 1997; Seaden & Manseau, 2001). Sustained and long-term relationships between customers, contractors and designers are known to be conducive for innovation (Nam & Tatum, 1997). These types of relationships are often underpinned by a culture of trust, commitment and understanding between parties (Wamuziri & Madan, 2009). There is also much evidence that customers with a broad experience and familiarity with the construction industry often have a positive impact on innovation and its diffusion (Hartmann, 2006a; Nam & Tatum, 1997). Customers often gain this experience through engagement in repeat construction activity and from this develop increased technical knowledge and awareness of the specific challenges embedded in the industry. Customers who not only accept innovation but demand it are often more successful at stimulating innovation (Barlow, 2000) and are considered to have a principal role in promoting innovation in construction (Winch, 1998).

Suppliers provide a source for construction innovation through the provision of innovative products and materials that are incorporated into buildings (Blayse & Manley, 2004). The past 15 years has seen a significant rise in firms externalising functions that would have previously been conducted in-house (Chesbrough, 2003; McIvor et al, 2006). This externalisation often includes NPD, where more frequently firms are entering into cooperative relationships aimed at innovation and the development of new products (Parker, 2000). It is widely accepted that this collaborative approach towards product development reduces both the cost and risk of NPD (Hagedoorn, 1993; McIvor et al, 2006). However the sustainability and viability of an alliance is largely influenced by appropriate partner selection, in particular the extent of technical, strategic and relational alignment (Emden et al, 2006).

The nature and structure of production in the construction industry significantly influences innovation. The one-off nature of projects limits the degree to which a given innovation will be appropriate to other situations and creates challenges in terms of organisational learning (Blayse & Manley, 2004). The product of construction, the built environment, is expected to be highly durable and creates a strong incentive for the use of tried and tested methods. The level of risk and complexity of a given project may also influence the degree of innovation adopted (Tidd, 2001). Traditional approaches towards the management of projects have been
shown to hinder innovation, including the appointment of tightly defined and hierarchical roles (Winch, 2000) and the practice of dividing projects into discrete work packages, which encourages managers to pass risk down the supply chain who are in turn encouraged to employ tried and tested techniques to mitigate risk (Barlow, 2000).

The construction industry frequently relies on temporary coalition of firms and individuals that come together to complete a project before disbanding (Blayse & Manley, 2004). Interaction between these entities during the collaboration often encourages bottom-up innovation (Winch, 1998), where innovations are developed in response to needs or opportunities unique to the project. Where the relationships between these temporary coalitions are stronger and sustained, there is a greater likelihood that learning is codified and applied to future projects, but this is often not the case. Some relief may be afforded through universities, professional institutions and construction research bodies who can provide innovation brokerage to the construction industry; producing and storing knowledge on behalf of the industry (Blayse & Manley, 2004; Findlay, 2009; Gann, 2001).

There are a number of procurement methods available to construction clients, some of which are not well suited to foster project-orientated innovation (Blayse & Manley, 2004). The principal procurement methods, their key characteristics and impact on innovation are summarised in Table 2-2:

<table>
<thead>
<tr>
<th>Procurement Method</th>
<th>Key Characteristics</th>
<th>Impact on Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional single-stage</td>
<td>Design and construction separated</td>
<td>Encourages fragmentation, hierarchy and division of work</td>
</tr>
<tr>
<td></td>
<td>Cost-orientated through competitive, fixed-price tendering</td>
<td>Encourages short-term relationships</td>
</tr>
<tr>
<td></td>
<td>Clear lines of accountability</td>
<td>Slow decision making</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited opportunity for contractor to engage in design</td>
</tr>
<tr>
<td>Two-stage tendering</td>
<td>Integration between design and construction through earlier involvement of contractor</td>
<td>Opportunity for contractor to add value and manage risk at design stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential for greater integration, often countered by sub-contracting strategies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More client involvement</td>
</tr>
<tr>
<td>Fast-track: management contracting</td>
<td>Overlapping design and construction stages</td>
<td>Allows greater flexibility for change</td>
</tr>
<tr>
<td></td>
<td>Popular for large or complex projects</td>
<td>Scope for value management and engineering</td>
</tr>
<tr>
<td></td>
<td>Complex approach requiring the management of a large number of contractors</td>
<td>Complex contractual relations and assignment of liability often leads to adversarial relationships</td>
</tr>
<tr>
<td>Fast-track: construction management</td>
<td>Contractor acts as an impartial client agent controlling all aspects of the project</td>
<td>Allows considerable flexibility</td>
</tr>
<tr>
<td></td>
<td>Requires experienced client</td>
<td>Scope for value management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Promotes longer-term relationships</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Allows full involvement of client</td>
</tr>
<tr>
<td>Design and build</td>
<td>Single point of responsibility for design and build</td>
<td>Encourages the use of tried and tested solutions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Competition of product as well as price</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Expensive tender process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential for long-term relationships</td>
</tr>
</tbody>
</table>

Table 2-2 - Procurement Methods and Innovation (Saad & Jones, 2003)
Government regulatory policies aimed at assuring the integrity and performance of the built environment can exert a strong influence on innovation and the direction of technological change (Gann et al, 1998). In the past, the construction industry has been subject to prescriptive regulations that specify the materials, configurations, and processes required to achieve a desired regulatory goal (Gann et al, 1998). More recently, there has been a shift towards performance-based regulations that specify the desired regulatory goal but not how it should be met, and are thought to promote innovation more than prescriptive methods (Gann et al, 1998; Winch, 1998). High performance standards create the demand necessary to force the industry to codify existing technologies and develop new ones in order to comply (Gann et al, 1998). A good example of this in action can be seen in the positive response from the construction industry to meet the carbon challenge.

There are a number of key factors internal to the construction firm that influence innovation, including the organisational climate for innovation (Hartmann, 2006b; Nam & Tatum, 1997), skills and capabilities of workforce, availability of resources (Hartmann, 2006a; Seaden et al, 2003), top level commitment (Dulaimi et al, 2005; Nam & Tatum, 1997; Winch, 1998), processes to facilitate and integrate innovation (Gann & Salter, 2000) and company strategy (Blayse & Manley; 2004; Stewart & Fenn, 2005). The control and capitalisation of this particular set of factors is within the remit of a firm and is central to the management of innovation, and therefore this research project.

Further research has been widely called for to explore the nature of relationships between innovation influences, and also the interaction of innovation influences with other aspects of business strategy and environment (Blayse & Manley, 2004; Dulaimi et al, 2005; Hartmann, 2006a; Reichstein et al, 2005; Seaden et al, 2003). Some of the initial work required in order to address this gap has formed an important element of this research project.

2.6 Innovation Performance of the Construction Industry

The construction industry is widely perceived to be a low innovation sector (NESTA, 2007). A number of major reports have criticised the industry as being highly conservative and risk averse, with its innovation performance undermined by short-termism, adversarial relationships and project orientated nature (Egan, 1998; Fairclough; 2002; Latham, 1994). This reputation is supported by traditional measures of innovation, such as R&D expenditure. During 2008 the UK construction industry invested just 0.4 per cent of sales in R&D (BERR, 2008). Investment is consistently less than any other sector and in absolute terms has fallen by 80 per cent since 1981 (Egan, 1998).

However, recent studies suggest that these traditional measures of innovation fail to acknowledge that different sectors achieve innovation in different ways and as a result are unsuitable for measuring the innovation output from construction firms (Dodgson et al, 2005; NESTA, 2007; Ozorhon et al, 2010). In particular, it is claimed that these measures fail to capture bottom-up innovation, referred to by NESTA (2007) as hidden innovation. Indeed, construction industry key performance indicators (KPIs) show that the industry has continued to produce annual performance improvements, revealing the partial impact of this hidden innovation (NESTA, 2007).

The problem is not that there has been no innovation, but that the rate of innovation is not satisfactory, lagging behind that of most other industry sectors (Drejer & Vinding, 2006;
Reichstein et al, 2005; Winch, 1998;). Without doubt, there is much room for improvement (Blayse & Manley, 2004; Nam & Tatum, 1997; Slaughter, 1998). There are real indications that enthusiasm and commitment to top-down processes of innovation via pre-competitive networks and collaborative research are in decline (Findlay, 2009), and that firms continue to fail to realise the full potential of bottom-up innovation due to lack of effective management and integration of processes (Acha et al, 2005; Ozorhon et al, 2009).

2.7 The Management of Innovation in the Construction Firm

The management of innovation comprises all of the activities which aim to successfully exploit ideas (Drejer, 2002) and the capitalisation and reinforcement of the capability and willingness of a firm to innovate (Hartmann, 2006a). It is the discipline of effectively and efficiently managing the top-down and bottom-up processes of innovation and the associated factors which are known to influence them.

Several decades of research on the management of innovation has created many useful insights, but has been based on a broad range of industries and therefore has adopted different methods, definitions and samples (Tidd, 2001). In particular, there is a large and growing body of research concerning the management of innovation in the manufacturing industry, where the highly linear innovation process lends itself to detailed analysis and refinement (Slaughter, 1998). Unfortunately, the management of innovation in construction has received far less attention from researchers and more work has been called for (Gann & Salter, 2000; Hartmann, 2006a, Ozorhon et al, 2009). There is a growing need for this work and the practical guidance it will generate, as the number of construction firms seeking to manage innovation in a more strategic and conscientious manner continues to increase (Hartmann, 2006a; Reichstein et al, 2008).

However, research has shown that there is unlikely to be one best way to manage and organise innovation in the construction firm; the different processes and outcomes of innovation will need to be managed in different ways (Slaughter, 1998; Tidd, 2001; Winch, 1998). Construction firms seeking to manage innovation more effectively will need to consider how to simultaneously support both top-down and bottom-up processes, which is unlikely to be achieved through the application of a single, one-size fits all, solution (Acha et al, 2005).

It is also prudent to acknowledge other existing management practices and interventions which can influence and bring about innovation in the construction firm, although application is not necessarily consistent or widespread in the construction industry. The more prevalent practices and interventions identified in the literature include R&D, participation in improvement networks, and application of value management and knowledge management.

According to the OECD (2008), R&D refers to creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. Some construction firms use formal R&D to achieve innovation. R&D is more likely to be observed in larger firms, who will collaborative with research communities and do so on a regular basis in order to achieve their R&D objectives (Findlay, 2009). Collaborative research is designed to assist the industrial and research communities to work together on R&D projects in strategically important areas of science, engineering and technology with the aim of delivering successful
new products, processes and services (TSB, 2010). This approach has a number of significant benefits, including distribution of risk and investment between members, improved access to people and knowledge, alignment with larger UK and EU strategic agendas, and reinforced relationships (Gann, 2001). Despite the immediate benefits of collaborative R&D there is a need to reinvigorate pre-competitive collaborative research in the construction industry (Findlay, 2009). It is widely perceived that contribution and commitment to collaborative research is in decline (BERR, 2008; CIOB, 2007). There are many small and medium size firms, along with some larger firms, that do not invest at all (CIOB, 2007).

Improvement networks provide member organisations the opportunity to access and diffuse innovation, best practice and knowledge. It is one of the available channels that innovation may permeate between firms and drive improvement at the industry level. Improvement networks also present an opportunity to build stronger collaborative relationships and, in some cases, to influence the regulatory environment and strategic research agendas at a national level (Gann, 2001). There are a number of well established improvement networks for the UK construction industry, such as those offered by Constructing Excellence, the UK Contractors Group, and the British Quality Foundation to name a few. To deliver on this potential, firms need to attract and retain highly trained industrial practitioners with the ability and skills to engage in, access and absorb the results of academic research in an environment of like-minded practitioner-researchers (Gann, 2001). However, there is evidence of some major UK contractors either not wanting to or knowing how to use these highly trained people (Findlay, 2009), which could limit the potential of both improvement networks and collaborative R&D in the construction industry.

Value management is a well defined methodology for defining and maximising value. The concept of value is based on the relationship between function and cost. The aim of value management is to resolve the wants and needs of stakeholders and to achieve the optimal balance between function and resources (IVM, 2010). It is based on principles of defining and adding measurable value by focusing on objectives before solutions and concentrating on function to bring about innovation (IVM, 2010). Value management incorporates value engineering, which is a continuous process in which all the components and processes involved in construction are examined to determine whether better value alternatives or new solutions are available, without detriment to quality, performance or reliability (OGC, 2007a). Value engineering usually takes place in the early design stages of a project and involves multiple stakeholders in a series of facilitated workshop sessions that centre on function analysis and encourage participation, team-working and end-user buy-in (OGC, 2007a). A series of case studies which investigated the benefits of value management in construction reveals creative solutions and innovation as one of the key benefits of the approach (OGC, 2007b).

Knowledge management relates to unlocking and leveraging different types of knowledge to make it available as an organisational asset (Robinson et al, 2005). Knowledge Management has been defined as the process of capturing, distributing and effectively utilising knowledge (Davenport & Prusak, 1998). There are a number of well documented tools and technologies to support knowledge management in construction (Carrillo, 2005). It is through effective knowledge management that innovation, regardless of its origin, may be codified and exploited by a firm. Practitioner research and problem solving solutions originating from projects need to be captured by the firm and shared with future projects (Winch, 1998). Likewise, innovation originating from collaborations, competitors or other industry sectors
Improving Innovation Management in Construction

requires successful acquisition and implementation by the firm (Winch, 1998). Indeed, the importance of knowledge management to a construction firm in improving its ability to innovate has meant that UK construction firms have become increasingly interested in implementing various knowledge management solutions (Robinson et al, 2005).

However, on the basis that the innovation performance of the construction industry has been shown to provide much room for improvement (Blayse & Manley, 2004; Nam & Tatum, 1997; Slaughter, 1998) it is asserted that these existing practices and interventions have not fully addressed the innovation management needs of the typical construction firm (Reichstein et al, 2005).

2.8 Opportunities for Improved Management of Innovation

The concept of actively and conscientiously managing innovation is relatively new in construction; the call for the industry to deliver more innovation and details of the benefits that will result are not so new.

The literature consistently highlights the importance of innovation for the construction firm, including the need to establish a deeper understanding of its processes and develop better approaches for its measurement and management. In particular, research needs to address:

- The lack of understanding of the factors that influence innovation and their relationships in the construction context (Winch, 1998), and from this the development of a conceptual model for understanding the sources and determinants of innovation performance in construction (Blayse & Manley, 2004; Hartmann, 2006a; Reichstein et al, 2005);

- The inappropriate measures of innovation that fail to capture the process of innovation in construction (NESTA, 2007). New methods of innovation measurement should incorporate both input and output indicators (Davila et al, 2006; Ozorhon et al, 2010);

- The poor integration of internal processes to support top-down and bottom-up innovation (Gann & Salter, 2000). There is a need to establish a strategic and systematic approach for developing, implementing, monitoring and sustaining innovation (Saad & Jones, 2003);

- The opportunity to make better use of key individuals or champions to promote and diffuse innovation within the firm, including appropriate selection, training and development (Dulaimi et al, 2005);

- The need to increase awareness and acceptance of the terminology of innovation in the construction industry (Findlay, 2009);

- The development and implementation of tools that can help engender, monitor and sustain organisational climates that are supportive of innovation (Findlay, 2009; Saad & Jones, 2003);

- The lack of exploitation of external support and integration (Reichstein et al, 2005; Saad & Jones, 2003), especially the role of suppliers and customers (Blayse & Manley, 2004; Ozorhon, 2009);

- The need to reinvigorate a network of senior executives to act as a focus for pre-competitive collaborative work (Findlay, 2009).
2.9 Summary

This chapter has presented the findings from an extensive literature review on the subject of innovation in construction. Innovation has been defined as the successful exploitation of ideas, and is at once a process and an outcome. It is essential for the industry and the wider economy; defining the way in which firms can provide added value and increased efficiencies. Innovation is achieved in the construction firm via two processes; a top-down process of innovation adoption and implementation, and a bottom-up process of problem solving and learning. An innovation may take many different forms, including incremental, modular, architectural, system and radical; all of which require management in different ways. The ability of a firm to innovate is influenced by a number of factors, including customers, manufacturers, the structure of production, relationships between firms, procurement methods, regulations and the nature and quality of organisational resources. The construction industry is widely considered to be a low innovation sector, but traditional measures of innovation fail to capture the type of innovation that prevails in the sector. Nonetheless, the consensus is that there is still much room for improvement. Some firms may utilise existing management practices and interventions which can influence and bring about innovation, such as R&D, improvement networks, value engineering and knowledge management, but these alone do not adequately address the innovation management needs of the construction firm. The industry remains relatively immature in terms of both its understanding and its ability to actively manage innovation. Practical guidance and new/improved approaches, tools and techniques to meet this need have been widely called for.
3 RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this chapter is to present the research methodology and methods applied, and explain the rational behind the chosen path. First, the methodological considerations are discussed, before the selected methodology for the project is described and justified. Finally, the different methods used during the course of the project are highlighted.

3.2 Methodological Considerations

It is important to highlight the ontological and epistemological assumptions that are held by the researcher and underpin the project, as they are central to the selection of an appropriate research methodology (Easterby-Smith et al, 2002) and interpretation of its outcomes (Crotty, 2003).

3.2.1 Ontology

Ontology refers to the assumptions that are made about the nature of reality (Easterby-Smith et al, 2002), and can be assessed along a fairly arbitrary continuum moving from a realist (objectivist) to a relativist (subjectivist) perspective (Coghlan & Brannick, 2005). At one extreme is the realist view that assumes that the world is concrete and external, and which exists independently of an individual’s cognition (Coghlan & Brannick, 2005). At the other extreme is the relativist view that assumes that multiple realities exist as subjective constructions of the mind (Easterby-Smith et al, 2002). A more recent variant of the realist position is the idea of critical realism, which makes a conscious compromise between the extreme positions and takes the view that there is a reality which exists independently of our experience, but acknowledges that discourse shapes reality, and is in turn shaped by it (Coghlan & Brannick, 2005; Easterby-Smith et al, 2002). The ontology held by the RE, and therefore that underpins this research, is from the perspective of critical realism.

3.2.2 Epistemology

Epistemology refers to the assumptions that are held regarding the best ways of inquiring into the nature of the world (Easterby-Smith et al, 2002). Creswell (2009) presents four different epistemologies and the main elements of each position, see Table 3-1.

<table>
<thead>
<tr>
<th>Positivism</th>
<th>Constructivism &amp; Interpretivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determination</td>
<td>Understanding</td>
</tr>
<tr>
<td>Reductionism</td>
<td>Multiple participant meanings</td>
</tr>
<tr>
<td>Empirical observation &amp; measurement</td>
<td>Social &amp; historical construction</td>
</tr>
<tr>
<td>Theory verification</td>
<td>Theory generation</td>
</tr>
<tr>
<td>Advocacy/Participatory</td>
<td>Pragmatism</td>
</tr>
<tr>
<td>Political</td>
<td>Consequences of actions</td>
</tr>
<tr>
<td>Empowerment issue-orientated</td>
<td>Problem-centred</td>
</tr>
<tr>
<td>Collaborative</td>
<td>Pluralistic</td>
</tr>
<tr>
<td>Change-oriented</td>
<td>Real-world practice oriented</td>
</tr>
</tbody>
</table>

Table 3-1 - Four Epistemologies (Creswell, 2009)
The epistemology that underpins this research is from the pragmatic standpoint. Pragmatism arises out of actions, situations and consequences rather than antecedent conditions and is concerned with application and problem solving (Creswell, 2009). Pragmatists are classically not committed to any one system of philosophy and reality, do not see the world as an absolute unity and look to many approaches for collecting and analysing data, rather than subscribing to only one way, in order to deal effectively with the full richness of a real world problem (Creswell, 2009).

3.2.3 Other Considerations

There were also context specific requirements that would influence the research design. A core element of the EngD is ‘the solution of one or more significant and challenging engineering problems with an industrial context. Thus the solution of the problem will have to take factors such as financial constraints, timescales and personnel management into account’ (CICE, 2010). This pre-requisite called for an approach to the research which would reflect the dynamic and commercial nature of the business environment and be able to accommodate some degree of flexibility to tolerate any changes that may emerge in the sponsoring company and its needs.

It was also a requirement that the project had ‘to make a significant contribution to the performance of the company and thus has to be in the mainstream, not a 'student' project on the sidelines’ (CICE, 2010). It was therefore considered imperative that the aim and objectives of the project were fully aligned with the aspirations of the sponsor, and that the project would need to adopt a more applied approach to the research, as opposed to a theoretical one, to ensure that outputs could be successfully implemented and evaluated within the four year timescale of the project. This required the project to be divided up into a number of smaller sub-projects that could be turned around quickly and demonstrate change and improvement within the sponsor more effectively.

3.3 Available Research Methodologies

Research can be defined as the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions (Oxford Dictionary, 2010). Essential to achieving this systematic investigation is the selection and application of suitable research methodologies and methods, of which there are many options.

A research methodology can be considered as the strategy, plan, process or design lying behind the choice and use of particular methods and linking the choice of methods to the desired outcomes (Crotty, 2003). Others have called them approaches to inquiry (Creswell, 2009) or research styles (Fellows & Lui, 2003). It provides the researcher with a systematic route to follow, starting with an initial set of objectives and finishing with a set of conclusions, and will most likely incorporate a number of major steps including the collection and analysis of relevant data (Naoum, 1998). Some of the more commonly encountered methodologies include action, case study, ethnographic, experimental and survey research (Crotty, 2003; Fellows & Liu, 2003):

Action research involves active participation in the process under study in order to identify, promote and evaluate problems and potential solutions (Fellows & Liu, 2003). Action
research can include all types of data gathering methods, with the aim of simultaneously solving a problem and contributing to knowledge (Coghlan & Brannick, 2005).

*Case study research* is an empirical inquiry that investigates a contemporary phenomenon in its real life environment (Yin, 1984). Cases are bounded by time and activity, and researchers collect information using a variety of research methods over a sustained period of time (Creswell, 2009).

*Ethnographic research* is the study of a group or culture and demands less intrusive involvement by the researcher, who becomes part of the group under study and observes behaviours to gain insight into what, how and why their patterns of behaviour occur (Fellows & Liu, 2003). Principal research methods include observation and interview (Creswell, 2009). This methodology focuses attention on determining meanings and the processes through which the members of the group make the world meaningful (Fellows & Liu, 2003).

*Experimental research* seeks to determine if a specific treatment influences an outcome (Creswell, 2009). This methodology is generally thought to be better suited to bounded problems in which the variables are known with some degree of certainty (Fellows & Liu, 2003). These experiments are usually carried out in controlled environments and require a high degree of control of the variables (Fellows & Liu, 2003).

*Survey research* primarily operates on the basis of statistical sampling, where the sample is surveyed through questionnaires or interviews (Fellows & Liu, 2003). It includes cross-sectional and longitudinal studies using questionnaires or interviews (Creswell, 2009), which may range from highly structured to unstructured depending on the research requirements (Fellows & Liu, 2003).

These methodologies were all reviewed for their suitability to facilitate the project aim and compatibility with the methodological considerations outlined in section 3.2. As a result of this review, *action research* was deemed the most appropriate methodology to meet the needs of the project. The following section presents the justification for this decision.

### 3.4 Adopted Methodology and Justification

Action research has been traditionally defined as *an approach to research which is based on a collaborative problem-solving relationship between researcher and client which aims at both solving a problem and generating new knowledge* (Coghlan & Brannick, 2005). It starts from the idea that if you want to understand something well you should try changing it (Easterby-Smith et al, 2002). This is achieved through a cyclic process of diagnosing, planning action, taking action and evaluating the action (Coghlan & Brannick, 2005).

The fundamental aims of action research (solve a problem and generate new knowledge) are matched to the requirements of the project; *the need to address a complex problem with an industry context whilst contributing to the body of knowledge* (CICE, 2010). Furthermore, the cyclic process of action research can be mapped directly against the research objectives, as shown in Figure 3-1, indicating the synergy between the research methodology and aim.
In addition, the cyclical nature of the action research process provided the flexibility required to accommodate the dynamic and commercial setting for the research and supported the necessity to divide the project into smaller sub-projects, where each complete cycle would result in the delivery of a sub-project. This was important to assist the RE demonstrate change and improvement in the sponsor within the four year timescale. This reflective process of progressive problem solving also enabled the RE to systematically build upon the problem solution and move towards a more holistic understanding, a key characteristic of action research (Coghlan & Brannick, 2005).

Action research is interactive and requires a collaborative approach, involving the participation of others involved in the process being studied (Coghlan & Brannick, 2005). It was anticipated that this highly collaborative approach would ease the implementation of problem solutions and assist the adoption of change, which would be key to enabling the project to make a significant contribution to the performance of the sponsoring company. Finally, the action research methodology follows a realist (objectivist) ontology and relativist (subjectivist) epistemology (Coghlan & Brannick, 2005). This is therefore compatible with the philosophical assumptions held by the RE (discussed in section 3.2) and also the level of involvement expected of the RE, see Figure 3-2.
3.5 Research Methods

*Research methods* are the techniques or procedures used to gather and analyse data related to some research question or hypothesis (Crotty, 2003). An action research methodology advocates the use of multiple research methods within a single study (Coghlan & Brannick, 2005). Various quantitative and qualitative methods are seen as having a beneficial contribution to make at different stages in the action research process and the use of mixed methods serves to reduce or eliminate the disadvantages of each individual approach whilst maintaining the advantages (Fellows & Liu, 2003). The rest of this section provides an overview of the methods applied.

3.5.1 Literature Review

Conducting a literature review reveals previous and parallel research efforts associated with the research subject and is an essential stage of any research project (Fellows & Liu, 2003). It provides the researcher with a foundation from which progress may be achieved and serves to:

- Assist in the determination and refinement of research aims and objectives;
- Highlight previous research, including common themes and disagreements;
- Reveal gaps in previous research and areas for further research (Fellows & Liu, 2003).
For this project a general literature review was conducted at the start of the project and was further supplemented with additional material throughout the project to address the specific needs of the sub-projects. The initial literature review examined the needs and benefits of innovation in construction, including an investigation of the factors which influence innovation performance, and the current approaches for the management of innovation in construction (see chapter 2 for an overview). This helped identify the gaps in innovation management research and provided some direction for the proposed solutions for supporting objective one. The additional reviews were concerned with innovation processes, organisational climates for innovation and measurement and are embedded in the published papers (see appendix).

3.5.2 Focus Groups

A focus group is a discussion based interview involving several participants and a moderator, whose role is to facilitate the discussion (Brewerton & Millward, 2001). They consist of a planned series of discussions with the aim of getting closer to the participants’ understanding and perspectives on a defined area of interest (Brewerton & Millward, 2001). The group dynamics of well conducted focus groups can encourage participants to raise important issues which may otherwise remain undisclosed and also reveal the joint construction of meaning (Brewerton & Millward, 2001).

In this research project the focus groups provided an important method to gain collaborative input from groups within the sponsoring company, enrich and validate data, and disseminate the research findings into the sponsoring company. A series of focus groups were conducted in order to better understand the current conditions for innovation within the sponsor highlighting any opportunities for improvement, these were then followed by a second set to evaluate the solutions implemented, supporting objective three.

3.5.3 Survey

A survey is a procedure in which information is collected systematically from a defined population. The primary aim is to construct a data set for analysis from which estimates can be made and conclusions reached about this population (Fellows & Liu, 2003). A survey can be conducted via interviews or questionnaires and can be structured, semi-structured or unstructured depending upon the specific needs of the research (Fellows & Liu, 2003). In the case of this research project, both interviews and questionnaires have been used.

In-depth interviews provide a suitable medium for obtaining rich, qualitative data. A number of semi-structured interviews were conducted during the project to triangulate with observations and findings from other research methods, including focus groups and surveys. The semi-structured interviews enabled the RE to explore specific issues in more detail in a controlled manner, but allowed some flexibility so that any new and unforeseen issues could be explored. Interviewees included Company Directors, Project Managers, Bid Managers, Design Managers, Engineers, and Graduate Engineers working for the sponsoring company, along with key customers and Innovation Management practitioners from outside the sponsor. Transcribing verbatim was ruled out as the purpose of the interviews was not as a detailed word by word analysis, but to capture key messages and indentify trends.

Questionnaires provide a means to collect the views from a large number of distributed respondents and be subject to both qualitative and quantitative data analysis (Fellows & Liu,


2003). A disadvantage of this approach is the reliance on respondents to be accurate and honest in their responses and there is minimal interaction with the researcher and therefore little assistance can be provided (Brewerton & Millward, 2001).

Nonetheless, online questionnaires provided a valuable method to solicit the views of the wider population and data was enriched and reinforced with feedback from interviews and focus group sessions. The questionnaires used within this project included both open and closed question formats and required the application of both thematic and statistical analysis to interpret the results. Questionnaires have been administered at regular intervals during the project as a principal means to monitor the perceived performance of the sponsor in terms of managing innovation supporting objectives one and three.

### 3.5.4 Thematic Analysis

Thematic analysis is a process of reducing qualitative data into meaningful groupings which is primarily concerned with the identification of patterns within the data (Naoum, 1998). Key points raised within interviews, questionnaires and focus groups are identified and collated in a thematic grid, consisting of a spreadsheet (Naoum, 1998). This facilitates the identification of repeated words or statements and can be used to categorise and extract themes from the data (Naoum, 1998). This method was used to analyse data from focus groups and open ended questions from the questionnaires enabling the RE to build up a richer understanding of the subject.

### 3.5.5 Statistical Analysis

Statistical analysis is concerned with the interpretation of data, usually in numerical format, in order to summarise and describe a collection of data (descriptive statistics) or to draw conclusions about the process or population being studied by investigating patterns in the data whilst accounting for randomness and uncertainty in the observations (inferential statistics).

Descriptive statistics were used to summarise data from the questionnaires, including means and standard deviations for continuous data types and frequencies and percentages for categorical data types. Another common goal for a statistical analysis is to investigate causality and in particular to draw a conclusion on the effect of changes in the values of explanatory on dependent variables using inferential statistics (Fellows & Liu, 2003). In this project both factor analysis and path analysis were applied to explore causal relationships between variables measured within the questionnaires.

Principal component factor analysis (PCA) was used to examine any underlying dimensions and to determine whether the data could be reduced (by combing variables into summated scales). Path analysis, a simple extension of hierarchical multiple regression, aims to provide estimates of the magnitude and significance of causal relationships between sets of variables in a model (Pedhazur, 1982). Data was extracted from the web-based questionnaires and input into a statistical software package, SPSS, which was used to perform the above tests.

The need for a deeper understanding and analysis of the influencing factors of innovation using statistical techniques is a theme echoed in the literature (Blayse & Manley, 2004; Dulaimi et al, 2005; Hartmann, 2006a; Reichstein et al, 2005; Seaden et al, 2003). The application of these methods provided the RE with a novel insight into the significance and relationships between the influencing factors of innovation identified during the literature
Improving Innovation Management in Construction

review and interviews. This would also serve to provide a valuable source of information for informing and justifying the interventions arising from objective two.

3.5.6 Triangulation

Validation of the research findings was an important process and was achieved for this study by combining research methods in an approach based on the principals of triangulation. Triangulation represents the process of converging upon a particular finding by using different types of data and data gathering techniques to cross-check the research findings, ensuring internal, external and construct validity (Fellows & Liu, 2003). Triangulation was undertaken in this project by comparing the survey and focus group findings against those reported within the literature. Combining research methods and associated data added depth, reliability and validity of the research findings, which in turn enabled accurate conclusions and recommendations to be drawn. Figure 3-3 shows at what stages of the project the various methods were applied.

<table>
<thead>
<tr>
<th>Action research stage</th>
<th>Research questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosing and planning action</td>
<td>What is state of the art in innovation management?</td>
</tr>
<tr>
<td></td>
<td>How does the sponsor approach innovation management?</td>
</tr>
<tr>
<td></td>
<td>How does the sponsor perform in terms of innovation?</td>
</tr>
<tr>
<td>Taking action</td>
<td>How can we improve support for top-down innovation?</td>
</tr>
<tr>
<td></td>
<td>How can we improve support for bottom-up innovation?</td>
</tr>
<tr>
<td>Evaluating the action</td>
<td>What is the intervention impact on innovation performance?</td>
</tr>
<tr>
<td></td>
<td>What are the conclusions/implications for industry?</td>
</tr>
</tbody>
</table>

Figure 3-3 - Summary of Research Methods

3.6 Summary

The key methodological considerations, including the need to work within a dynamic and commercial industry environment, solve a complex and significant industry problem, and to deliver a performance improvement within the four year timeframe of the project are described. The ontological assumptions (critical realism) and epistemological assumptions
(pragmatism) held by the RE are outlined and linked to the methodology. The adoption of an action research methodology, which involves a collaborative approach towards a process of problem solving to bring about change in organisations and add to scientific knowledge, is described and justified in advance of the description of each of the various research methods employed to gather and analyse data.
4 RESEARCH UNDERTAKEN

4.1 Introduction

This chapter describes the research undertaken to meet the aims and objectives of the project, as set out in section 1.4, and conducted in accordance with the research methodology presented in Chapter 3. A research development map is provided to illustrate the various activities that took place to meet the objectives and the sequence in which these occurred. Each activity is then described in turn and, where applicable, the reader is requested to refer to the appended papers for further detail.

4.2 Taught Element

To fulfil the requirements of the taught element of the EngD the RE selected and completed a number of post-graduate modules at Loughborough University during the first two years of the project. The modules completed included; Research & Communication, Lean Construction, Management & Professional Development, Teamwork & Leadership, Strategic Management in Construction, Management of Innovation, Lean & Agile Manufacturing, and Strategy & Leading Change. These modules were carefully selected to align with the needs of the RE and to assist in the acquisition of knowledge, tools, techniques and contacts of benefit to the project. This encouraged the RE to participate in modules delivered from a range of departments, including Civil & Building Engineering, Information Science, Mechanical & Manufacturing Engineering and the Business School.

The RE also enrolled on a number of additional courses to meet specific needs during the project and attended a range of academic and industrial seminars in order to keep pace with the latest developments and thinking in the field of innovation management.

4.3 Research Development Map

The main research activities and papers published during the four year project are shown in Figure 4-1.
The research development map shows how the research project comprises of two action research cycles, as defined in the research methodology. Both cycles had durations of approximately two years, with a period of reflection occurring in-between the cycles. The timing of the acquisition and merger of the sponsor was opportune, occurring at the start of the second action research cycle. This enabled the RE to conduct another complete iteration of the research methodology and deliver solutions that were appropriate for the new business and changing market, whilst ensuring that these complemented those already developed and adopted from the first cycle, culminating in a more holistic set of solutions. The rest of this chapter is structured according to these two cycles and the various activities that they included.

### 4.4 First Research Cycle

The four year project commenced with a brief period of general investigation, learning and participation in a variety of internal business activities. This provided the RE with the opportunity to:

- Adjust to a new working environment;
- Develop an appreciation of the sponsor’s culture, ethics and background;
- Establish relationships with key stakeholders of the project;
- Understand the sponsor’s need for the research;
- Become familiarised with the sponsor’s processes and procedures.

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**Figure 4-1 - Research Development Map**

The research development map shows how the research project comprises of two action research cycles, as defined in the research methodology. Both cycles had durations of approximately two years, with a period of reflection occurring in-between the cycles. The timing of the acquisition and merger of the sponsor was opportune, occurring at the start of the second action research cycle. This enabled the RE to conduct another complete iteration of the research methodology and deliver solutions that were appropriate for the new business and changing market, whilst ensuring that these complemented those already developed and adopted from the first cycle, culminating in a more holistic set of solutions. The rest of this chapter is structured according to these two cycles and the various activities that they included.

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- Understand the sponsor’s need for the research;
- Become familiarised with the sponsor’s processes and procedures.
Most importantly, this period served to set the foundations for the action research methodology, which is underpinned by collaborative participation and active engagement between the RE and sponsor, as described in section 3.3.

It was also during this prelude that the RE joined the sponsor’s Capability & Performance (C&P) steering group. This group comprised of directors, senior managers and technical experts from across the sponsor, and had the main task of increasing the capability and performance of the firm through a range of initiatives under the leadership of the Director of Capability & Performance. The RE’s role within this group was intentionally aligned with the EngD project and was concerned with the innovation performance of the firm. This group provided a forum in which the RE could:

- Report on progress;
- Receive strategic feedback;
- Influence and participate in decisions;
- Use as a platform for implementing interventions arising from the research, actively engaging the sponsor in the project.

4.4.1 Diagnosing & Planning Action – Objective 1

In order to achieve the first objective the RE needed to; 1) determine the pre-intervention state of innovation management and performance; 2) diagnose areas for improvement; and 3) develop a plan of action for improvement. A literature review was also conducted to ascertain current theory and practice for the management of innovation in construction (see chapter 2), revealing an emergent field of research with limited practical guidance for practitioners.

The pre-intervention state was determined through the combination of assessing existing activities that facilitate innovation within the sponsoring company, gathering employee feedback on general performance and conditions for innovation, and finally a triangulation exercise with the literature. The assessment of existing activities was conducted using a variety of methods, including a desk study (based on extensive review of documentation and process maps published on the company intranet), semi-structured interviews with senior managers and attendance at C&P steering group meetings. A list of the activities that were identified from the desk study and interviews is provided in Table 4-1.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviours programme</td>
<td>A corporate behavioural change programme initiated during the early stages of the project. This aimed to promote a number of desired behaviours across the business through a series of company wide road shows, performance reviews, posters and a DVD.</td>
</tr>
<tr>
<td>Case studies</td>
<td>The sponsor occasionally documented specific project innovations and related benefits in the form of short reports, made available on the intranet. Only a small number of these reports existed and the quality of the content varied. Sometimes used to provide material for tender documents.</td>
</tr>
<tr>
<td>Collaborative R&amp;D</td>
<td>The sponsor frequently partnered with other firms and Universities to conduct research projects at both UK and European levels, often focused on ICT and off site manufacturing. Limited evidence of implementation on projects, with a few exceptions (e.g. AVANTI). Dedicated budget allocated on annual basis.</td>
</tr>
<tr>
<td>Customer heartbeats</td>
<td>A formal customer feedback process, which was carried out on all projects and on a regular basis. A semi-structured interview approach was used to capture feedback and scoring on a range of predetermined criteria, plus provided opportunity for general feedback. Innovation performance often discussed.</td>
</tr>
<tr>
<td>Activity</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Design Managers forum</td>
<td>An annual forum for Design Managers to network, share best practice and explore new ideas. Usually incorporated presentations and debates led by different members and on occasions included a site visit/tour led by the respective Design Manager.</td>
</tr>
<tr>
<td>Extranets</td>
<td>4Projects extranet was the preferred collaboration tool for project teams. Most teams used the extranet to manage drawings and documents. More advance users enabled additional features and used the tool to comment/mark up drawings and facilitate discussions, supporting problem solving and new ideas.</td>
</tr>
<tr>
<td>Graduate programme</td>
<td>Structured two year training programme for graduates joining the sponsor. Course comprised of a series of six modules and aimed to equip delegates with knowledge and skills for managerial roles in the sponsor, introducing management theory, tools and techniques and tasking delegates with personal development assignments.</td>
</tr>
<tr>
<td>Improvement networks</td>
<td>The sponsor was involved in a number of improvement networks, with the aim of discussing problems and sharing best practice. These networks included the British Quality Foundation, Constructing Excellence and the UK Contractors Group.</td>
</tr>
<tr>
<td>Knowledge Management database</td>
<td>The sponsor had developed a database of lessons learnt and technical top-tips, usually captured by the Knowledge Manager during project visits or extracted from contract review documentation. The database was hoped to provide a potential means of diffusing innovation between projects and the firm.</td>
</tr>
<tr>
<td>Knowledge Management Wiki</td>
<td>A relatively short lived project which provided employees with a wiki to share and discuss ideas, problems and best practice. After initial interest from employees, participation declined and eventually the wiki was closed down. This occurred before the EngD project had commenced.</td>
</tr>
<tr>
<td>Performance reviews</td>
<td>Annual meeting between employee and manager to review performance and discuss personal objectives. The subject of innovation should be discussed, including identification of contributions made and potential opportunities for future innovation, specific to the individual’s role/objectives.</td>
</tr>
<tr>
<td>Project close-out reviews</td>
<td>A formal meeting with structured agenda that occurs at project close out stage. Led by Operations Directors, with Project Manager and team. Feedback captured in a report and made available online. Report includes section on lessons learnt and innovation, but often incomplete or vague.</td>
</tr>
<tr>
<td>Project Managers forum</td>
<td>An annual forum for project managers to network, share best practice and explore new ideas. Usually incorporated presentations and debates led by different members and sometimes the introduction of new processes and procedures. Widely considered to be a valuable activity by all.</td>
</tr>
<tr>
<td>Red team reviews</td>
<td>A special tender review process for high value/risk tender opportunities. In addition to the usual tender panel review, a secondary ‘red team’ would be tasked to really challenge the bid and explore alternative options in parallel to the standard process. Red teams often comprised of technical experts.</td>
</tr>
<tr>
<td>Staff induction</td>
<td>Staff induction included a standard presentation, which highlighted desired company behaviours and examples of some of the sponsor’s innovations. New staff were welcome to share ideas and experiences from previous employment during the induction process.</td>
</tr>
<tr>
<td>Team meetings</td>
<td>Team meetings often provided a good forum to critically evaluate working practices and share/develop ideas. Project teams were known to regularly hold meetings, whereas this was less commonly observed in functional teams based at regional and head offices.</td>
</tr>
<tr>
<td>Technology Centre helpline</td>
<td>The helpline provided project teams direct access to an internal team of consultants, engineers and scientists based at the sponsor’s Technology Centre. Queries would be directed to the most appropriate expert and advice would be given on all manner of subjects. Frequently used for trouble shooting.</td>
</tr>
<tr>
<td>Training &amp; development courses</td>
<td>All employees were required to identify training and development needs during performance reviews. A selection of courses (often external) were available to all employees and advertised on the intranet, some of which focused on developing skills for creative problem solving and managing change.</td>
</tr>
<tr>
<td>Activity</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Value engineering</td>
<td>The Technology Centre occasionally facilitated Value Engineering workshops and its application was recommended in the tender process. Some guidance documentation was also available on the intranet. Senior Managers reported some evidence of application and results, but not entirely widespread and consistent.</td>
</tr>
</tbody>
</table>

Table 4-1 - Pre-intervention Activities Supporting Innovation

In order to examine an example of an initial innovation within the sponsor and identify the challenges encountered by those involved the RE facilitated a group workshop with the Building Information Modelling Team, who had introduced a 4D construction modelling service to their portfolio. The principal aim of this group workshop was to identify the lessons learnt and produce a case study (see paper 1 and section 5.2.1).

An online questionnaire was also administered to gather employee feedback on the general performance and conditions for innovation within the firm. The literature was consulted to guide the design and content of the questionnaire, and input was also provided by the C&P steering group. The questionnaire included 16 items (12 Likert scaled and 4 open-ended questions) and was used to elicit the views of employees on the performance of the sponsoring firm in terms of encouraging, supporting and exploiting innovation. Following good practice guidance, a small group of people were invited to participate in a pilot version of the questionnaire to assess its clarity, completeness and ease in which it could be completed (Naoum, 1998). This revealed no major issues and subsequently a link to the online questionnaire was sent to all employees (circa 1300 at the time). A copy of this questionnaire is provided in appendix 5.

The results of the questionnaire were collated and analysed in Microsoft Excel. Descriptive statistics were used to generate averages, standard deviations and assess correlations in the responses to the Likert scaled questions. Following the method proposed by Naoum (1998) the responses to the open ended questions were extracted, placed with all similar answers in a general category and assigned a code. Each general category was then divided into sub-categories and re-coded, in an attempt to make each category mutually exclusive and independent (Naoum, 1998). Where applicable, the collective results from this questionnaire were also compared to the findings from the desk study and interviews to further enrich and validate the pre-intervention assessment.

In summary, the pre-intervention assessment highlighted that the sponsor could do more to support innovation and that existing activities did not provide the necessary level of support. Triangulation of findings from the pre-intervention assessment with the literature indicated that the main barriers of innovation experienced by employees were consistent with those of the wider industry and that the activities in place to support and promote innovation were also typical. For more details regarding the results of the pre-intervention assessment see section 5.2.1.

The pre-intervention assessment was presented to the EngD industrial supervisors and then the C&P group for discussion and evaluation. This led to the validation and prioritisation of areas for improvement, with top priority allocated to improving access to resources for innovation. The questionnaire had revealed that employees felt that they lacked resources for innovation, but the desk study had identified an annual budget available to support
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innovation, the Technology Centre comprising of a team of technical experts, and a Director responsible for innovation, leading to the hypothesis that the issue was one of awareness, access and availability of resources rather than existence. Therefore, it was decided that any future intervention needed to:

- Increase employee awareness of the importance of innovation and the support available;
- Provide a simpler means for employees to access and benefit from this support;
- Ensure that support is available to all employees, regardless of location or job grade.

This provided the RE with the required knowledge to commence the second research objective and develop an intervention for improved innovation management.

4.4.2 Taking Action – Objective 2

To achieve the second objective the RE was required to develop and implement an intervention for improved innovation management. The literature was consulted for ideas, guidance and potential solutions that would meet the sponsor’s requirements, which were based on the findings from the pre-intervention assessment carried out in order to meet the first objective (see section 4.4.1). Since the literature on innovation and its management in construction is limited, other sources of inspiration and guidance were sought to assist with the design of the intervention. There is an abundance of research on innovation and its management in the manufacturing sector, and despite some clear differences between the sectors there are a number of examples where management practices have been successfully adopted, such as Total Quality Management (Boaden & Dale, 1992), Lean Manufacturing (LCI, 2010; Ozorhon et al, 2010) and Six Sigma (Han et al, 2008) to name a few.

Of particular relevance for this project was the research of New Product Development (NPD) which is concerned with the development and refinement of the complete process to bring a new product or service to market (Cooper, 2000). NPD research and practice in the manufacturing context is well established and provided the RE with an abundant source of knowledge to support the development and implementation of the intervention. The literature review on NPD revealed that:

- A well defined process is essential for successful NPD (Cooper, 2000; Griffin, 1997; Rainey, 2005; and Trott, 2002) and defines the normal means by which a company can repetitively convert embryonic ideas into saleable products and services (Page, 1993).
- The likelihood of a successful NPD process is greatly increased by the appointment of teams, owners or champions (Cooper, 2000; Griffin, 1997; Littler et al, 1995; Rainey, 2005; and Trott, 2002).
- Supporting technologies can lead to decreased time-to-market, improved quality, improved manufacturability and smoother transition through the NPD process (Öhrwall, 2000). These technologies include new types of collaboration tools that enable the integration of geographically disperse teams along a value chain into NPD teams (Christensen et al, 2006).

Informed by these findings, the decision was made to develop and implement a process with a supporting ICT system and network of innovation champions to provide the sponsor with a new platform for stimulating, capturing, evaluating and developing ideas outside the normal scope and boundaries of a single project. It was anticipated that this would meet the needs
identified from the first objective; providing a simple, visible and assessable route for employees to seek support for new ideas and potential innovations.

The process was based on a simplified *stage-gate process* (Cooper, 2000); in this case consisting of five activity stages and controlled by five gateway checkpoints. The objectives, activities, resources, outputs, targets and timeframes were defined for each stage and gateway. The process was presented to the C&P steering group, which was then approved and published on the sponsor’s intranet as a standard business process, see Figure 4-2.
Figure 4-2 - Idea Management Process
The process itself was designed to provide a more systematic and transparent approach for the development of ideas, but to be of any value it would require a steady source of new ideas and a robust method to capture and store them. Therefore, together with the new process, a web-based system was developed to provide all employees with online access to the form required to submit a new idea and to a database of all previously submitted ideas (including a summary of status). This web-based system was developed in-house using the Google Apps suite due to the following factors:

- Budgetary and time constraints (the sponsor already held a license for Google Apps);
- Scalability (access to the idea form and database could be extended beyond the sponsor);
- Employee familiarity with the interface (Google Mail was the sponsors email solution at the time);
- The RE’s previous knowledge of the tool.

A simple web-form was created and made available on the company intranet front-page (set as the default home page for all employees). Once submitted it would automatically update the idea database ready for the next gateway review. Gateway review owners would also be notified of any new ideas by an automatically generated email. The feedback arising from a gateway review could be directly uploaded to the database and an email notification sent to the idea originator. Screen shots of the idea form, idea database and notification setting menu are provided in Figure 4-3.
Figure 4-3 - Screen Shots of Supporting System
A pilot evaluation of the system was conducted with a small group of volunteers to assess usability and check for errors. General feedback indicated that the system was simple and easy to use.

The importance of innovation champions is a theme which is echoed in the literature, regardless of industrial context (Dulaimi et al, 2005; Littler et al, 1995). Innovation champions need to be technically competent, provided with resources and have the authority to make decisions, whilst possessing a natural enthusiasm for innovation (Nam & Tatum, 1997). Based on this and the immediate needs of the new intervention, the various responsibilities of the innovation champion were defined as follows:

- Visibly encourage, seek out and share ideas;
- Empower people to develop ideas, providing ‘hands-on’ support when necessary;
- Feed all ideas that require significant support and/or investment into the innovation process via the online idea form;
- Encourage a common understanding of the meaning and value of innovation;
- Collaborate with the wider innovation champion network and attend quarterly forums;
- Provide monthly reports on progress to divisional management;
- Participate in gateway reviews when required.

The RE worked with each division to identify suitable candidates to perform the innovation champion role, ideally from a senior management position. Uptake was very encouraging with all divisions of the business being represented. A mandatory induction session was held for all of the newly appointed innovation champions in advance of the launch of the process (this was also the first innovation champion quarterly forum). During the session the RE provided a brief overview of the pre-intervention assessment and key findings, followed by a detailed presentation of the new process, supporting system and role of the innovation champion network. The forum was concluded with a question and answer session.

To ensure widespread coverage and a high impact launch an internal marketing campaign was devised by the RE, with the support of the Marketing Team. This included the production and distribution of posters and leaflets to all site teams and regional offices, the publication of a news item on the company intranet (with links to the process, idea form and database), and a group wide email from the director responsible for innovation. Innovation champions were also tasked with the marketing of the new process and system as part of their day-to-day activities. More details about the development of the process, system and innovation champion role can be found in paper 2.

The strategy was officially launched in 2007 and the RE was fully engaged throughout the implementation. This included regular attendance at gateway reviews (passive role) and innovation champion forums (active role) and the general monitoring of new ideas and progress through the stage-gate process, in order to identify potential improvements, problems and solutions. The day-to-day management of the process was handed over to the gateway review teams and innovation champions, with oversight provided by a newly formed Innovation & Knowledge Team.

It was during this period that the opportunity to extend the strategy to include the sponsor’s Strategic Alliance Partnership (SAP) was investigated. Originally set up in 2001 with three of
the UK’s leading building services providers, the SAP had grown into a business alliance consisting of 16 firms, covering a number of key building trades. This investigation aimed to provide specific recommendations to the Supply Chain Management Team, who would be responsible for extending the solution to the SAP. Specifically, the study set out to:

- Determine the current status of NPD practice and performance in the SAP;
- Investigate which factors increase the likelihood of successful collaborative NPD within the SAP;
- Make recommendations for improved collaborative NPD within the SAP.

The investigation revealed that there was significant enthusiasm for more collaboration at this level, but that there was no obvious or immediate platform for this to occur outside the boundaries of a single project. A set of recommendations were made to the Supply Chain Management team for consideration, with the intention of extending the intervention to include the 16 firms that made up the SAP. More details about this study and the recommendations can be found in paper 3.

However, the Supply Chain Management team were disbanded shortly after completion of the study due to an extensive reorganisation in the sponsor required after the acquisition and merger. This presented some uncertainty, since the future of the SAP was also under review. It was then decided to terminate this particular line of enquiry and instead refocus on bringing about improvement in the management of innovation at the intra-organisational level.

4.4.3 Evaluating the Actions – Objective 3

The third and final objective was to critically evaluate the intervention developed and implemented from the previous objective. This included an assessment of impact on innovation management performance within the sponsoring company and identification of implications for the wider industry. The intervention was evaluated using a variety of sources and methods to provide a balanced assessment of the post-intervention impact and to allow direct comparison with the findings from the pre-intervention assessment. These included the analysis of the R&D budget, review of process dynamics, capture of innovation champion feedback and a post-intervention employee questionnaire. It was also important to allow time for the strategy to become embedded and for successful ideas to progress all the way through the new process to ensure a fair evaluation, whilst remaining mindful of the challenge of completing a second action research cycle within the four year timescale of the project. Therefore, the questionnaire was administered six months after the strategy was implemented, whilst other sources of feedback and data were compiled during the same period.

The R&D budget was examined in order to determine how it had been used and to establish any changes in the distribution and allocation of funds. Data from the ideas database was cross checked against information obtained from the accounts department and used to populate an Excel spreadsheet. This method enabled the RE to identify cases where an idea had been allocated funds from the budget. This revealed that more of the budget had been allocated and that investment was spread across a much broader portfolio of opportunities in comparison to previous years. This provided evidence that the strategy had raised awareness and improved access to this support, leading to more ideas receiving financial support.
Regular monitoring of and reporting on the new process provided another interesting source of data for evaluation. These reports were based on data extracted from the idea database and included data on the frequency of new idea submissions, the progress of ideas already in the process and the success/mortality rates of these new ideas, see Figure 4-4.

**Figure 4-4 - Idea Management Process Progress Report**

This data was extracted and compiled in an Excel spreadsheet for further analysis, including the calculation of the idea mortality curve (the progressive rejection of ideas/projects through stages of the process). Using the findings from the SAP CPD investigation (see paper 3) and comparative benchmarks available from the Product Development Management Association (PDMA) Comparative Performance Assessment Studies (Barczak et al, 2009; Griffin, 1997), it was also possible to relate these findings to a wider context (see section 5.2.2).

A focus group session was held with the Innovation & Knowledge Team to reflect upon the project. The session was informal and loosely structured around the perceived performance of the process, including strengths and weaknesses. During this focus group it was reported that many of the ideas submitted for review were considered inappropriate for the structured and formal review process, primarily on the basis that the vast majority of ideas did not require funding or additional support to be taken forward due to their simplicity. This observation was also supported by feedback received during attendance at gate-way reviews and potentially reflected in the steep gradient of the idea mortality curve (see section 5.2.2). The issue was that these incremental, bottom-up, ideas still required feedback from the gateway.
review teams, as set out in the process, and were causing a bottleneck. This was an issue that the RE would need to address in the next action research cycle.

In the final stage of the post-intervention evaluation, the same 16-item questionnaire that was administered during the pre-intervention stage a year previous was reissued to respondents. The response rate was acceptable (39 per cent) and provided a suitable source of data for direct comparison. This activity aimed to evaluate the perceived impact of the strategy on general performance and conditions for innovation in the firm. The results indicated positive shifts across a number of measures and, although unobserved explanatory variables cannot be ruled out, provided the basis for a grounded hypothesis that the strategy had resulted in a positive impact on employees perceptions of the organisational climate in terms of encouraging, supporting and exploiting innovation. For more details about the post-intervention evaluation results see section 5.2.2 and paper 2.

4.4.4 Reflection

Completion of the post-intervention assessment marked the end of the first action research cycle, which had encompassed the three research objectives. In line with the adopted research methodology, it was essential that the findings from the first cycle were reflected upon before the second cycle commenced. The general conclusion at this stage was that whilst the strategy for innovation had improved both employee perceptions and access to the budget for innovation, it had also highlighted the very different processes of innovation in the construction firm and the need to address them with different management systems. The strategy developed as a result of the first research cycle was better suited to support top-down processes of innovation and future research would need to address how to better support bottom-up innovation; the type of innovation thought to prevail in the typical construction firm (Nam & Tatum, 1997; NESTA, 2007). More details about these conclusions can be found in paper 2.

Moreover, during the brief interlude between cycles the original sponsor (Taylor Woodrow Construction) had been acquired by VINCI Plc and consolidated with a number of other existing subsidiaries to form the new sponsor of the project (VINCI Construction UK Ltd). It was also at this point in time that the economy went into a recession. As a consequence of all these changes the sponsor undertook an extensive reorganisation to ensure that it was in the best possible position to survive the recession. This reorganisation included the rebranding and structuring of company divisions, rationalisation of overhead staff, office relocations, and integration of front and back office systems. The C&P steering group was disbanded, the Innovation & Knowledge Team was reduced in size and the R&D budget was withdrawn. It was recognised that although it was crucial for the RE to try and maintain continuity of the original objectives, it would also be important to reflect on how all these changes in the sponsor and market environment may impact on the project.

4.5 Second Research Cycle

The purpose of the second research cycle was to reflect, respond to and build upon the findings from the first cycle by revisiting each of the three original research objectives. It was clear at the start of this second action research cycle that any decisions and resulting actions would need to take into consideration the unprecedented trading conditions faced by the sponsor and wider industry at the time.
4.5.1 Diagnosing & Planning Action – Objective 1 Revisited

The first priority for the RE at this stage was to understand what changes had been made as a result of the acquisition, merger and formation of the new sponsor, and how this might have impacted on the management of innovation. Therefore a desk study, employee questionnaire and series of focus group sessions were conducted in order to diagnose and inform a plan of action appropriate to the new sponsors needs and build upon the intervention originating from the first research cycle.

The desk study was undertaken in order to identify any new or modified activities that support innovation inherited during the transition. This exercise, which was performed in the same manner as in the previous cycle, exposed that although innovation was considered to be an essential activity, very little formulated management intervention could be observed outside what was previously reported in Table 4-1. The only notable changes were the addition of an innovation awards programme administered by the group company, VINCI SA, and the intervention developed during the previous research cycle, which had endured the re-organisation and would receive a re-launch in the new sponsor.

An online questionnaire was administered to elicit employees’ views on innovation performance and its management. The purpose of this exercise was to:

- Raise the profile and awareness of the project across the new sponsor;
- Provide a source of data to enable direct comparison and internal benchmarking against the baselines previously established during the first research cycle;
- Provide a source of data to enable a deeper analysis and insight into the factors thought to influence innovation and their relationships.

The decision to perform a more extensive investigation on the factors that influence innovation and their relationships was triggered by the experience and findings from the first research cycle and due to increasing calls for more empirical research by others in the field (Blayse & Manley, 2004). Relevant literature was consulted to update the previous study and to gain additional insight into the theory of organisational climate for innovation and methods used for its measurement. The findings from this review were used to develop an input model representing the key factors considered to influence innovation and their hypothesised causal relationships, see Figure 4-5.
The questionnaire used during the previous action research cycle was updated to include a total of 43 items, which were designed to measure each factor included in the input model using previously validated scales and multiple items wherever possible to improve reliability and validity (see appendix 6). The questionnaire was administered across three out of the five company divisions (Air, Civil Engineering, and Technology Divisions) in three phases by emailing randomly selected people with a covering note and link to the online questionnaire. By guaranteeing the anonymity of respondents and the use of a randomly selected sample helped to mitigate the risk of social desirability, where respondents attempt to respond in a socially desirable way or in order to please the researcher (Brewerton & Millward, 2001).

Data from the questionnaire was subjected to a number of statistical tests using SPSS. Principal component analysis (PCA) was performed on the items that made up the customer profile construct in order to examine any underlying dimensions and to determine whether the data could be reduced. All data was checked for normality and suitability for path analysis. Path analysis, an extension of hierarchical multiple regression, was performed on the data in order to evaluate the input model (Figure 4-5) and compute a path coefficient (standardised beta weights) for each connection between factors to provide an indication of the relative strength of causal influence (Loehlin, 1987). This is used to produce an output model (see Figure 5-4); a revision of the input model which indicates what was actually observed in the data. This would provide the RE with an important insight into which factors influence innovation and assist with the development of the intervention, whilst making a contribution to an area of research that has been highlighted by others (Blayse & Manley, 2004; Dulaimi et
Research Undertaken

al, 2005; Hartmann, 2006a; Reichstein et al, 2005; Seaden et al, 2003). A more detailed account of the design and results from this exercise is provided in paper 4 and section 5.2.3.

The key findings were also presented to the management team of each participating division. These sessions provided an opportunity to discuss the results and explore potential ways the sponsor may improve. Inclusion of the management teams in the planning activity helped to ensure that the project continued in the collaborative manner, as stipulated by the research methodology, and to secure the buy-in from decision makers for any future intervention.

Following these discussions with the Technology Division management team it was decided that the RE would facilitate a series of focus group sessions with staff, with the aim of; 1) validating and enriching the findings from the questionnaire; and 2) to identify potential actions arising as a result of the feedback and securing employee buy-in. A total of nine focus group sessions were held with groups of no more than six participants who had volunteered to take part prior the sessions. The sessions adopted a semi-structured approach to ensure that key questions were addressed, whilst allowing flexibility for open discussion in the group. The general interview structure used for these focus groups is shown in Table 4-2.

<table>
<thead>
<tr>
<th>Line of enquiry</th>
<th>Question pool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validate and enrich findings from the questionnaire</td>
<td>* Did the survey cover all of the relevant issues?</td>
</tr>
<tr>
<td></td>
<td>* What was missing?</td>
</tr>
<tr>
<td></td>
<td>* Why is this important?</td>
</tr>
<tr>
<td></td>
<td>* What additional feedback would you like to add?</td>
</tr>
<tr>
<td></td>
<td>* Was the survey clear?</td>
</tr>
<tr>
<td></td>
<td>* Was it easy to complete?</td>
</tr>
<tr>
<td></td>
<td>* Was it interesting?</td>
</tr>
<tr>
<td></td>
<td>* How can we make it better?</td>
</tr>
<tr>
<td>Identify potential actions</td>
<td>* What is blocking innovation?</td>
</tr>
<tr>
<td></td>
<td>* What is promoting innovation?</td>
</tr>
<tr>
<td></td>
<td>* What do you think the results tell us?</td>
</tr>
<tr>
<td></td>
<td>* What are the big issues?</td>
</tr>
<tr>
<td></td>
<td>* How would you respond to the findings?</td>
</tr>
<tr>
<td></td>
<td>* How can we make it easier to innovate?</td>
</tr>
<tr>
<td></td>
<td>* What would get you involved?</td>
</tr>
</tbody>
</table>

Table 4-2 - Focus Group Example Questions

Feedback was captured during the session on a flipchart, which enabled the group to confirm the accuracy of what was recorded. This was immediately transferred into Microsoft Excel after the session in order to tabulate and codify the results in terms of ideas and themes by following the method presented in Naoum (1998). Each distinct theme that had been indentified through this process was provided with a short descriptor and example statement. The results of this analysis were distributed to those that had participated in the focus groups to check that it accurately and fairly represented what had been discussed, no requests for any changes or additions were received.

The findings from the desk study, employee questionnaire, management team reviews and the focus groups sessions were presented to the director responsible for innovation. It was agreed that the RE would develop and implement a solution to promote bottom-up innovation and compliment the intervention arising from the first research cycle. The principal arguments for this were that:
The literature indicated that both processes of innovation need to be managed, and managed in different ways (Winch, 1998). A strategy was already in place to support top-down processes of innovation and had achieved its principal objective, but the sponsor had yet to address the provision of support for bottom-up innovation;

The central budget originally used to fund need ideas and innovation had been withdrawn, meaning that innovation would need to be funded and delivered at business unit or project level (apart from exceptional cases) and that greater emphasis and performance of bottom-up processes of innovation would be essential for the sponsor during the recession;

The size and remit of the Innovation & Knowledge Team had been significantly reduced, limiting the availability of management resources to support any potential intervention arising from the EngD project. Instead, a solution based on the empowerment and decentralisation of management would be required;

Employee feedback obtained through the questionnaire and focus groups sessions had highlighted the need to raise awareness, support and recognition for bottom-up innovation. Subsequent discussions with management teams also revealed a general desire for the sponsor to do more to exploit this process of innovation.

4.5.2 Taking Action – Objective 2 Revisited

The decision was made to develop and publish an online innovation resource, comprising of a collection of select tools and guidance aimed at promoting, supporting, disseminating and rewarding bottom-up innovation. During the research and attendance at numerous meetings the RE had often observed, participated in or facilitated the application of tools and techniques aimed at generating, evaluating or developing ideas or problem solutions in groups of various sizes. A case study of this type of activity is provided in paper 1, which presents an example of the outcomes from a problem solving workshop to improve the process of developing a 4D construction model and the benefits achieved from the effective used of an extended tool kit.

This form of activity was occurring on a daily basis, at both individual and team levels across the sponsor and when performed correctly often led to positive results. However, the range of tools used by employees seemed to be relatively limited (predominately brainstorming and group voting/scoring tools) and it was common for tools to be used incorrectly (for example, the application divergent thinking tools to achieve a convergent thinking task). The online innovation resource would make more tools available and provide better guidance on when and how they are best applied, with the aim of supporting and promoting bottom-up innovation as specified by revisiting the first objective.

The RE produced a conceptual version of the online innovation resource in Microsoft PowerPoint, which illustrated the proposed page structure, links, content and style for the end product. This was reviewed by both the academic and industrial supervisors before the development of the first online version commenced. The intention was for the resource to evolve over time, with others contributing new and refined tools and guidance, and case study examples of their application. The first version needed to provide the foundation for this and convince stakeholders of the merits of the concept.

To achieve bottom-up innovation people need to be provided with the means, motive and opportunity to do so (Tidd, 2001; Winch, 1998). It was therefore decided to structure the online innovation resource around these three themes. The first section, means, provided tools...
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and guidance to support problem solving, creative thinking and idea development and was targeted for use by both teams and individuals, including application in meetings and workshops. The second section, motive, was aimed at those responsible for a team and provided tools and guidance to assist in the assessment and development of team working environments that are more supportive of bottom-up innovation. The third and final section, opportunity, provided some general guidance for those seeking further support and also information on current innovation related activities within the sponsor. The main structure and tools included in the resource is illustrated in Figure 4-6.

![Figure 4-6 - Online Innovation Resource Site Map](image)

Rather than just providing access to a general selection of tools via the online resource, it was imperative that users would be assisted in making the correct tool selection. The first decision users face would be to identify which section to use to locate the appropriate tools or guidance. The home page was designed to help users quickly make this decision, as well as providing a brief overview of the general purpose of the resource. Hyperlinks to the main three sections are provided directly from the home page, and were also available in the intranets navigation tree. A screen shot of the home page is shown in Figure 4-7.
Within the *means* section, links to tools and guidance were located in the most appropriate stage of a simplified four step innovation process, see Figure 4-8. This association between tool and stage was intended to help users find the most appropriate tool for the task in-hand. A limited number of tools were selected for inclusion in the first version of the resource, mainly due to time limitations and the desire to keep the proof of concept clear and concise. More tools and guidance could always be added into future revisions as necessary. It was also within this section of the resource that users seeking additional support for ideas may be directed to the innovation process developed during the first research cycle. The *means* page also included a link to the homepage to assist with navigation and a link to the Innovation Awards programme identified during the desk study (see section 4.5.1).
The *motive* section of the resource followed the same structure, this time using a process based on the *plan, do, check, act* cycle to help encourage those responsible for a team to follow a process and use the tools in sequence. The empirical investigation into the impact of organisational climate on innovation (described in paper 4) had revealed some of the hidden dynamics of innovation in the team environment, including which factors influence bottom-up innovation. The basic aim of this section of the resource was to equip managers with a set of simplified tools based on this to monitor and assess the team climate for innovation. To help assessment it was considered necessary to provide access to benchmarks for comparison. Therefore, the results from all previous innovation related employee questionnaires were published on the resource. This would enable any manager who had conducted his or her own team assessment to compare their results with the aggregated results from 2006 to 2010 at group or divisional level. A screen shot of the *motive* page is shown in Figure 4-9.
The purpose of the opportunity section was to provide a single channel where the sponsor could communicate ongoing R&D activities and provide the opportunity for those who have an interest to find a point of contact. It was not uncommon for project teams or individuals to be unaware of relevant R&D projects and outcomes; a problem that was exacerbated by the new divisional structure of the sponsor. Therefore, the opportunity section provided a table of current R&D and innovation related projects ongoing across the sponsor. This table included project titles, description and key contact details.

The tools and guidance documentation was informed from a combination of what already existed on the sponsors intranet, lecture notes from the taught element of the EngD and the literature. The importance of keeping this documentation as concise and easy to use as possible was emphasised during the concept review. Where possible the guidance notes followed a standard template created for the resource which included common sections and was restricted to a single A4 page (divided into two columns). An example is provided in Figure 4-10. Where appropriate, supporting tool templates were create in either Microsoft Word or Excel to accompany the guidance, such as a blank ‘force field analysis’ template or ‘paired comparison analysis’ matrix.
To make the resource as widely available as possible it would need to be published on the company intranet. This meant that the online resource would be developed using Microsoft Sharepoint (the sponsor’s intranet solution), with assistance from the IT department who were responsible for all intranet content. Access to the resource was provided at the top level of the intranet under a section for group services, helping to reinforce the importance of innovation and to indicate that the resource was aimed at all staff, regardless of division or job grade. Before the first version of the online resource could go ‘live’ and become available to all employees, a pilot evaluation of the new intervention needed to be conducted by the RE. This would be used to assess the efficiency and effectiveness of the solution and identify any improvements or corrections that need to be made before full implementation and in terms of this project would represent the activity conducted in order to realise the third and final objective of the second research cycle.

4.5.3 Evaluating the Actions – Objective 3 Revisited

In order to meet the third objective and evaluate the solution developed for supporting bottom-up innovation in the sponsor, a series of usability tests of the online resource were conducted with a group of employees. This would enable the RE to validate the solution and make any necessary improvements before full implementation in the sponsor.

Usability can be considered to be a general quality of appropriateness to a purpose; including how usable and useful a given system is (Brooke, 1996; Corry et al, 1997). The usability of any tool or system has to therefore be viewed in terms of the context in which it is being used and its appropriateness to this context (Brooke, 1996). According to ISO 9241-11, a usability test needs to address the effectiveness, efficiency and user satisfaction with the system under investigation.
A 30-40 minute usability test was developed based on this guidance. The first section of the test comprised of three open format questions aimed at capturing participant’s initial impressions of the online innovation resource when presented with the homepage. These pre-test questions included:

- “Just from looking at the homepage and without clicking on any buttons, what kind of information do you think you could get from this site?”
- “Who do you think this site is designed for?”
- “What are your first impressions?”

The next stage of the test was concerned with assessing effectiveness; the ability of users to complete tasks using the system and the quality of the output of those tasks (Brooke, 1996). This was achieved by observing participants attempt to complete pre-defined tasks using the system and asking them to ‘think aloud’ whilst performing the tasks. Instead of setting instructional tasks, a total of three scenarios were defined that attempted to replicate real life situations that the target user group may face and that would provide a good indicator of the effectiveness of the intervention. These scenarios included:

- “You are chairing a meeting this afternoon with a small group of work colleagues and intend to hold a short group brainstorming session. What can you do to help ensure that it runs smoothly?”
- “The brainstorming session went exceptionally well and your manager, who didn’t attend the session, has asked for a summary of the best ideas. However, you didn’t get time during the meeting to review the output and have a long list of potential ideas. How might you go about sorting out the best from the rest to send to your manager?”
- “A new employee has asked you for an overview of current R&D projects in the business. What advice can you provide them?”

A forth scenario was also tested, but this time each participant was asked to provide their own scenario based on how they think they might use the site and then asked to perform it. For each task the RE made notes regarding the pathways used to access information, whether the task was completed with or without assistance, any navigation issues, wrong pathways, confusion with terminology and general user comments. Efficiency is concerned with the level of resource consumed in performing the tasks (Brooke, 1996) and was assessed by recording the time taken to complete each task, along with the number of mouse clicks and any mistakes made.

On completion of the four scenarios the participant was then asked a further series of five open-format questions, as follows:

- “What is your overall impression of the resource?”
- “What did you like best about the site?”
- “What did you like least about the site?”
- “How could it be improved?”
- “Would you recommend it to others?”
- “Without looking, how much can you remember about the site?”
These questions were included to provide the RE with direction for further usability improvements and to test how memorable the content was to users, an important element of usability testing (Corry et al, 1997).

The final stage of the test assessed user satisfaction with the online innovation resource. Subjective measure of users reactions to using the system are often captured though the use of questionnaires (Brooke, 1996). The literature reveals a number of non-proprietary usability questionnaires designed for this purpose, with various degrees of reported reliability (Bangor et al, 2008). Following a review of the options, the decision was made to use the System Usability Scale (SUS) developed by Brooke (1996). The SUS has demonstrated good levels of reliability (Tullis & Stetson, 2004) and is technology agnostic, making it flexible to assess a wide range of interface technologies, including websites (Bangor et al, 2008). The SUS instrument is composed of 10 items that are scored on a five point Likert scale of strength of agreement, and is quick and easy to complete (Bangor et al, 2008). These attributes have made the SUS popular with practitioners and academics alike, and a good source of comparative data is available from the literature. A further 10 Likert scaled items were added by the RE to obtain user opinion regarding the effectiveness of the solution and its likely impact on innovation performance in the sponsor at the individual, team and group level. Participants were asked to complete the questionnaire by hand immediately following the test.

The usability tests were carried out on a face-to-face basis with a sample of six participants over a two week period. The sample size was guided by findings from the literature, where it is generally agreed that 80% of usability problems are detected with four or five subjects and that additional subjects are less and less likely to reveal new information, with the most severe usability problems being detected by the first few subjects (Lewis, 1994; Nielsen & Landauer; 1993; Virzi, 1992). The participants were selected from a range of job grades and divisions to reflect the diversity of roles and positions in the sponsor, all of whom had no prior knowledge of the online innovation resource. Invitations to take part in the study were sent via email, which included a brief outline of the purpose of the study. For the results see section 5.2.3.

The RE took steps to ensure that participants felt as comfortable as possible throughout the test and travelled to each location so that they were able to use their own workstations in a familiar environment. All feedback and observational notes were recorded by hand during the tests on a template developed by the RE. This was then copied into Microsoft Excel for further analysis, including data from the SUS questionnaire.

4.6 Summary

This chapter has provided a description of the research undertaken in order to meet the aim and objectives set out for the project in section 1.4. The research development map, Figure 4-1, illustrates the sequence and timing of various research activities and which objectives they aimed to address. It also depicts how these activities were organised into two action research cycles (inline with the adopted research methodology, discussed in chapter 3) and major change events that occurred within the sponsor and its operating environment during the project, including an acquisition, merger and onset of economic recession. Details of the work undertaken during the first research cycle is provided in section 4.4 and describes the justification, development and evaluation of an intervention for improved management of top-down innovation, comprising of a new stage-gate innovation process, supporting ICT tools and a network of innovation champions. Following the evaluation and general reflection on
the first research cycle the argument to supplement the intervention with a solution for supporting bottom-up innovation is put forward. The design and evaluation of the intervention arising from the second action research cycle, an online resource that provides access to tools and guidance for bottom-up innovation, is provided in section 4.5.
5 FINDINGS AND IMPLICATIONS

5.1 Introduction

This chapter presents the main findings of the EngD research project. The pre-intervention practice and performance of the sponsoring company is discussed. This is followed by the findings and implications regarding the management of both top-down and bottom-up innovation.

5.2 Key Findings

5.2.1 Innovation Management – Pre-intervention Practice and Performance

Initial interviews with senior managers indicated a growing recognition and desire within the sponsoring company to manage innovation more proactively, but this was undermined by a lack of understanding and practical guidance on how it could be approached. It was also asserted that further evidence of this desire to improve innovation management is shown through the sponsor’s commitment to this four year research project. These interviews revealed that formal R&D was generally seen as the primary mechanism for innovation and was co-ordinated at firm level with little or no awareness of other processes of innovation and the ways in which these may be supported.

Indeed, in some cases bottom-up innovation was not considered to constitute innovation and was instead seen as general improvement. Inconsistency and confusion surrounding the terminology used for innovation was common during discussions, this is an observation also reported in other related research. Out of all the activities considered to contribute to or support innovation and identified during the pre-intervention stage of the research (summarised in Table 4-1), only a small number were pinpointed by the interviewees. There was little evidence of coherent plans, measures or processes to co-ordinate these activities for innovation.

Through administering the first questionnaire to all employees it was possible to elicit views on the quality of existing support for innovation and levels of satisfaction with team innovation performance to provide a baseline for future comparison (see paper 2 and section 4.4.1). The key findings from responses to the Likert scaled questions included:

- Almost a third (31%) of respondents were either unhappy or very unhappy with the levels of innovation in their team (49% felt neutral and 20% were either happy or very happy);
- More than half (52%) of the respondents were either unsatisfied or very unsatisfied with levels of encouragement and recognition for innovation (34% felt neutral and 14% were either satisfied or very satisfied);
- More than half (61%) of the respondents were either unsatisfied or very unsatisfied with the availability of time and resource for innovation (31% felt neutral and 8% were either satisfied or very satisfied).

Thematic analysis of the responses to the open-ended question regarding blockers of innovation confirmed the issue of resource availability as a key constraint, followed by access to practical support and then conditions of organisational climate for innovation (see paper 2).
The findings also suggested that innovation was largely considered to be a strategic level activity, centred around formal R&D and outside the scope and day-to-day responsibilities of most employees. Many employees reported that they could not see how or when they could contribute to innovation, perhaps based on the conjecture that innovation was a highly specialised and inaccessible activity.

Attendance and facilitation of various meetings and workshops had demonstrated the benefits of applying tools aimed at problem solving and innovation (see paper 1), but also revealed that the application of tools was infrequent, the range of tools in use were limited and were often used incorrectly (see section 4.5.2).

These findings led to the conclusion that the pre-intervention state of innovation performance was unsatisfactory and that existing practices did not provide the necessary level of support. The findings from the interviews, questionnaire and literature also highlighted the need to raise general awareness and understanding of innovation, and make the support available more visible and available to all staff. It also became apparent that the sponsor would benefit from taking more action to recognise and capitalise on bottom-up processes of innovation, which often remained virtually hidden in projects. Hence, this bottom-up approach became the focus of the second research cycle.

5.2.2 Improving the Management of Top-down Innovation

As discussed in section 4.4.2, priority was given to improving the performance of top-down innovation during the first action research cycle. The potential to broaden participation in the identification, adoption/development and application of ideas/innovation from being a relatively exclusive activity into a companywide initiative became an opportunity that the sponsor felt they could not afford to miss. In order to achieve this, the intervention needed to overcome the issues of fragmentation of teams, awareness, and availability of resources to support innovation.

This project demonstrated that it is possible to overcome these challenges and create a platform for developing ideas and launching innovation that sits outside the traditional boundaries of a project. Therefore, a combination of a stage-gate process, company wide network of innovation champions and a web-based ICT system to support the capture and storage of ideas was implemented to provide this platform.

In less than a year ninety-nine new ideas were submitted for review, see Figure 5-1. These ideas ranged from incremental through to radical and originated from teams and project across the business, providing evidence that the intervention had been able to penetrate both horizontally and vertically in the sponsor.
Of these ninety-nine ideas, six were successfully developed to commercial launch with support from the sponsor’s budget for innovation, whilst many others were simply immediately put into practice by the innovation champion network and Innovation & Knowledge Team. These successfully exploited ideas (innovations) ranged from:

- **(No.87):** Fixing A6 sized instructional placards above all room temperature control systems in one of the company offices to explain how to operate, thus preventing incorrect use and wasted energy.

- **(No.10):** The introduction of a new business stream (Energy+) that provided energy management services to help clients identify and implement simple measures to reduce energy consumption and manage it on an on-going basis, generating a turnover in excess of £2 million within the first 12 months from commercial launch.
Further evaluation of the intervention through the post-intervention questionnaire, focus group sessions and review of the budget for innovation also supported that the intervention had achieved its aims and had provided improved support for top-down innovation (described in paper 2 and section 4.4.3). The budget had been allocated to a broader portfolio of innovation projects, which had helped to mitigate some of the risk associated with investing in new ideas. The Innovation & Knowledge Team, who were responsible for the budget, reported a profit of £10k on an investment of £360k within the 2008 financial year, with a projected ROI of £1.5m for 2009 (based on awarded contracts for two new business streams). This was an improvement in comparison to previous budgets in terms of the time required to achieve breakeven point and 12 month profit/loss. The post-intervention questionnaire showed that employee perception regarding general innovation performance, encouragement of ideas, empowerment to take the initiative, time and resource availability for innovation, and leadership commitment for innovation had all improved following the intervention in comparison to the base line captured during the post-intervention questionnaire (see paper 2).

Focus group sessions helped to critically evaluate the intervention and highlight the lessons learned. The stage-gate process provided the rigour necessary to enable robust decision making regarding the allocation of funds and transparency in those decisions. It also provided an ideal framework for measurement and target setting; each month an update on the number of new ideas entering the process, the mortality rates at each gateway review and the overall idea-to-success ratio were provided in the board report.

The network of innovation champions were an essential element of the intervention, providing the critical ‘go between’ from firm to project and encouraging participation. The literature also emphasises the importance of the ‘champion’ role for innovation, and this research lends further support to that notion. An interesting and unanticipated finding was that after a few months of operation the original group of voluntary innovation champions recruited a second tier of innovation champions on their own initiative. This rapid expansion
of the network not only helped to increase the use of the process, but also reinforced visible and demonstrable commitment to innovation. In effect, the innovation champion goal became ‘to make everybody in the business an innovation champion’ and was very much aligned to the values of the business.

The web-based ICT system was also essential for the success of the initiative. It provided a central point of focus, a talking point and an open all hours channel for new ideas and feedback. Without the application of such a tool the recording and tracking of ideas and associated communications would have quickly become unmanageable. The flexibility and scalability of the web-based solution also provided the sponsor with the opportunity to potentially open up access to those beyond the immediate boundaries of the firm, including customers and suppliers (see paper 3).

However, the implementation of the intervention for top-down innovation was not without its problems. Direct feedback obtained from those responsible for facilitating the process raised concerns a few months after implementation that it was quickly becoming a challenge to deal with a growing number of smaller, incremental type ideas. This is also reflected in the idea mortality curve, which represents the progressive rejection of ideas through stages of the process, see Figure 5-3.

![Figure 5-3 - Idea Mortality Curve](image)

The idea mortality curve shows that a large percentage of ideas were rejected at an early stage in the process (52% rejected or rerouted at the first gateway review) compared to similar data captured from the SAP (see paper 3) and benchmarks available from the Product Development Management Association (PDMA) Comparative Performance Assessment Studies (Barczak et al, 2009; Griffin, 1997), which are based on NPD data from US firms (mainly from the manufacturing sector).
Further investigation established that although many of these rejected or rerouted ideas showed potential, they were often highly context-specific and better suited for development, implementation and exploitation within the project of origin. The intervention was designed to provide a platform for developing ideas outside the boundaries of any single project and as a result struggled to process these types of ideas, but performed well in terms of supporting top-down moments of innovation. This approach toward managing innovation was also resource intensive, requiring support from the innovation champion network, gateway review teams, Innovation & Knowledge Team and the availability of a budget to seed fund potential ideas.

This led to the conclusion that this intervention alone did not present a holistic solution for the improved management of innovation. Changes in the sponsor and its operating environment during the onset of the recession also made this resource intensive intervention less tenable, increasing pressure on the RE to find an alternative but complimentary solution; to encourage and support employees in pursuing appropriate ideas at the project level.

5.2.3 Improving the Management of Bottom-up Innovation

Before any intervention could be developed to better support bottom-up innovation it was first necessary to understand the dynamics. Data from the questionnaire administered at the beginning of the second research cycle (see Appendix 6) was analysed using path analysis to investigate how various factors influence innovation in the firm (see paper 4 and section 4.5.1). The resultant output model reveals the causal influence between factors that were observed in the data, see Figure 5-4. The path coefficients (numbers between factors) are standardised beta weights. The squared value of a path coefficient provides the proportion of the dependant factor variance that is caused by the explanatory factor.
The results showed that organisational support for innovation was the strongest predictor of innovation, which includes the extent of articulated and enacted encouragement, expectation, approval and practical support of attempts to innovate. It was also found that innovation was reported as a short-term and reactive activity, which was typically dealt with on a more informal basis and interwoven into the day-to-day problem solving nature that is typical of the sector. Failure to support this informal, bottom-up, mode of innovating was found to have an overall negative impact on innovation (see paper 4).

The focus group sessions that were conducted following this questionnaire helped to validate and explore these findings. Thematic analysis of feedback captured at these sessions exposed that participants felt that the top five issues were concerned with:

- Maintaining a common and shared understanding of what innovation is, why it matters and how it can be achieved, including the attachment of value to smaller, incremental, everyday type innovations;
- Providing people with the confidence, responsibility and tools to take the initiative and see through their own ideas and suggestions and break away from previously accepted norms;
- Providing consistent encouragement of innovation at all levels of the business, including the recognition, diffusion and celebration of success stories;
- The ability and willingness to make timely and robust decisions on new and/or challenging ideas that break away from the norm and requiring the acceptance and management of risk as appropriate;
Maintaining a sense of urgency, purpose and direction for proactive innovation and improvement efforts, including the identification and communication of wider issues/opportunities, as well as the future needs of the business and its customers.

The online innovation resource was developed during the final year of the project with the aim of promoting, supporting, disseminating and rewarding bottom-up innovation (see section 4.5.2). Due to time constraints it was not possible to fully implement the whole online innovation resource within the sponsoring company. However, in order to judge the suitability and fitness of the intervention for the purpose, a fully functional initial version of the tool was subjected to a series of usability tests (see section 4.5.3).

In all cases participants were able to correctly judge the general purpose and intended audience of the online resource following brief interaction with the homepage, providing evidence that information on the homepage was adequate and clear. The first impressions reported on the intervention were positive; participants showed interested in the concept and were keen to investigate if it would meet their expectations, although two participants expressed some difficulties with some of the terminology used. The scenario tests showed that participants were largely able to complete tasks in a quick and efficient manner, without expressing any major issues, see Table 5-1 for a summary of these results.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average task time (seconds)</th>
<th>Average clicks count (mean)</th>
<th>Reported level of difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>You are chairing a meeting this afternoon with a small group of colleagues and intend to hold a short brainstorming session. What can you do to ensure it runs smoothly?</td>
<td>100.3</td>
<td>2.7</td>
<td>All 6 completed the task easily</td>
</tr>
<tr>
<td>The brainstorming session went exceptionally well and your manager, who didn’t attend the session, has asked for a summary of the best ideas. How might you go about sorting out the best ideas to send to your manager?</td>
<td>67.2</td>
<td>2.8</td>
<td>All 6 completed the task easily</td>
</tr>
<tr>
<td>A new employee has asked you for an overview of current R&amp;D and innovation related projects in the business. What advice could you provide them?</td>
<td>79.8</td>
<td>3.7</td>
<td>3 completed the task with difficulty / 3 completed the task easily</td>
</tr>
</tbody>
</table>

Table 5-1 - Usability Study Task Results

Participants were also able to provide their own examples of suitable scenarios when prompted and select appropriate tools or guidance using the online innovation resource, see Table 5-2 for an example. This demonstrated that participants understood the purpose of the intervention and were able to apply it to a number of real life situations.
Findings and Implications

<table>
<thead>
<tr>
<th>User based scenario</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>“How do I structure a tender evaluation workshop?”</td>
<td>Identified three potential tools (evaluation matrix, paired comparison analysis and six thinking hats).</td>
</tr>
<tr>
<td>“Who do I go to for more support with a brilliant, but challenging idea?”</td>
<td>Identified link to innovation process (previous intervention from first research cycle)</td>
</tr>
<tr>
<td>“How can I improve innovation in my department?”</td>
<td>Identified the ‘motive’ section and the need to follow the process and use tools in sequence.</td>
</tr>
<tr>
<td>“How can I help to ensure that the introduction of 4Projects 3G goes smoothly with new users?”</td>
<td>Identified one potential tool (force-field analysis)</td>
</tr>
</tbody>
</table>

Table 5-2 - User Based Scenarios and Results

Assessment of the user satisfaction with the online innovation resource using the System Usability Scale (SUS) provided an average group SUS score of 79.6, with individual scores ranging from 60 to 92.5. From their study of almost a decade worth of SUS data, Bangor et al (2008) proposed an acceptability range for the SUS score. Based on this guidance the online innovation resource was considered to be acceptable in terms of usability satisfaction and had an above average SUS score for this form of web-based user-interface, see Figure 5-5.

![SUS Acceptability Range](image)

Figure 5-5 - SUS Acceptability Range (Bangor et al, 2008)

Participants also provided feedback on a further 10 Likert scaled items intended to elicit opinion on the effectiveness of the online innovation resource and whether they considered it to be of benefit for bottom-up innovation, this is shown in Table 5-3. Interpretation of these results and responses to open format questions reinforced that participants understood the purpose of the intervention, could see how it supported ‘bottom-up’ innovation, and perhaps most importantly, that they would be likely to use the resource again in the future.
### Table 5-3 - User Evaluation of Online Innovation Resource

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree or disagree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was easy to find the right information</td>
<td>0</td>
<td>0</td>
<td>1 (17%)</td>
<td>5 (83%)</td>
<td>0</td>
</tr>
<tr>
<td>The information provided with this website is clear</td>
<td>0</td>
<td>0</td>
<td>1 (17%)</td>
<td>3 (50%)</td>
<td>2 (33%)</td>
</tr>
<tr>
<td>I can see how the website could help my work</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1 (17%)</td>
<td>5 (83%)</td>
</tr>
<tr>
<td>It will help encourage people to innovate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2 (33%)</td>
<td>4 (67%)</td>
</tr>
<tr>
<td>It provides practical support for those trying to innovate</td>
<td>0</td>
<td>0</td>
<td>1 (17%)</td>
<td>2 (33%)</td>
<td>3 (50%)</td>
</tr>
<tr>
<td>I think it will increase awareness and understanding of innovation</td>
<td>0</td>
<td>0</td>
<td>1 (17%)</td>
<td>2 (33%)</td>
<td>3 (50%)</td>
</tr>
<tr>
<td>The content met my expectations</td>
<td>0</td>
<td>0</td>
<td>1 (17%)</td>
<td>3 (50%)</td>
<td>2 (33%)</td>
</tr>
<tr>
<td>It will help the company meet its innovation goals</td>
<td>0</td>
<td>0</td>
<td>2 (33%)</td>
<td>2 (33%)</td>
<td>2 (33%)</td>
</tr>
<tr>
<td>It will help the company to build a more creative and innovative culture</td>
<td>0</td>
<td>0</td>
<td>1 (17%)</td>
<td>3 (50%)</td>
<td>2 (33%)</td>
</tr>
<tr>
<td>I would be likely to use this website in the future</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2 (33%)</td>
<td>4 (67%)</td>
</tr>
</tbody>
</table>

The feedback and observations made during the usability study were not only valuable in terms of evaluating the concept, but could also be used to further refine the online innovation resource. A number of key recommendations were suggested by participants or identified as a result of this exercise, including to:

- Revise some of the terminology used on the homepage and throughout the resource, using project orientated terminology wherever possible;
- Make the association between tool/guidance and process stage more explicit;
- Provide links to the online innovation resource from other sections of the intranet and incorporate into the sponsor’s training and development courses;
- Include more case study examples.

Based on the findings of the usability study it is asserted that the online innovation resource would provide beneficial support for bottom-up innovation in the sponsor. The research had demonstrated that the intervention could help to raise awareness and communicate the value of incremental innovation, provide tools and guidance to empower employees to self-deliver bottom-up innovation and would work in parallel with the intervention for top-down innovation.

### 5.3 Summary

This chapter has provided an overview of the key research findings. Section 5.2.1 presented the results from the pre-intervention assessment, which showed that despite a desire from senior managers to manage innovation more effectively performance was considered unsatisfactory and that existing practices failed to provide adequate support. This was followed by an account of the results arising from the first intervention for improved
innovation management in section 5.2.2. Evaluation of the intervention for top-down innovation revealed that more employees were seeking support for innovation, the performance of the budget for innovation had improved, and that employees were generally more satisfied with the support available. However, the evaluation also highlighted that in order to provide a more holistic solution, and to respond to changes in the sponsor and its operating environment, a complementary intervention to address the encouragement and support of employees pursuing innovation at the project level was required. In section 5.2.3 an in-depth examination of the factors that influence innovation using multivariate methods revealed the significance of both organisational climate for innovation and the role of articulated and enacted support. Finally, usability tests of the intervention for bottom-up innovation demonstrated that participants understood the purpose of the tool and were able to apply it to a number of real life scenarios.
6 CONCLUSIONS

6.1 Introduction

This final chapter presents how the research aim and objectives have been met and discusses the implications of the research on both the sponsoring company and the wider industry. It provides a critical evaluation of the research and offers suggestions for future work.

6.2 Realisation of Aim and Objectives

The aim of this project was to improve the management of innovation in the context of a construction firm. The project focused on planning, developing and evaluating two complementary management interventions that sought to address the need to better support innovation within the sponsoring company. Table 6-1 provides a summary of how this research has satisfied the objectives set out in section 1.4.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Findings</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>To investigate current approaches for the management of innovation in</td>
<td>- There is a growing recognition of the need to more proactively manage</td>
<td>Thesis</td>
</tr>
<tr>
<td>construction and assess the performance and needs of the sponsor</td>
<td>innovation in construction</td>
<td>Paper 1</td>
</tr>
<tr>
<td></td>
<td>- RAD is generally seen as a primary mechanism for innovation in</td>
<td>Paper 2</td>
</tr>
<tr>
<td></td>
<td>construction</td>
<td>Paper 3</td>
</tr>
<tr>
<td></td>
<td>- There is little evidence of coordinated plans, measures or processes</td>
<td>Paper 4</td>
</tr>
<tr>
<td></td>
<td>for innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Employers generally consider innovation to be a strategic level</td>
<td></td>
</tr>
<tr>
<td></td>
<td>activity outside day-to-day responsibilities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Existing approaches towards the management of innovation did not</td>
<td></td>
</tr>
<tr>
<td></td>
<td>provide the necessary level of support</td>
<td></td>
</tr>
<tr>
<td>To develop an intervention for improved innovation management within the</td>
<td>- Firms need to overcome the issue of fragmented teams to enable wider</td>
<td></td>
</tr>
<tr>
<td>sponsoring and overcome barriers to its implementation</td>
<td>inclusion in top-down innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Stage-gate process provided a framework for measurement and a structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>for robust decision making</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Innovation champions provided the critical interface between firm and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>project teams</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Firms need to overcome low levels of awareness and recognition of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bottom-up innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Firms need to equip and empower employees for bottom-up innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Provision of tools can help support bottom-up innovation and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>communicate its value</td>
<td></td>
</tr>
<tr>
<td>To critically evaluate the intervention, including its impact within the</td>
<td>- The intervention for top-down innovation helped to improve the</td>
<td></td>
</tr>
<tr>
<td>sponsoring and implications for the wider industry</td>
<td>performance of the budget for innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Employee perception of the adequacy of support for innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>increased following the intervention for top-down innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- User evaluations of the online innovation resource indicated that it</td>
<td></td>
</tr>
<tr>
<td></td>
<td>provided encouragement and practical support for bottom-up innovation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- The project will assist other construction firms to assess and diagnose</td>
<td></td>
</tr>
<tr>
<td></td>
<td>innovation management performance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- The research has provided practical examples of interventions for</td>
<td></td>
</tr>
<tr>
<td></td>
<td>improved innovation management</td>
<td></td>
</tr>
</tbody>
</table>

Table 6-1 - Summary of Findings

6.3 Implications for the Sponsor

This project helped to raise awareness and understanding of both top-down and bottom-up innovation, including the need to monitor and manage performance and the introduction of practical ways by which this may be achieved. As a result, the sponsor has benefited from:

- Improved efficiency and effectiveness in the use of its innovation budget;
- Increased levels of employee satisfaction with innovation support;
Increased levels of employee enthusiasm and participation in innovation;
Improvement in self-reported innovation performance;
An increased portfolio of successful innovation projects.

The project led to the development of both full-time and part-time formal roles for innovation; a clear indication of commitment towards improving the management of innovation and the impact of this project. Another indicator of the value attached to the research was the sponsor’s decision to continue with the project following the acquisition and merger, and the level of commitment demonstrated by the sponsor during the recession which triggered a sustained period of uncertainty for the whole industry.

The sponsor is now equipped with practical methods to continue to support top-down innovation in the form of a platform for capturing, evaluating, developing and exploiting ideas outside the boundaries of any single project. This is complimented by the online innovation resource which provides practical tools that can help encourage and bring about innovation in the day-to-day activities of employees, helping to drive bottom-up innovation. The methods used to evaluate these interventions have also provided the sponsor with the means to continue to monitor the organisational climate for innovation, track employees’ satisfaction with the support for innovation and provide essential sources of information for informing future decisions about innovation performance and its management.

6.4 Implications for the Wider Industry

The literature highlighted that despite a growing recognition of the need to more proactively and conscientiously manage innovation, there is little practical guidance for those who seek to address this and research on the subject is limited (Gann & Salter, 2000). In particular, more work has been called for in order to better understand the processes of innovation in the construction firm (Winch, 1998), the significance and relationships between factors that influence these processes (Blayse & Manley, 2004) and the possible management interventions that might improve performance (Hartmann, 2006a).

This project contributes to knowledge on innovation while addressing the above gaps by demonstrating how the planning, implementation and evaluation of management interventions for improved innovation performance assisted a major UK construction, facilities and associated services firm to overcome many of the perceived barriers of innovation in construction. This output provides a practical example for other construction firms who are seeking similar goals and a much needed foundation for future research.

6.5 Contribution to Knowledge and Practice

This research makes the following contributions to knowledge and practice in the field of innovation management in construction:

- A novel insight into the significance of and relationships between factors that influence innovation in a construction firm, highlighting the significant role of organisational climate for innovation and areas to consider when developing a strategy or intervention for the improved management of innovation, and the provision of a model for others to test, refine and validate in the wider industry.
The development and application of a method for the measurement of innovation in the construction firm, demonstrating a set of suitable indicators for monitoring both inputs and outputs of innovation which can be refined and extended upon through future research.

The development, implementation and evaluation of two interventions for the improved management of innovation that successfully addressed some of the barriers reported in the literature and those presented by the sponsoring firm, providing practical guidance for those in the industry who seek similar goals and demonstrating the need to and value of adopting a more proactive and structured approach for the management of innovation in construction.

An example of how an action research methodology can be used to systematically diagnose, plan, take action and evaluate interventions for improved innovation performance in a construction firm for potential use by future researchers and practitioners.

6.6 Critical Evaluation of the Research

The aim of this project was to investigate and improve innovation management within the context of a construction firm. This is a challenging task considering the breadth of innovation as a subject area, coupled with the time constraints on the project and the significant changes that occurred within the sponsoring company and its operating environment during the course of the research. Four limitations have been recognised:

- The research was primarily focussed on the development and implementation of an intervention for improved innovation management within the sponsoring company, which represents a fraction of the construction industry. In addition, the acquisition and merger of the sponsor during the research project may have influenced the research findings.

- Self-report questionnaires were used to evaluate team effectiveness for innovation and elicit views on conditions for innovation within the sponsor. Whilst self-report measures can provide useful insights into team effectiveness there are a number of limitations which should be expressed, including; reliance on the ability of the respondent to introspect and reflect on the area of questioning; sensitivity to a range of response biases; and, the need to aggregate performance ratings (Brewerton & Millward, 2001). It is also important to note that the shift in opinions observed in responses to the pre- and post-intervention questionnaires may have been influenced by a real change as a direct result of the intervention (alpha change), a recalibration of the scale in light of new experience gained from the intervention (beta change) or a redefinition of the construct underlying the scale (gamma change) and relies upon the vigilance of the researcher to identify these possible sources of error (Brewerton & Millward, 2001). In this project, the pre- and post-intervention evaluation utilised a combination of objective and subjective measures (such as ROI) to provide a more balanced evaluation and reduce the possibility of incorrectly interpreting the change.

- It was not possible to implement the second intervention for improved management of innovation within the allocated timeframe; therefore a usability study was conducted with a small sample in order to provide an evaluation of the proposal. The usability tests were not conducted in a real life situation and this may have influenced the responses provided by participants due to the setting. The small sample sized was deemed sufficient to perform the objective of the exercise (Lewis, 1994), but caution must be exercised in generalising these results and they should only be considered indicative.
The action research methodology adopted for this project has been key to realising the research aim and delivering both academic outputs and practical solutions that have significant potential to bring lasting competitive advantage to the sponsor. As with all research methodologies, action research presents some limitations and has received criticism for lack of rigour. The careful selection and application of research methods is important to overcome these concerns and the publication of the refereed papers presented in the appendix provides testament to the quality of the research undertaken.

6.7 Further Research

In view of the research findings and conclusions a number of areas are recommended for further research:

- This project has focused on the management of innovation at the intra-organisational level, with the exception of the work presented in paper 3. There is also a need to investigate the role of inter-organisational innovation in the construction industry and opportunities for improved performance. It is anticipated that this work would need to address how to achieve improved customer and supply chain integration and participation in innovation at all stages of the project lifecycle;

- This research has provided an initial model that describes the factors which influence innovation and how they are related in a major UK construction, facilities and associated services firm. However, there is a need to build upon this work in order to test, refine and validate the model in the wider industry through the collection and analysis of data from a wider range of firms;

- This project was not confined to investigating the improved management of innovation at any particular project stage, but instead was concerned with the general improvement of the management of innovation between the firm and projects. However, there is a need to also investigate innovation at different stages of the project lifecycle, along with the associated barriers and opportunities for intervention. Innovation requirements are likely to change between project lifecycle stages, therefore it is expected that future methods of innovation management will need to adapt to these changes in needs;

- Although the importance of reward and recognition for innovation has been acknowledged during the research, further work on the motivating factors of innovation at the individual and team level needs to be considered. In particular, the integration of innovation into employee selection, training and appraisal warrants further investigation.

6.8 Recommendations

Based on the research the following recommendations are submitted for consideration by the construction industry:

- Develop a common definition and understanding of innovation and its associated terminology. Without this many people will continue to fail to understand how they can contribute to innovation and much innovation will remain hidden and underexploited;

- Recognise, monitor and seek ways to manage the different processes of innovation. Innovation requires more than a reference in a mission statement or as a company value, it should be a core business objective and therefore treated as such, actively supported by strategy, resources and co-ordinated across the firm (and beyond);
Firms need to be flexible in their approach towards the management of innovation; there is unlikely to be a single ‘off-the-shelf’ solution. However, this project has demonstrated a successful and systematic approach towards the diagnosis, planning, development and evaluation of two interventions for innovation. This approach can be used by others, along with the interventions resulting from this project, in order to improve the management of innovation in the construction firm;

- Develop suitable measures of innovation to monitor performance. These need to include a combination of tangible and intangible innovation inputs (such as budgets, staff motivation and climate for innovation), and outputs (such as new product/technology introductions, ROI and customer feedback). The pre- and post-intervention evaluation methods used in this project provide a practical approach to the initial measurement of innovation inputs and outputs in the construction firm, which could be developed further and used by firms to monitor the performance and conditions for innovation.

6.9 Summary and Conclusion

This final chapter has described how the research has fulfilled the aim of improving the management of innovation within the context of a construction, facilities and associated services firm. This was achieved by:

- Identifying the need to provide support for top-down and bottom-up innovation and the associated barriers (objective one);
- Developing and implementing two interventions designed for this task (objective two);
- Evaluating each intervention, including the impact on the sponsor and the implications for the wider industry (objective three).

Innovation in construction is a broad and complex field, and there is still much to learn about it. It also remains important for the construction industry and wider economy. However, there is evidence of increasing interest from academics, practitioners and policy makers which will help develop understanding and bring about change.

Future efforts should seek to refine the measures of innovation at both national and firm level, where they should become integrated into a balanced scorecard type approach for performance assessment. The wider testing, refinement and validation of models of innovation in construction will inform the design of these important indicators, which should include both tangible and intangible metrics.

The customer is known to play a central role in innovation, but this must be extended to include end-users. A more structured and systematic approach towards the capture, interpretation and response to latent and expressed stakeholder/end-user needs would provide a valuable source of direction and stimulus of ideas for innovation efforts. Once again, some insight may be gained from the manufacturing sector where management methodologies such as Quality Function Deployment have already been applied for similar means.

Advancements in information communication technologies also present new possibilities for the management of innovation in construction, such as the application of virtual prototyping for immersing end-users in design for product evaluation and innovation. The introduction of new tools for collaboration and social networking also enable firms to engage a wider
audience for participation in innovation efforts and an important means for un-tapping the ‘wisdom of the crowd’.

This research has demonstrated the potential of defining new possibilities for the management of innovation by introducing practical methods and evaluating their impact in a major UK construction, facilities and associated services firm, revealing the benefits of a proactive and holistic approach to the management of innovation in construction.
7 REFERENCES


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References


APPENDIX 1  PAPER 1

STRATEGIC REVIEW OF THE PRODUCTION OF A 4D CONSTRUCTION SEQUENCING MODEL – THE LESSONS LEARNT

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ABSTRACT
Construction project losses can often be associated to information failures caused by poor coordination between the multi-disciplinary organisations that deliver them. Information failure could include late, inaccurate, inadequate and inconsistent information. 4D Construction Sequencing Models (CSM) seek to improve the coordination of design, plant, equipment and labour through the visual representation of the construction process by linking project programmes with 3D design information.

This paper reports on the experiences of a major UK contractor during the development of a 4D CSM, with a focus on the lessons learnt and the recommendations made. Team problem solving workshops, semi-structured interviews and a lean study review were conducted to establish these findings.

The concluding recommendations not only highlighted the importance of establishing a standard method and procedure, but also identified several software limitations that have subsequently been reported to the developers and will be incorporated as future enhancements. The challenge of maximising the value of 4D CSM for clients and change management also form key topics within the paper.

KEYWORDS: 4D, construction, sequencing, process, lean
1 INTRODUCTION

Building design has been the main driving force for the application of virtual prototyping to various stages of construction projects from conceptual design to construction on site. By allowing architects to visualize and present their designs, a much clearer understanding is gained of both the qualitative and quantitative nature of the space (Nimeroff et al 1995). 3D modelling also enables designers to evaluate proportion and scale using intuitive interactive modelling environments (Kurmann 1995) and simulate various performance aspects such as lighting, ventilation and acoustics within internal environments (Shinomiya, et al. 1994). Visualization can also be used to better communicate design intent to clients by generating walkthrough models giving users a feel of the design in a more direct manner (Ormerod & Aouad, 1997).

Another useful application of Virtual prototyping is in the modelling of the construction sequence in order to simulate and monitor site progress. This can be done by linking 3D models to construction programme information to be able to visualise stages of the construction sequence at any given time of the process (Barrett, 2000; Hu et al, 2005; Lee and Pena-Mora, 2006).

At present the benefits that virtual prototyping can bring to the construction industry are fully appreciated by the majority of practitioners. However despite the continually falling costs associated with the hardware and software, there remains a big obstacle to its full uptake, this is the low compatibility between systems and tools making its implementation costly due to the resource intensive tasks of creating the models.

2 PRACTICAL APPLICATIONS

The 4D CSM this paper reports on was produced for the £250 million private finance initiative (PFI) Whiston Hospital contract. The New Hospitals Consortium of Taylor Woodrow Construction and Innisfree has achieved financial closure which now secures one of the largest private finance initiative (PFI) contracts in ten years to provide two hospitals in Merseyside for the St Helens and Knowsley Hospitals NHS Trust. Total financing raised for the project is approximately £430 million, £338 million of which is construction works. The design and build contract includes the construction of new In Patient facilities, including Accident and Emergency, Diagnostic, theatres and 823 beds to replace the existing facility at Whiston in Merseyside, along with the construction of a Diagnostic Treatment Centre (DTC) at St Helens Hospital. Main construction work is planned to commence on 3 July 2006. Construction at St Helens is scheduled for completion in Autumn 2008, with Whiston Hospital construction completion following in Spring 2010. TWC are working with Innisfree to develop the infrastructure and services of St Helens and Knowsley Hospitals NHS Trust. In addition to the construction contract, Planned Preventative Maintenance and Life Cycle Replacement works worth in excess of £100 million will be undertaken by TW's Facilities Management business as part of the PFI contract and extend over a 30 year period.

The 4D CSM of Whiston Hospital has been commissioned by the TWC led project team to improve the communication of the sequence of the complex project and to identify the potential risks of installing over 600 prefabricated bathroom and toilet pods, and over 2500 prefabricated building services modules.
The project was in the early stages of construction when the project modelling team were approached to carry out this 4D CSM project. The product would represent one of the largest 4D CSM produced to date in the UK, see Figure 1.

The TWC led project team required the 4D CSM to assist in the coordination of numerous subcontractors on site, to clearly and visually identify logistical restraints on site and to effectively communicate the integrated design and programme to relevant project stakeholders.

The 3D object information was created by the TWC Technology Centre Collaborative Working group using Autodesk Architectural Desktop 2006 software. These 3D CAD model files were stored in DWG format in a pre-determined folder hierarchy on the group’s local server. The 4D CSM model was produced by referencing the 3D CAD model files into Navisworks Jetstream V5 (herein referred to as Navis). Any changes in the original source of DWG files were automatically reflected in the Navis 4D CSM. The construction programme information was originally created in Microsoft Project and was manually imported into the Navis 4D CSM.

Production of the 4D model began in August 2006 with an expectation of 7 man weeks worth of work. Final completion and delivery of the 4D CSM exceeded this estimate. A lean study investigation, two team problem solving workshops and several semi-structured interviews were conducted to identify the lessons learnt during production of the 4D CSM and to provide recommendations for future projects of a similar nature. This paper reports on these findings.

Figure 1 - A Static image of the 4D CSM of Whiston Hospital
3 PROBLEMS AND SOLUTIONS

3.1 Synchronisation

The team experienced difficulty with managing changes in the source 3D object information and the synchronisation of this with the 4D CSM software (Navis). In the early stages of the project review this issue was thought to be due to technical limitations of the software application. However, it was later established that the approach towards linking the 3D object information to the programme information was not the appropriate method. The team manually created selection sets within the 4D CSM software (Navis). Each selection set contained a group of objects in the model relating to a certain task in the programme. The appropriate selection sets where then attributed to the relevant programme tasks. The problem occurred when changes were made in the source 3D CAD model DWG file information, as new objects introduced to the 4D CSM would not be assigned to a selection set and therefore a task. The generic cause of the problem was the absolute linkage of 3D objects to a selection set and selection set to a task.

An alternative approach would have been the use of task rules. For each task in the project programme a rule can be created to search and select particular object types in the 4D CSM. The search criterion includes object type, location, and material. In this case, if a new object is created in the 3D modelling environment, upon opening the 4D CSM the new object will automatically be added to the 3D visualisation and to the relevant task through the rule definition. Great care has to be taken in both configuring the selection set rules and in creating the 3D CAD model files with respect to the construction programme.

3.2 Change Management

Synchronisation was further complicated as the 4D CSM was being created by multiple users in separate geographical locations and changes to the 3D model information were automatically incorporated into the 4D CSM but were not automatically flagged by the software to the user. It is possible to identify changes through a manual process, but the team regularly forgot to check. It was indicated that even if the task rule method was adopted that automatically synchronises objects with tasks, clear indication of changes in the 3D model information needed to be clearly communicated by the software. This could be accomplished through a visual indication (for example a red coloured wall could indicate that it has been added since the last update) or the generation of an audit log. This suggestion has subsequently reported to the software developers and will be considered as a possible future enhancement.

3.3 Process

It is important to distinguish between NWF (Navisworks Files) and NWD (Navisworks Document) formats. The NWF format is the file type used for the active model that incorporates dynamic links to the referenced 3D CAD model file design information. The NWD format is the file type used for publication of the model at a particular point in time, as it is a self-contained file with no linkage to external DWG files. An NWD file type should only be published to provide the client with an off-line published 4D CSM or an archive file for auditing. The basic system architecture that was adopted is illustrated in Figure 2. A simple improvement to this architecture would be the provision of a link between the client interface environment and the central shared server. Another approach would be the use of a web based viewer where the client could access a secure site to view the 4D CSM. In a
situation where multiple users are involved in the development of a 4D CSM it is essential that the team understand the purposes and interface of each file type. The distinction between model files and published files are fundamental to this. In the 4D CSM under review, errors relating to this issue had a significant impact on time.

The most apparent error occurred when work on the 4D CSM needed to be carried out off-line from the server that contained the source DWG files. The team generated a NWD file (publication file) from the 4D CSM to capture all the 3D object information and worked on the model off-line to the server. Any changes in the source DWG data would now not be reflected in the 4D CSM. The only readily available solution to this problem would be to relocate all the referenced DWG files from the server location onto the local machine, but due to the size and number of files this was not practical. Since this research, the team has developed a standard method and procedure to reduce the risk of a reoccurrence of this error.

3.4 Delivery
The 4D CSM was produced for a project in the construction phase. To maximise the value of such information, it should be produced and available as early in the project lifecycle as practically possible. With the correct processes in place, a very early stage 4D CSM could evolve over the project lifecycle increasing in complexity and detail as the design develops. From the contractor’s perspective, the earliest realistic stage of involvement is during the initial tender stage. A 4D CSM at this stage would deliver many benefits to all project stakeholders:

- Provide a clear, accurate and shared visualisation of the project.
- A platform to test different construction scenarios and perform what if analysis.
- Identify and communicate value-engineering exercises.
- Provide the opportunity to perform further analysis such as quantity take-off for estimating.
- Improve design coordination, reducing project risk.
- Test and evaluate project programmes and make necessary adjustments.

Deploying a 4D CSM at a later stage of a project still provides project teams with a valuable tool. However, as project time elapses, the cost of change increases, reducing the value of many of the benefits indicated above. In this case study, the 4D CSM is only being utilised to assist visualisation of the project in comparison to programme and to aid communication at sub-contractor co-ordination meetings.

3.5 End User Interface

The client was using Navisworks Freedom, a freely available viewer from the Navisworks suite to allow a limited level of interaction with the 4D CSM. This version allows the user to open a Navis model file and perform standard 3D view functions such as orbit, zoom, look around, walk. It also allows playback of the construction sequence, but is limited to play, pause, fast forward and rewind. No functionality for viewing step-by-step or specific dates/times is provided. The full functionality of the 4D CSM was only available to the client when a member of the modelling team was demonstrating the model on a PC with the full 4D CSM software package installed (Navisworks Jetstream). Instead, numerous static images were produced of the 4D CSM on different dates of the programme from different views. Although this satisfied the client and their requirements, the true value of the 4D CSM had been missed. Images should only be by-products of the 4D CSM and the client should have the ability to manipulate not only the views of the model, but also the time properties.

To enable the full functionality of the 4D CSM, a copy of Navisworks Roamer software would need to be purchased. This application would allow the end-user to fully interact with the 4D CSM, ideally from a central shared server or web-based project extranet, manipulating the views and time properties of the 4D CSM but without editing rights. As espousal of this type of technology is still relatively low on live projects, a few roaming software licenses would suffice at this point in time. Discussion around this issue was taken up directly with the software vendors and it has been since reported that the next freeware version of Navisworks Freedom will indeed incorporate the timeline function, solving the issue of achieving maximum functionality for the end-user (although this still only provides viewing capability with no editing rights).

3.6 Smart Tags

Smart Tags in Navis are information lists that appear in the viewer when the cursor is hovering over an object with a Smart Tag enabled. The information displayed in the list can be user defined and usually would refer to the attribute information relating the object in question. Currently, the software allows users to define the Smart Tag information display. However, these options are user specific and not transferable. It was suggested that a global command that allows different sets of information to be set-up and displayed depending on with Smart Tag group is selected. For example, one Smart Tag group might be concerned with quantity and cost information, whereas another may be concerned with material type and manufacturer information.
This sort of functionality would be highly beneficial in a scenario where different end-users are utilising the 4D CSM for different purposes, one such example being a planning versus estimating team. Although Smart Tags were not used in the case study project, the team indicated a desire to incorporate them in future models.

4 CONCLUSION
The 4D CSM reported in this paper was well received by the client. However, the research findings have highlighted a number of lessons learnt and opportunities for future improvements, both technical and process driven. These can be summarised as follows:

- Deploy the 4D CSM as early as possible in the project lifecycle to maximise value.
- Establish a standard method and procedure to ensure compliance with a process.
- Ensure that the end-user interface provides the level of functionality required.
- Adopt a method that allows dynamic and automated synchronisation of objects to task.
- Ensure that a strategy to highlight and track changes in the model is present.
- Clearly distinguish between reference models files and publications files.
- Utilise Smart Tags to take advantage of object information inherent in the model.
- Avoid absolute links between information sets.

5 REFERENCES


APPENDIX 2  PAPER 2

THE IMPACT OF A STRATEGY FOR INCREASED INTRA-ORGANISATIONAL INNOVATION IN A CONSTRUCTION FIRM

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ABSTRACT
The need for increased innovation and improvement in the construction sector is well documented. In response to this many construction firms are seeking ways to exploit innovation in a more proactive and conscientious manner. However, there is little practical guidance for professionals and progress towards the optimisation of intra-organisational innovation in construction is widely considered to have been slow. The research presented in this paper forms part of an ongoing effort to bridge this gap and provides a pre- and post-intervention evaluation of a strategy for increased intra-organisational innovation in a large UK construction, facilities and associated services firm. Good practice developed in other industry sectors assisted in the formulation of the strategy, which included a process for the capture, selection, development and exploitation of ideas, a simple web-based system for supporting the process, and a network of ‘innovation champions’ responsible for driving the initiative within the firm. Pre- and post-intervention evaluations provided an insight into the impact of the strategy on employee perceptions and innovation performance, suggesting that the strategy for innovation significantly impacted idea input and perceived support for innovation across the firm. However, the research also revealed that the strategy was better suited to supporting modes of innovation that were characterised by a longer-term focus, sitting outside the traditional boundaries of a project, rather than the project-orientated and incremental modes of innovation that are known to prevail in the construction context. Firms seeking to optimise intra-organisational innovation will need to address all modes of innovation and therefore a more holistic solution is called for. Ongoing research will aim to address this need and further explore the nature of innovation in the construction firm.

KEYWORDS:
Case Study, Construction, Evaluation, Innovation, Strategy

1 INTRODUCTION
In simple terms innovation is the successful exploitation of an idea (DTI, 2003) and represents the principal method by which firms can respond to the need for change and improvement in the industry; this being a need that has been well documented in the UK (Fairclough, 2002; Egan, 1998). Innovation can also provide a route to market differentiation and increased competitiveness.

Indeed, recognition of the role and value of innovation for increased profitability and market performance in construction is growing (Seaden et al, 2003; Tatum, 1991), with more and more firms seeking ways to exploit innovation in a more strategic and proactive manner (Hartmann, 2005). The question is, ‘what can firms do to drive greater levels of innovation?’ There is little practical guidance for construction professionals on how to make innovation flourish within their firms and research on innovation management specifically for the construction sector is very limited (Gann and Salter, 2000).
Much of the existing research has centred on the role of various stakeholders in construction innovation performance. Both clients and suppliers have been shown to play multiple and critical roles in innovation (Shaw and Bouchlaghem, 2008). However, construction firms must also address innovation performance within their own corporate boundaries or risk becoming the weak link in the chain. This is also the domain in which a firm is most likely to have the greatest influence - over its own resources, processes and strategies.

The challenges of increasing innovation at the intra-organisational level should not be underestimated. Innovation in the construction firm is multifaceted and can take various forms (Slaughter, 1998). The project centric nature of the sector exerts considerable influence over the type and methods by which innovation is created and exploited by the firm. This characteristic is eloquently captured in the two-moment model developed by Winch (1998, p273), which comprises of a top-down moment of adoption/implementation and bottom-up moment of problem solving/learning that broadly describes the different ways in which a construction firm can achieve innovation (see Figure 1). Furthermore, it has been asserted that these distinct modes of innovation require different methods of management (Winch, 1998), although practical and effective methods for this achievement are less established.

![Figure 1 - Two moment model of innovation (Winch, 1998)](image)

This paper forms part of an ongoing research programme which aims to bridge this gap and develop appropriate guidance for the improved management of innovation at the intra-organisational level in construction. Specifically, this paper provides a case study evaluation of one strategy for increased intra-organisational innovation, developed and implemented within a major UK construction, facilities and associated services firm.

The design of the solution was influenced by practices and research from the manufacturing sector, where a more formal approach towards innovation and product development is commonplace. Although the solution itself might not be considered unique in its general sense because of these synergies, its successful application in the construction context and a unique insight into the impact of such a strategy will be of interest to those who seek to improve the innovation performance of construction firms at the intra-organisational level.

2 RESEARCH CONTEXT

The research presented in this paper was conducted as part of an Engineering Doctorate programme, in collaboration with the Centre for Innovative and Collaborative Engineering, Loughborough University, and VINCI Construction UK Ltd. The Engineering Doctorate
programme aims to develop practical guidance for improved innovation management and performance.

VINCI Construction UK Ltd is a large construction, facilities and associated services firm, with a turnover exceeding £1 billion, and over 3000 employees in the UK. The firm operates within five primary sectors including Air, Building, Civil Engineering, Facilities, and Technology. The company was formed on 29th December 2008 with the objective of integrating its principal construction subsidiaries. This reorganisation was initiated as a result of the acquisition of Taylor Woodrow Construction in September 2008. Prior to this acquisition, Norwest Holst Limited had been the principal contracting entity; now Norwest Holst, Taylor Woodrow Construction and a number of other regional contracting companies have been consolidated into a single, coherent contracting entity.

The case study centres on the impact of a strategy for innovation that was developed and implemented in Taylor Woodrow Construction, before the company’s reorganisation in December 2008.

3 METHODOLOGY
The research sought to establish the impact of a strategy for innovation on performance and individual perceptions of the innovation receptiveness of the sponsoring firm. In order to meet this aim a form of case study design known as a ‘single-case experiment’ was adopted, as it allows the investigation of contemporary phenomena within real life criteria (Yin, 1984). The single-case experiment approach involves the systematic evaluation of change over a set period of time (Hilliard, 1993), which is of key relevance when assessing the before and after impact of any intervention - in this case a strategy for innovation. The case study was achieved by supporting the project team responsible for both the development and execution of the strategy for innovation, enabling first hand experience of the issues, barriers and performance of the strategy, from conception through to post launch evaluation.

A structured questionnaire was the selected principal investigation method for the systematic evaluation of the impact of the strategy. The structured questionnaire incorporated 16 questions (12 likert scaled and 4 open-ended questions) and was used to elicit the views of employees on the performance of the sponsoring firm in terms of encouraging, supporting and exploiting innovation. The pre-intervention evaluation questionnaire was administered in December 2006 to all employees of Taylor Woodrow Construction (circa 1300 people at that time). A total of 579 complete and usable responses were received, achieving a response rate of 44%. The post-intervention questionnaire was administered to the same respondents in December 2007, following the implementation of the strategy for innovation. A response rate of 39% was achieved.

The case study and impact evaluations were further enriched through regular attendance at working group meetings and pre- and post-intervention workshop sessions with key stakeholders across the sponsoring firm. These meetings and workshops provided an opportunity to highlight issues and barriers to the implementation of the strategy, to discuss performance and to indentify refinement opportunities, providing much of the source for the narrative presented in this paper.

A potential weakness of the impact evaluation approach is the assumption that change will be meaningfully and visibly demonstrated and observed (Brewerton and Millward, 2001). Other
potential difficulties associated with case study research in the general sense include issues with interpretation and the lack of a guaranteed method to control for unobserved explanatory variables (Brewerton and Millward, 2001). However, impact evaluation can provide some means of documenting what works in a particular context, and can be a valuable source of grounded hypotheses for intervention refinement and/or further research (Brewerton and Millward, 2001).

4 CASE STUDY

4.1 Pre-intervention state

During 2007 the firm launched a company-wide improvement initiative with the ambition of driving business performance from good to excellent. A core component of this effort included a behavioural programme, which clearly defined a number of key values and behaviours that were considered to form an integral part of the initiative. One of these values included innovation.

Despite a united desire and recognition of the need to be more innovative, the firm had no processes, strategies or systems to help facilitate innovation across the business. An annual budget of significant proportions was available as a seed fund for innovation and was replenished annually, but historically this had been under-assigned. This is not to say that innovation was not occurring; on the contrary, innovation was (and is) embedded into the daily working practices and problem solving culture typical of the sector. What the firm wanted to achieve was greater exploitation of these existing skills and to create an organisational environment where innovation could thrive beyond the boundaries of a project.

Before any strategy for increased innovation could be formulated it was deemed necessary to establish a baseline of the pre-intervention state, including employee perceptions of the organisational environment in terms of encouraging, supporting and exploiting innovation. This was achieved by issuing a 16-item structured questionnaire to all employees. Topics covered by the questionnaire included:

- Satisfaction with levels of innovation
- Encouragement of ideas
- Leadership vision & commitment
- Empowerment
- Company attitude toward risk
- Reward & recognition for innovation
- Goals & targets for innovation
- Time & resource availability
- Innovation barriers
- Support for innovation

The responses provided a number of benchmarks, which were reassessed post-intervention in order to gauge the impact of the strategy on employee perceptions. General feedback was extracted from the open-ended questions using good practice methods (Brewerton and Millward, 2001). Coding and interpretation of this qualitative data suggested that the sponsor needed to address perceived barriers to innovation, paying particular attention to resource availability, practical and available management support, tackling a culture of tradition and improving the quality and frequency of communication (see Table 1).
Appendix 2

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource availability</td>
<td>Insufficient time, money and human resource for innovative activity</td>
<td>36%</td>
</tr>
<tr>
<td>Management support</td>
<td>Lack of practical support and leadership commitment for innovative activity</td>
<td>11%</td>
</tr>
<tr>
<td>Culture</td>
<td>Tradition, resistance to change and a ‘we have always done it this way’ attitude</td>
<td>10%</td>
</tr>
<tr>
<td>Communication</td>
<td>Broken and inefficient communication, including poor or limited feedback and dissemination of knowledge</td>
<td>9%</td>
</tr>
<tr>
<td>Rigidity</td>
<td>Restrictions posed by strict and embedded processes and procedures, including regulations</td>
<td>7%</td>
</tr>
<tr>
<td>Incentivisation</td>
<td>Lack of motive and opportunity to innovate, including employee empowerment to drive change</td>
<td>6%</td>
</tr>
<tr>
<td>External stakeholder</td>
<td>Resistance from customers and/or suppliers, often driven by risk avoidance or perceived costs</td>
<td>5%</td>
</tr>
<tr>
<td>Focus</td>
<td>Tendency to focus on the here and now, within the bounds of a single project, and lack of awareness of the big issues</td>
<td>5%</td>
</tr>
<tr>
<td>Integration</td>
<td>No/limited access to the right people at the right time, including early stage involvement</td>
<td>4%</td>
</tr>
<tr>
<td>Skills</td>
<td>Insufficient skills and competencies to confidently identify, evaluate and exploit innovation</td>
<td>4%</td>
</tr>
<tr>
<td>Measurement</td>
<td>Difficulties associated with the measurement of innovation, and therefore quantify value before/after</td>
<td>1%</td>
</tr>
</tbody>
</table>

Table 1 - Perceived barriers to innovation (pre-intervention)

4.2 Strategy Development

The formulation of the strategy for increased intra-organisational innovation began shortly after the data collected from the pre-intervention questionnaire had been analysed and discussed by key stakeholders. This sequence ensured that the firm benefited from a) a baseline for future comparison and b) feedback/insight provided by employees to assist in the shape and design of the intervention.

A seven-member working group was formed to guide the formulation of the strategy and assist with implementation. The group consisted of an executive board member, senior management representatives from each company division, and two members of the central team responsible for knowledge and innovation across the firm. It was decided at an early stage working group meeting, supported by the evidence from the questionnaire, that an inter-project platform for sharing, evaluating, funding, and developing ideas outside the normal scope and boundaries of a project environment would help address some of the issues identified at the pre-intervention stage.

Literature on innovation and idea management was consulted to provide guidance, but since the literature from a construction-specific context was limited much inspiration was drawn from experiences and theory developed from the manufacturing sector. A useful source of material was concerned with new product development and the underpinning process for product innovation, where the process is considered to form a fundamental cornerstone for the delivery of businesses’ new product programmes and innovation (Cooper, 1993), defining the normal means by which a company can repetitively convert embryonic ideas into saleable products and services (Page, 1993).
In simple terms the process, often described as an ‘idea pipeline’, consists of a number of activity stages and is controlled by gateway checkpoints (Cooper, 2000). The fundamental stages consist of idea capture, evaluation, development and exploitation. For each gateway, a predefined set of criteria must be satisfied before progression onto the following stage can be made (Cooper, 2000). In some cases, the output of a particular stage may not be satisfactory to pass through the proceeding gate. In this situation, the innovator may be asked to go back and repeat some tasks in the hope that this will resolve the problems or the idea may be rejected, stored for future use or even sold to another company (Page, 1993).

Using this good practice guidance and adapting where necessary for application in the construction context, a simplified stage-gate process for the inter-project management of ideas was developed. The process included five stages, namely; idea stimulation and capture, concept investigation, study, pilot, launch and hindsight review. Each stage in the process had a respective gateway review, along with a set of predefined assessment criteria. In addition to this, the core objectives, activities, resources, outputs and ownership responsibilities were defined for every step in the process. It was also decided early in the implementation stage to set targets for various gateways. The process was incorporated into the firm’s standard business processes and published on the company intranet, available to all employees. The process provided structure, support and resource for potential innovations, in an effort to address the resource availability issues identified in the pre-intervention evaluation.

In parallel to the introduction of a new process for delivering innovation, a web-based system was developed to provide all employees with access to a database of previously submitted ideas, progress reports and the forms required to submit an idea or concept for consideration. This system was developed in-house and was intended to be user-friendly, easy to access and quick to use. For example, the initial form required to share ideas only required basic information such as name, idea details, and anticipated value, and could be accessed directly from the firm’s intranet home page, which automatically opened on start-up. Once submitted, details from the form would immediately and automatically update the idea database ready for the next scheduled gateway review. This system provided the inter-project platform specified in the initial working group meeting and aimed to alleviate communication inefficiencies discussed in the pre-intervention evaluation.

In order to drive the strategy across all divisions and their respective projects the formalised role of ‘innovation champion’ (IC) was created. Each division was provided a brief overview of the IC role and responsibilities, and were each requested to identify a voluntary IC candidate, ideally from a senior management position. The IC role was considered to be key for facilitating the successful implementation of the strategy and encouraging participation across fragmented teams. ICs were also required to participate in regular gateway reviews and to provide monthly reports to divisional management on progress. Uptake of the voluntary role was encouraging, with all divisions of the firm represented. All ICs would meet on a quarterly basis to share and discuss issues and suggest improvements and before long had recruited a secondary tier of ICs both horizontally and vertically across the firm. This network of ICs provided visible leadership and commitment to the innovation strategy, in addition to improved management support.

The strategy was officially launched during June 2007 and included an internal marketing campaign to raise awareness. Posters and leaflets were distributed to all sites and offices. An article was published in an internal newsletter and a notice was uploaded onto the company
Appendix 2

intranet homepage for one month. ICs were also tasked with the general communication of the initiative during their day to day activities.

4.3 Post-intervention impact

The strategy was evaluated using a variety of methods to provide a balanced assessment of the post-intervention impact. For example, the monthly IC progress reports provided a source of data to compare with archival sources. Metrics such as number of applications for funding and total allocation of funding provided an interesting insight into how the strategy had influenced the use of the fund compared to previous years. Historically the fund was typically invested into a few larger scale research and development projects, often in collaboration with external research partners. After the intervention a significant increase in numbers of applications for smaller investments was observed, resulting in a broader distribution of funds and a more mixed portfolio of investment. To put this numerically, applications had increased by a factor of ten in 2007 compared to the same period in 2006.

To assess the impact of the strategy from a wider perspective, the same 16-item questionnaire that was administered at the pre-intervention stage a year earlier was reissued to respondents. The response rate was acceptable (39%) and provided a suitable source of data for direct comparison.

Figure 2 Pre- versus post-intervention perceptions

The results indicated positive changes in perceptions across all aspects, with some significant change reported for certain items - in particular the encouragement of ideas (see Figure 2). Although unobserved explanatory variables influencing the observed change cannot be ruled out (Brewerton and Millward, 2001), the findings do provide the basis for a grounded
hypothesis that the introduction of the strategy for innovation resulted in a positive impact on employee perceptions of the organisational environment in terms of encouraging, supporting and exploiting innovation.

Finally, feedback on the impact of the strategy was also captured through attendance at post-launch workshop sessions with key stakeholders across the sponsoring firm. These informal sessions provided a valuable insight into the performance of the strategy for innovation, including barriers to implementation. From discussions with the individuals responsible for the day to day management of the process it became evident that timely review and adequate feedback on proposals was becoming difficult to manage effectively. On further enquiry, the root cause of the issue seemed to be associated with an overload of very simple, incremental type ideas which required minimal funding and were found to be inappropriate for such a structured and formal assessment. Many of these incremental mode ideas were project specific in focus, with lower potential for diffusion and reapplication, but represented the more prevalent form of innovation in the firm.

The next stage of the research programme aims to address this issue and provide the sponsor with a more holistic strategy for the improved management of intra-organisational innovation, whilst providing the much needed practical guidance for practitioners who aspire to drive more innovation in the construction firm.

5 CONCLUSIONS

There is little practical guidance for professionals who seek to manage intra-organisational innovation in a more efficient and effective manner. Literature on the subject is scarce and often highly theoretical. The research presented in this paper forms part of an ongoing effort to bridge this gap and it is hoped that the case study provides valuable insight for others who seek similar goals.

This paper has provided a pre- and post-intervention evaluation of a strategy for increased intra-organisational innovation in a large UK construction, facilities and associated services firm. The strategy for innovation had a positive impact on employee perceptions of their ability to innovate in the firm and on the performance of the budget for innovation in terms of return on investment and allocation. Although the strategy made extensive use of good practices from the manufacturing sector, it is thought that the execution and thorough examination of such a strategy in the construction context has provided a unique and useful contribution to the field.

The extent of variance in the modes of innovation in the construction firm has been highlighted by this case study examination and triangulates with the findings of previous efforts (Slaughter, 1998; Winch, 1998). The vast majority of ideas and innovation generated in the firm were incremental and project-orientated in their nature, typically focussing on solving a specific problem within the bounds of a project. The strategy presented in this research was better suited to support modes of innovation that were characterised by a longer-term focus that sat outside the traditional boundaries of a project, rather than incremental modes of innovation. Referring to the model of innovation developed by Winch (1998), it could be considered that the strategy was more supportive of top-down moments of innovation. Firms seeking to optimise intra-organisational innovation will need to address both top-down and bottom-up modes and therefore a more holistic solution is called for. Our ongoing research will aim to address this need and further explore the nature of innovation in
the construction firm, with a greater emphasis on providing support for bottom-up modes of innovation.

Some limitations of the research include the difficulties associated with controlling unobserved influencing factors during the pre- and post-intervention impact evaluations. The combined use of questionnaires and focus group sessions as investigatory methods was intended to mitigate some of this risk. Secondly, this case study is based on a single firm and may not be entirely representative of the wider industry. The use of good practice research methods and subsequent triangulation with the theory suggests that the generalised findings are relevant to the wider industry and provide a much needed grounding for future research and those operating in the field.

6 REFERENCES


APPENDIX 3  PAPER 3

CHALLENGES, OPPORTUNITIES AND RECOMMENDATIONS FOR COLLABORATIVE PRODUCT DEVELOPMENT IN CONSTRUCTION – A UK CONSTRUCTION STRATEGIC ALLIANCE PARTNERSHIP PERSPECTIVE

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ABSTRACT
Firms that don’t innovate die - that is the message from many authors and business leaders in the field. New Product Development (NPD) is vital for firms of every size in every industry and has been labelled the lifeblood that sustains and ensures the continuing survival of an organisation. However, the UK construction industry is still widely considered to be risk adverse and resistant to change. Innovation in this industry is often, at its best, marginally incremental and is often driven by an increasing base of expert customers who demand for it. Many different arguments exist to reason why the construction industry is innovation shy, but a more open and collaborative approach towards innovation presents an opportunity for the industry to change. There has been a fundamental shift in the way in which firms innovate. The traditional closed model of innovation is being superseded by the principle of open innovation – where firms use internal and external ideas and internal and external paths to market to advance their business and develop or improve products or services. Continuing advancements in technology, such as the introduction of the internet, have supported this evolution. This paper reports on research conducted by a major UK construction organisation to establish the current condition of NPD within its Strategic Alliance Partnership (SAP) and to explore the key requirements to encourage more intra and inter-organisational innovation. The research suggested that the NPD capability within the SAP is still relatively immature. The majority of members within the SAP did not have a formal process in place for developing and improving products or services, and only a quarter have appointed full time NPD process owners – both frequently regarded as essential ingredients for successful NPD. This is not to say that Collaborative Product Development (CPD) is not considered as important, as over two thirds of the sample set considered it of major importance to their businesses and the appetite for more CPD was strong. A number of key recommended actions to improve both the capability and performance of the SAP in terms of CPD conclude this study, from a balanced people, process and technology perspective.

KEYWORDS: New Product Development, Collaborative Product Development, Construction, Open Innovation, Strategic Alliances
1 INTRODUCTION
Firms in many industries are facing the challenge of increased competition, rapidly changing market conditions, radical technological change, shorter product lifecycles and more frequent demand for innovation (McIvor et al, 2006; Griffin, 1997; Christensen et al, 2003). Indeed, NPD is often labelled as the lifeblood that sustains and ensures the continuing survival of organisations in these challenging times (Gordon et al, 1995). However, NPD is resource intensive, expensive and notoriously risky (Page, 1993). Therefore firms are looking for ways to reduce NPD cycle times, improve quality and decrease costs whilst remaining lean and agile to react quickly to changing needs (McIvor et al, 2006; Christensen et al, 2003; Parker, 2000).

CPD between an alliance of organisations has been identified as one route to reduce the cost and risk of NPD, where many traditionally internalised functions are carried out externally (Hagedoorn, 1993; McIvor et al, 2006). CPD has been defined in various ways, and even a brief examination of the literature reviews little agreement on terms (Littler et al, 1995). Lawton et al (1991) define CPD as the cooperative relationship between firms aimed at innovation and the development of new products. Littler et al (1991) provide a similar definition with the addition that collaboration might occur with partners at various stages of the value chain, such as customers, competitors, or suppliers. The CPD investigated in this research concerns the cooperative relationship between suppliers and buyers.

This study was conducted with a large UK construction firm and it’s Strategic Alliance Partnership of 16 organisations with the following objectives:
- Determine the current status of product development practices and performance in the SAP
- Investigate the factors that increase the likelihood of successful CPD in the SAP
- Identify recommended actions for improved intra and inter-organisational NPD within the SAP

2 METHODOLOGY
This paper reports on the first two stages of an ongoing research project. The first stage comprised of an extensive literature review to identify the drivers for intra and inter-organisational NPD and the factors that increase the likelihood of success.

The second stage involved the design and administration of a questionnaire survey. This was based around the key findings from the literature review and incorporated a number of questions designed specifically to benchmark NPD performance. Guidance was also provided through the analysis of previous studies conducted by Griffin (1997), Littler (1995), Parker (2000), and Booze et al (1968 and 1982). The survey was issued to all members of the SAP, which is made up of 16 individual firms, and achieved a 100% response rate of fully completed surveys. The surveys were sent to the Managing Director of each SAP member, with a request to forward the survey onto the person within the organisation with primary accountability for NPD.

The small sample, all of which are members of a SAP, may suggest a degree of sample bias in the findings due to the relationships between the organisations. However, the intention of this applied research was to identify recommended actions to improve the intra and inter-organisational NPD performance and capability within this specific SAP and not to
Appendix 3

3 RESEARCH AND DISCUSSION

3.1 People
The literature review suggested that the likelihood of successful NPD is greatly increased by the appointment of teams, owners or champions (Littler et al, 1995; Cooper, 2000; Rainey, 2005; Trott, 2002; Griffin, 1997). To establish the maturity of the SAP NPD capability in this respect the sample was asked whether they had appointed roles and/or responsibilities for NPD. The results show that none of the respondents had a full time NPD team and only a quarter had appointed full time roles and responsibilities for NPD in their firms, see Figure 1. The majority of members used part-time roles or appoint responsibilities on an as required basis for managing NPD.

![Roles for New Product Development](image)

Figure 1 - Roles for New Product Development

This could be due to a number or a combination of factors including (but not necessarily limited to) resource constraints or pressures, lack of relevant expertise, a low perceived importance of NPD, and low perceived importance of allocating dedicated resource for NPD. Indeed, the sample was asked to rate how important NPD was to the success of their business and of the respondents that perceived NPD as of minor (11%) or moderate (22%) importance, none had full time allocated roles or defined processes in place, therefore suggesting that a higher perceived importance of NPD increases the likelihood of allocated roles and responsibilities.

3.2 Strategy
We were interested to explore how NPD projects were triggered in the SAP. The need for a NPD strategy for increased new product success is consistent throughout the literature (Griffin, 1994; Booz et al, 1982; Booz et al, 1968). Experience told us that NPD projects in the SAP were most likely to evolve from a reactive situation, such as finding a solution to a
particular problem or trend of problems, rather then proactively in light of strategic identification of customer needs or market insights.

Partial evidence of this was provided through the response to the question asking if a formalised method for capturing or predicting the needs of their customer to strategically inform NPD activities was in place, with just over half (56%) responding negatively. This finding was supported by the response to a process related question investigating the stages included in NPD processes, which showed that of those respondents with a formalised process only 65% included a market and customer analysis stage to strategically inform direction for NPD efforts. The findings were not conclusive to prove the hypothesis true, but identified an opportunity for future improvement.

3.3 Idea mortality

Many new ideas do not make it full launch. The sample was asked to provide an idea mortality curve, which represents the progressive rejection of idea or projects through stages of the new NPD process (Griffin, 1997). This showed an average idea to success ratio of 100:3 across the SAP, see Figure 2.

![Idea Mortality Curves](image)

Figure 2 - Idea Mortality Curves

Similar benchmarks from the construction industry were limited, so a comparison was made with findings from the Product Development Management Association (PDMA) Comparative Performance Assessment Studies (CPAS) conducted in 1995 and 2003. The PDMA CPAS surveys are part of a series that are conducted approximately every 5 years to identify trends in process, organisation and outcomes in NPD in the US from a diverse and extensive sample.
Historically, the first published idea mortality curve was from Booz et al (1968) report. At that point in time 100 ideas led to 1.7 successes. By 1982, it took on average 100 ideas to generate 14.3 commercially successful projects (Booz et al, 1982). The 1995 PDMA CPAS survey shows a slight improvement over Booz et al (1982) results, where 100 ideas led to 15.2 successes, but the 2003 PDMA CPAS survey showed a slight decrease where 100 ideas led to 12.8 successes.

In addition to the differences in idea to success ratios between this research and the PDMA CPAS surveys, another important aspect for consideration is the shape of the curve. In her report, Griffin (1997) noted that the differences between the gradients of the curves produced in 1982 and 1995 showed that more ideas were eliminated earlier in the process stages whilst roughly the same numbers of ideas were generating successes. In other words, firms had become more effective at identifying successes and sorting out the wheat from the chaff.

In the results of this study, the idea mortality curve shows that from the business analysis phase through to launch, the gradients (and therefore the idea mortality rates) are comparable to the findings of the 2003 PDMA CPAS survey. However, a higher mortality rate exists earlier in the SAP curve, with an average of 80% of ideas killed at the business analysis phase compared with 55% in the 2003 PDMA Survey, which has a closer correlation to Booz et al (1968) results.

This high early stage idea mortality rate could be due to a number or combination of factors including (but not limited to) more adversity towards risk, regulatory issues, resource constraint limitations to evaluate or develop ideas, low quality ideas to start with, and low perceived importance of NPD. Indeed, there is a possibility that a yield of low quality ideas could be a result of a lack of strategic direction for NPD as discussed earlier in this paper. Gordon et al (1995) discuss the impact of product depth and breadth and the ability of firms to absorb product failures. For example, consider an organisation that has a wide and deep mix of 5000 products that focuses on making incremental improvements to these existing products. A failure of any one product is unlikely to negatively influence customer perceptions of the company nor will it prove detrimental to long-term company profitability. This organisation would be able to focus on speeding products to market, avoiding difficult gate assessment criterion. In contrast, consider an organisation that provides bespoke costly products to a narrow market. A failure of any one product is more likely to have a damaging and lasting effect on corporate image and profits. This potentially provides an explanation for the relatively steep gradient of the idea mortality curve captured within this study.

3.4 Process definition

The literature review indicated that defined processes are essential for successful NPD (Griffin, 1997; Cooper, 2000; Rainey, 2005; and Trott, 2002). Using a formal NPD process and sticking to it has long been a differentiating factor between successes and failures (Cooper, 2000; Griffin 1997). Griffin (1997) suggested that the trend in NPD process over the past 15-20 years have been more evolutionary than revolutionary. The research, which also incorporated previous findings from Booz et al (1968 and 1982), Page (1990), Kuczmański (1993), and McGrath et al (1992), identified 5 primary process approaches for NPD:

- Informal – no formally documented process, but a clearly understood path of the tasks to be completed
- Functional, sequential – formally documented process where one function completes a set of tasks and passes the results on to the next function
- Cross functional stage-gate – formally documented process where a cross-functional team completes a set of tasks, management reviews the results and gives approval for the team to complete the next task
- Cross functional facilitated stage-gate – formally documented process where a facilitating ‘process owner’ helps cross-functional teams move through the stages and gates
- Cross functional 3rd generation stage-gate – formally documented process where a cross functional team uses a stages process with overlapping, fluid stages and fuzzy conditions on gateway decisions.

The 1995 PDMA CPAS survey established that many firms did not use a formal NPD process, with 38.5% of the respondents’ still either using no process at all, or using only an informal process. For this research, the sample was also asked to indicate what type of process they had in place for NPD, using the categories as described above. In this case, 56% of the respondents were using no process at all, or using only an informal process for NPD, considerably more than in the 1995 PDMA survey – see Figure 3.

Of the sample that has a formal process in place, 22% use cross functional facilitated stage-gate (2nd generation) processes compared to 11% for both cross functional stage-gate (1st generation) and cross functional flexible stage-gate (3rd generation) processes. The survey results suggest a lack of defined process adoption and potential immaturity in terms NPD process development.

![Figure 3 - Processes for product development](image-url)
These results were also compared to the findings from the 1995 PDMA CPAS survey. In response to the same question in the 1995 PDMA CPAS survey it was established that the majority (69%) of ‘the best’ performers and (52%) of ‘the rest’ had adopted formal cross functional stage-gate processes for NPD (Griffin, 1997), compared to just 44% in this study.

Results for the application of flexible stage-gate (3rd generation) processes in this study were similar to the results for ‘the rest’ in the 1995 PDMA CPAS survey, with 11% and 12% of the samples using this type of process respectively (Griffin, 1997). However, 24% of ‘the best’ reported use of 3rd generation processes in the 1995 PDMA CPAS survey – more than double the number found to be using 3rd generation processes in this study.

It should be pointed out at this point that may authors suggest that there is no single best practice PDP, where more often situation-specific events and management decision unique to an individual organisation prove to be the main drivers of success (Gordon et al, 1995). Each company should tailor their own PDP to best meet their individual requirements and these requirements change over time. One essential practice to ensure optimisation of processes is through measurement (Parker, 2000). In NPD, process measurement is often in terms of time-to-market (how much time elapses between stages), idea to success ratio (derived from the idea mortality curve discussed previously), and return on investment (Cooper, 2000). The SAP was asked whether they captured and measured the performance of their PDP and of the respondents that had a formalised process in place, 78% measured performance.

3.5 Supporting technologies

Supporting technologies can lead to decreased time-to-market, improved quality, improved manufacturability and smoother transition through the PDP (Öhrwall, 2000). New types of collaboration tools enable the integration of geographically disperse teams along a value chain into NPD teams (Christensen et al, 2003). Geographically dispersed teams benefit from adequate system tools for coordination and communication, reducing the risk of both distortion and misinterpretation of information (Rognes, 2002; Öhrwall, 2000) For example, the internet has created a universal technology platform upon which a number of CPD tools have been developed (Christensen et al, 2003).

The application of these types of technologies was investigated and it was found that 56% of respondents did not use an IT system to support their NPD activities. Where IT tools were in place they could be divided into two categories; CAD/CAM solutions and Idea Management Software. Interestingly, the SAP use a Collaborative Working Environment to share project information but no single respondent identified this as a potential tool for improved CPD.

3.6 Success factors for Collaborative Product Development

Littler et al (1995) researched the risks and benefits of CPD as well as the key success factors for such relationships. They identified 7 key categories from the literature and provided the summary as in Table 1.
### Table 1 - Success factors for CPD (Littler et al, 1995)

<table>
<thead>
<tr>
<th>Factor identified</th>
<th>Specified by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting up the collaboration (Choice of appropriate collaborative partner; specification of clear goals; responsibilities and accountabilities; establishment of limits in terms of the information to be shared as part of the collaboration)</td>
<td>Anderson &amp; Narus (1990); Blecke &amp; Ernst (1991); Devlin &amp; Bleackley (1989); Farr &amp; Fischer (1992); Gyenes (1991); Hamel et al (1989); Harrigan (1986); Lorange (1988); Lynch (1990); Lyons (1991); Nueno &amp; Oosterveld (1988); Perlmutter &amp; Heenan (1986)</td>
</tr>
<tr>
<td>Process Management (Frequent monitoring of progress; frequent consultation between partners and between marketing and technical personnel in particular; maintenance of flexibility; development of trust)</td>
<td>Anderson &amp; Narus (1990); Blecke &amp; Ernst (1991); de Young (1990); Dodgson (1993); Gugler (1992); Lorange (1988); Lynch (1990); Lyons (1991); Perlmutter &amp; Heenan (1986)</td>
</tr>
<tr>
<td>Allocation of resources (Sufficient financial resources; sufficient staff resources)</td>
<td>Lawton-Smith et al (1991); Lorange (1988)</td>
</tr>
<tr>
<td>Personal involvement (Involvement of senior management; personal chemistry between staff; presence of collaboration champion)</td>
<td>Devlin &amp; Bleackley (1989); Forrest &amp; Martin (1992); Lawton-Smith et al (1991); Lynch (1990)</td>
</tr>
<tr>
<td>Ensuring equality (Of perceived contribution and benefits between partners)</td>
<td>Bleeke &amp; Ernst (1991); Devlin &amp; Bleackley (1989); Lynch (1990); Lyons (1991);</td>
</tr>
<tr>
<td>Past experience of collaboration management</td>
<td>Farr &amp; Fischer (1992); Rice (1991)</td>
</tr>
<tr>
<td>Assessing external factors (Attention paid to monitoring environmental changes)</td>
<td>Lynch (1990)</td>
</tr>
</tbody>
</table>

The factors identified by Littler et al (1995) in Table 1 were investigated further in their study of UK Manufacturers of Information and Communications Technology Products. Their survey respondents were asked to freely indicate the major factors which contributed most to successful CPD. An open-ended question format was used and the results obtained were categorised by the researchers. These categorised responses were then grouped further to reveal six types of response that were frequently mentioned, namely; choice of partner, establishing the ground rules; ensuring equality; process factors; people factors and environmental factors (Littler et al (1995)).

The most frequently mention factor was the need for establishing ground rules, by both experienced and less experienced respondents. Managing to ensure equality was the second most mentioned factor offered by the respondents. Factors relating to the people and choice of partner were areas of considerable importance, especially by respondents with more experience of CPD, and were the third and forth most frequently mentioned factor respectively.

In this study, the respondents were asked to rate the importance of the six key types of success factors identified by Littler et al (1995) on a scale of very low, low, medium, high and very high importance.
It was found that the SAP considered people factors of most importance, see Figure 4. Both factors relating to the choice of partner and establishing the ground rules were jointly rated as the second most important criterion for successful CPD. Therefore the top 3 factors considered most important for successful CPD by the SAP correlate to 3 of the 4 most mentioned factors found in Littler et al (1995) study. However, ensuring equality was only ranked as the 5th most importance factor, although it was still considered of high importance.

![Figure 4 - Perceived success factors for CPD](image)

<table>
<thead>
<tr>
<th>Success factor</th>
<th>Mean average score</th>
<th>Mode average score</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>People factors — such as, commitment at all levels, appointed roles/leads, personal relationships, adequate time and resource, reward and recognition</td>
<td>4.44</td>
<td>5.80</td>
<td>0.75</td>
</tr>
<tr>
<td>Choice of partner — such as, complementary expertise/strengths, culture/mode of operation and past collaboration experience</td>
<td>4.33</td>
<td>4.80</td>
<td>0.71</td>
</tr>
<tr>
<td>Establishing the ground rules — such as, clearly defined goals and responsibilities; defined project-colleagues, and realistic aims</td>
<td>4.33</td>
<td>4.80</td>
<td>0.71</td>
</tr>
<tr>
<td>Process factors — such as, frequent communication, regular reviews, integrated/advisory processes, effective collaboration tools, trustworthiness, and flexibility</td>
<td>4.00</td>
<td>4.80</td>
<td>0.50</td>
</tr>
<tr>
<td>Ensuring equality — such as, mutual benefits, equality in power/dependency, and equality in contribution</td>
<td>4.00</td>
<td>4.80</td>
<td>0.87</td>
</tr>
<tr>
<td>Environmental factors — such as, un paired/customer need for product/service</td>
<td>4.00</td>
<td>5.80</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Although factors relating to people, such as appointed teams and roles, were considered the most important factor for CPD, the research also showed that the majority of SAP members used part-time roles for managing NPD, see Figure 1.

### 4 KEY FINDINGS AND RECOMMENDED ACTIONS

The study found that over 50% of the SAP does not have a formalised PDP in place. It consistently features in the literature as an essential ingredient for successful NPD. One potential action could be the introduction of an alliance wide CPD process. However, several authors have noted that practitioners often make the mistake of assuming that ‘it worked there, so it will work here’. NPD processes need to be tailored to meet the specific needs of the organisation in question.

- **Recommended Action 1:** Work with the SAP to introduce more formalised and collaborative processes across the alliance, whilst allowing enough flexibility for processes to be tailored to suit the individual needs of each SAP member.

According the survey results, 78% of the respondents capture and measure the performance of their NPD efforts. One difficultly encountered whilst conducting the study and analysing the results was the lack of appropriate benchmarking data for the construction industry.
To provide more meaningful metrics, the SAP need to not only compare performance metrics across the alliance, but also with the wider industry.

- Recommended Action 2a: Define standard key performance indicators for NPD performance within the SAP and benchmark performance across the alliance
- Recommended Action 2b: Conduct a study to benchmark NPD performance of the wider UK Construction Industry

The study highlighted that the SAP lacked dedicated full-time resource for the leadership and management of NPD. Once again, this is frequently identified in the literature and other studies as a key factor for the success of both intra and inter-organisational NPD. Part-time resources for NPD suggest that product development might not be high priority in the SAP, but this contradicts the finding that the vast majority of the SAP considered NPD as of major importance for their businesses.

- Recommended Action 3: Define and appoint shared roles and responsibilities for CPD, alleviating resource strain and increasing the integration of teams

The literature highlighted the need for NPD Strategy. The study suggested that NPD projects in the SAP were more likely to be triggered from a reactive situation, as opposed to proactive identification of a challenge or opportunity. The study also found that a high proportion of the sample did not have a formal method and procedure in place for capturing the needs of the customer.

- Recommended Action 4: Implement specific SAP NPD Strategies that incorporate the needs of the customer and market insights to focus and steer NPD efforts

5 CONCLUSIONS

There is an abundance of excellent literature and research material relating to the subject of NPD, most commonly within the domain of manufacturing. It was found that research in this field within the context of construction is somewhat limited. This study has shed new light on NPD in construction, investigating the NPD capability and performance of a major Construction Strategic Alliance Partnership based in the UK and drawing recommendations for future improvement.

The study revealed that NPD is considered as of major importance for construction business success, directly supporting the ‘lifeblood’ type statements that frequently make appearances in the literature. Equally, this research established that a healthy appetite for more CPD exists across the alliance. This issue here is not one of desire or recognition of the need for Product Development, but one more about improving NPD capabilities and performance.

It was found that the NPD capabilities of the individual companies within the alliance were relatively immature in terms of people, process and technology when compared to benchmark data and best practices from industries more commonly associated to NPD. Defined processes for NPD and dedicated roles and responsibilities for its leadership, both consistently reported as essential ingredients for successful NPD in the literature, were lacking in the SAP. The application of strategies for NPD, including customer and market insights, was not consistent across the SAP and the perceived importance of the customer role in NPD was low.
Appendix 3

It could be argued that the relative immaturity of NPD capabilities in the SAP are reflected in the performance metrics captured in the study. The idea mortality curve suggested that the idea to success ratio for the SAP was considerably less than benchmarks from the PDMA CPAS surveys. However, it should be noted that we’re not truly comparing apples with apples here. The depth and breadth of an organisation’s product mix should be taken into consideration when assessing NPD performance. In an industry where the end products are often bespoke, costly, complex and subject to extensive regulations and controls in a highly competitive market where one mistake could permanently damage both reputation and profits it might be fair to expect a slightly more reserved attitude towards risk. The challenge is learning how to manage those risks and adapting NPD work in the construction environment. This requirement for comparative data highlighted the need for capturing the NPD practices, trends and benchmarking of best practices in the UK construction industry.

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APPENDIX 4  PAPER 4

KEY INFLUENCES OF INNOVATION MAGNITUDE AND MODE

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ABSTRACT
There is plenty of recognition of the need for more innovation in the construction sector. Increasing levels of competition, rapid technological and regulatory change, the current economic climate and environmental concern all accentuate this requirement. In response, many construction firms are seeking ways to manage innovation more actively and conscientiously in order to remain competitive. However, there is little practical guidance for construction professionals on how to make innovation flourish in their teams. Those who aspire to improve the management of innovation will need to understand how innovation happens, what are the driving forces and how can they be influenced. This paper reports on an empirical investigation that was undertaken to explore some of these questions, specifically the role of organisational climate, customers, risk and complexity on the levels of innovation in teams and the various modes of innovation that prevail - with the aim of providing practitioners with clearer guidance on where efforts should be focused. The findings suggest that there are a limited number of fundamental factors that significantly influence innovation magnitude and mode. For industry professionals it is hoped that this stimulates debate and assists in establishing a much needed foundation for improved innovation management in construction.

KEY WORDS: Management, Research and Development, Statistical Analysis

1 INTRODUCTION
The need for change and improvement in the construction industry has been well documented (Egan, 1998; Fairclough, 2002). Indeed, it is argued that the industry is facing some of its greatest challenges yet, including increased competition, radical technological change, increasing product complexity, tougher regulations and the need to minimise environmental impact, and as a consequence this need for change has never been greater.

It is through innovation, which can be defined as ‘the successful exploitation of an idea’ (DTI, 2003), that construction firms will be able to create solutions in response to many of these
challenges. As a result, innovation is becoming an ever more essential ingredient for winning work and increasing profitability in the sector (Seaden et al, 2003; Tatum, 1991), with more and more construction firms recognising the need to manage innovation in a more strategic and conscientious manner (Hartmann, 2005; Wamuziri and Madan, 2009).

The premise of this paper is that in order for construction firms to achieve improvement in the management of innovation, they will first need to establish a firmer understanding of how innovation is realised in practice. In other words, organisations need to be clear about what they are trying to manage; as the rest of this paper will attest, innovation comes in many different forms.

However, understanding the modes of innovation is not enough. Construction firms will also benefit from gaining a better understanding of the driving forces behind these events. Although there has been a recent spate of research into the driving and restraining forces for innovation, little empirical work has been carried out in construction firms to validate the theory.

This paper presents an overview of a recent research project, conducted and led by a large UK construction, facilities and associated services firm, which aimed to empirically investigate how innovation is realised in practice and what factors significantly influence these activities. The findings from this research are hoped to help inform and reinforce future strategic decisions relating to the management of innovation and its capitalisation in construction firms.

2 RESEARCH METHODOLOGY

The research project was divided into five stages, where the output from each stage was required for the subsequent stage, see Figure 1.

A variety of recognised research methods were implemented across the stages. Key activities included:

- An extensive literature review – to establish current ‘state of the art’ construction innovation management, including theory on the driving and restraining forces of innovation. These findings were used to inform the development of the input model.
- Input model – to visually represent the key variables of innovation magnitude and mode and their hypothesised causal relationships, as identified in the literature review. The input model was also used to guide the survey content and structure.
- Survey design and field study – designed to collect the necessary data to validate the input model. Each factor included in the input model was measured in the survey, using
multiple items and previously validated scales from the literature where possible. The
survey was administered in June 2009 and the sample included 93 people in 12
autonomous teams working in various managerial and technical roles. A total of 69
complete and usable responses were received (achieving a very satisfactory response rate
of 74 per cent) with appropriate representation from 11 teams.

- Data analysis – Path Analysis was used to analyse the survey data to provide estimates of
  the magnitude and significance of hypothesised casual connections between the sets of
  variables included in the input model. The product of this analysis is an output model.
- Output model - a revision of the input model which shows what was actually observed in
  the data, based on established statistical methods. This output model was used to assess
  which variables had the greatest influence on innovation magnitude and mode.

3 DEVELOPMENT OF THE INPUT MODEL

This section of the paper presents an overview of the theory and draws out the critical factors
for inclusion in a theoretical input model of innovation at the project/team level. The input
model attempts to describe the variables that influence team innovation performance and
modes of innovation, and shows the hypothesised causative relationships between these based
on the literature, see Figure 2. The rest of this section explores each variable in turn, including
a brief review of the supporting literature.

3.1 Innovation mode

How does innovation happen in construction? Without a clear understanding of this, how can
firms improve their management of innovation?
The construction industry is often criticised for resisting change and is frequently characterised as one that fails to innovate in comparison to other sectors. Traditional measures of innovation, such as investment in formal research and development (R&D) and number of patents awarded, only lend support to such criticism. Indeed, during 2008 construction sector investment in R&D as a percentage of sales was mere 0.4 per cent, which is markedly less in comparison to other industry sectors (BERR, 2008).

However, are these traditional measures of innovation representative of how innovation is realised in the sector? Recent work by the National Endowment for Science, Technology and the Arts (NESTA) suggests that these traditional measures are based on a formal R&D ‘pipeline’ model of innovation that is increasingly less relevant, and that they fail to measure the form of innovation that dominates many sectors – including construction (NESTA, 2007).

To increase understanding of innovation it is essential to acknowledge that learning, research and development is not solely restricted to the R&D department in construction firms (Gann and Salter, 2000). Innovation in construction often takes place locally, at the micro-level on projects, and is very much an intrinsic part of the day-to-day problem solving and ‘learning by doing’ nature of the sector, where research is conducted and expertise is developed during the course of a project (Gann and Salter, 2000).

Insightful work by Winch (1998) highlights the important role that this informal mode of innovation plays in the construction firm, and asserts that solutions resulting from problem-solving and learning by doing type activities on projects must be captured, learned, diffused and applied on future projects before it can be considered as innovation. Most top managers in construction indicate that innovations are usually developed in this way (Nam and Tatum, 1997).

Other researchers have emphasised the need to distinguish between this mode of informal innovation, which is often incremental in its nature, and the concept of general improvement. The general consensus is that innovation must involve a creative, inventive or exploratory step and result in a tangible benefit in the firm concerned, whereas general improvement may not necessary incorporate invention or result in a firm wide impact on performance (NESTA, 2007).

Of course, innovation also occurs at a more strategic level in construction firms. One such route is via formal R&D activities, but R&D intensity figures for the industry would suggest that this is not a favoured method of innovating in the sector (BERR, 2008). Other activities at a more strategic level include decisions concerning the adoption and implementation of new technologies, products, materials and processes sourced externally from the firm (Winch, 1998).

So what are the typical characteristics which can be used to define these formal and informal modes of innovation? Interviews with industry practitioners indicates that formal innovation is more likely to be triggered proactively, in anticipation of a future opportunity or challenge, and have a longer-term focus in comparison to informal, learning by doing modes of innovation (Shaw and Bouchlaghem, 2008). It is also argued that formal innovation is less likely to be bound by traditional project constraints (Hartmann, 2005; Shaw and Bouchlaghem, 2008) but is conducted ‘off-line’ from daily operations - often as a project in its own right. Because of this it, this mode of innovation is commonly subjected to more rigid
processes and controls, similar to new product development processes used in the manufacturing industries. The longer time scales often involved provide greater opportunity for a more outward focus and often enables collaboration with customers, suppliers and the scientific community.

Conversely, it is proposed that informal innovation is much more likely to be a reactive event, triggered in response to solve a problem or seize an opportunity. This form of innovation is typically practitioner led, and often occurs in the project environment where it will be constrained and pressured by project time frames and budgets (Hartmann, 2005; Shaw and Bouchlaghem, 2008) To successfully exploit an idea in this type of environment requires agility and autonomy, working with the people and expertise at hand rather than seeking additional internal or external support.

From this it is reasonable to distil at least four attributes that can be used to help differentiate formal and informal innovation; the trigger event (reactive versus proactive), the focus of the innovation (short-term need versus long-term opportunity), the method of development (flexible, ad-hoc and bespoke processes versus rigid, structured and established processes), and the source (internally centred versus externally centred activity).

Surely to achieve improved management of innovation it is essential to understand these different modes of innovation, as contingency theory would attest that they need to be managed in different ways (Winch, 1998)? In order to explore the relationships between innovation mode and innovation magnitude, the four attributes highlighted above were included in the input model, see Figure 2.

In addition to establishing a better understanding of the modes of innovation in construction, it is also essential to ascertain the driving and retaining forces that influence levels of innovation. Current research on the topic reveals convergent themes, largely centred on the impact of organisational climate for innovation and the role of the construction customer.

3.2 Climate for innovation
The role of climate and its influence on innovation performance continues to receive considerable attention from researchers and practitioners alike. However, the notion of climate is complex and frequently misunderstood. Therefore, it is perhaps useful to first provide a brief definition and briefly discuss related difficulties.

3.2.1 Definition of climate
There are conflicting views regarding the notion of climate (Baer and Frese, 2003) since there are both theoretical and disciplinary differences in what climate represents (Patterson et al, 2005). For the purposes of this research the predominant approach was selected, which conceptualises climate as employee’s shared perceptions of organisational policies, practices and procedures (Patterson et al, 2005). The principal is that if people in an organisation share similar perceptions of a psychological climate dimension, it is legitimate to aggregate these individual perceptions into a composite indicator of climate (Baer and Frese, 2003). This leads to the next complexity, what unit of analysis should be selected to represent a collection of shared perceptions?
3.2.2  Level of analysis

Researchers have studied climate at different levels of analysis, such as proximal work groups, departments or organisation (Patterson et al, 2005). This is commonly achieved by aggregating individual scores from psychometric questionnaires to the desired level, using the mean average to represent the climate at that level. The rationale behind this is that the diversity and sheer size of many organisations warrant a more micro-analytical examination of shared perceptions at the level of the work group, team or sub-unit (Anderson and West, 1998). Indeed, there are real concerns about the extent to which agreement of climate perceptions can be demonstrated across entire organisations.

This assertion seems particularly logical when considered in the context of the typical construction firm, which consists of multiple, semi-autonomous, temporary and fragmented teams which, when considered in their widest sense, include team members from outside the boundary of the firm. Logic suggests that it is unreasonable to expect consistent and shared perceptions across an organisation of such a complex and dynamic nature. Therefore in this research climate was investigated at the proximal team level, which has been eloquently defined by Anderson and West (1998, p236) as ‘the permanent or semi-permanent team to which individuals are assigned, whom they identify with, and whom they interact with regularly in order to perform work related tasks’.

3.2.3  Climate dimensions

Many researches in the field of organisational psychology attest that it is meaningless to apply the concept of climate without adopting a facet-specific approach, where climate has a focus on a dimension of interest – often dependant on the purpose of the investigation (Patterson et al, 2005; Anderson and West, 1998). As a result a plethora of measures for various dimensions of climate have been developed, many of which are concerned with innovation at various levels of analysis.

Once such measure which has demonstrated robust reliability and validity is the short version of Anderson and West’s (1998) Team Climate Inventory (TCI). Their work has indentified four factors that are highly influential in an organisational climate for innovation. These are summarised below:

- **Vision** – A concern with providing clear, high order, organisational goals and a motivational force at work – reinforcing team member understanding and commitment to objectives (Anderson and West, 1998). Previous research in construction firms has also suggested that innovation needs to become a shared value within a firm for it to flourish (Hartmann, 2005).
- **Task orientation** – A shared concern with excellence in task performance, characterised by overtly reviewing and reflecting upon objectives, strategies and work processes, in order to adapt to the wider environment (De Dreu, 2002; Anderson and West, 1998) Research in the construction sector has provided evidence that worker autonomy and flexible role definitions have a significant influence on innovation performance (Winch, 2000).
- **Participatory safety** – An employee’s sense of being able to express one’s self without fear of negative consequences and where involvement in decision making is encouraged and reinforced (Anderson and West, 1998).
- **Support for innovation** – The extent of articulated and enacted encouragement, expectation, approval and practical support of attempts to successfully exploit ideas and
deliver innovation in the work environment (Anderson and West, 1998). Perceived support for innovation has been consistently shown to be significantly related to levels of innovation in construction teams (Dulaimi et al, 2005).

However, it should be recognised that there are also a number of factors external to the typical construction firm that are widely considered to influence both innovation magnitude and mode, in particular the role of the customer.

3.3 Customer profile

The importance of the customer role in innovation is a theme echoed across industries (Winch, 1998). In the manufacturing industry this role is generally passive but held in high regard, where innovation is supported by the capture, interpretation and validation of both expressed and latent customer needs for input into new product development processes (Cristiano et al, 2000). Customers of the construction industry play a much more active and integrated role throughout the project lifecycle and are considered to be highly influential in the delivery of innovation (Blayse and Manley, 2004; Nam and Tatum, 1997).

Conceptual and empirical investigations on the role of the customer in construction innovation have drawn out a number of consistent attributes that are supportive of an environment that fosters innovation (Blayse and Manley, 2004).

Sustained and long-term relationships between customers, contractors and designers are known to be conducive for innovation (Nam and Tatum, 1997). These types of relationships are often underpinned by a culture of trust, commitment and understanding between parties (Wamuziri and Madan, 2009), which is related to the concepts of climates for psychological safety, vision, task orientation and support for innovation discussed earlier in this paper.

Frequent interaction and engagement with customers is beneficial for the generation of innovation in a number of ways. Regular contact can decrease idea approval times, provides more opportunity to discuss needs and explore alternatives, and can provide a good basis to reinforce relationships.

There is also much evidence that customers with a broad experience and familiarity with the construction industry often have a positive impact on innovation and its diffusion (Hartmann, 2005; Nam and Tatum, 1997). Customers often gain this experience through engagement in repeat construction activity and from this develop increased technical knowledge and awareness of the specific challenges embedded in the industry – reinforcing the role of relationships and interaction.

Increased technical awareness is closely related to active participation in projects, better understanding of technical issues, and the ability to overcome the uncertainty of construction innovation - resulting in timely approval and support of new ideas (Nam and Tatum, 1997).

Customers who not only accept innovation but expect it, are often more successful at stimulating innovation (Barlow, 2000). Once again, strong parallels exist between customer demand patterns, the level of technical competency, construction experience and the strength of relationship. Perhaps more experienced customers attach more value to long-term relationships, which in turn increases technical competency, ambition and expectations?
3.4 Work profile
Perceptions of risk, whether at the industry, firm or project level, can exert a significant influence on both the magnitude and management of innovation (Tidd, 2001). This is extremely topical, given the challenges faced in the current market conditions. The notion of complexity is also considered to play an influential role, where complexity is considered to be a function of the number of technologies and their interactions (Kivimäki and Elovaino, 1999). Although risk and complexity are not necessarily highly correlated, greater levels of complexity often leads to increased risk as the number of technologies and interactions grow. Precisely how these contingencies independently or collectively affect the degree, type and management of innovation is less clear and more empirical research has been called for.

In addition to the factors discussed above, the literature review revealed a number of other explanatory variables for innovation performance in the sector, but due to the need to control the size and complexity of the input model of innovation to ensure its appropriateness for analysis it was decided to focus only on these dominant themes at this stage.

4 SURVEY DESIGN AND FIELD STUDY
The input model and the supporting literature were used to guide the design of the 43 item field study survey. For each factor identified in the input model the survey had a corresponding set of items designed to measure it. Wherever possible, previously validated scales and multiple items where used in the survey to improve reliability and validity. All composite measures included in the model were checked for reliability and provided a Cronbach’s alpha > 0.70, a commonly adopted and acceptable level for internal reliability (Hair et al, 2005).

The survey was administered in June 2009 and the sample included 93 randomly selected people from 12 autonomous teams working in various managerial and technical roles. A total of 69 complete and usable responses were received (achieving a very satisfactory response rate of 74 per cent) with appropriate representation from 11 teams.

4.1 Survey measures
Risk and complexity were measured using single items by asking respondents to rate the perceived risk and complexity of their project on a scale of 1 (very low) to 5 (very high), following a similar format to Dulaimi et al (2005).
A slightly modified version of Anderson and West’s short version of the Team Climate Inventory (TCI) was used to measure the perceived climate for innovation (Kivimäki and Elovaino, 1999). The TCI (short version) includes 4 factors; vision (4 items), task orientation (4 items), participatory safety (5 items) and support for innovation (4 items). All items were measured on a five point scale.
Customer profile was assessed using 7 items on a five-point scale. The authors developed 7 items based on the literature to provide a rounded definition of the role and influence of the customer on innovation levels including; attitude to risk, willingness to sponsor new ideas, construction experience, technical competence, relationship strength, frequency of interaction, and levels of expectation.
Innovation mode was measured using 4 items on a four-point scale to capture the typical trigger of innovation (proactive versus reactive), the focus of efforts (long versus short-term), the method of realisation (formal versus informal) and the source (internal versus external to the company).
Level of innovation was measured using a slight modification of the items adopted by Dulaimi et al (2005). The construct reflects the degree of perceived ability to innovate in the workplace, including the generation and exploitation of new ideas which lead to the introduction of improved processes, technologies and materials.

5 ANALYSIS OF RESULTS

5.1 Factor analysis

In order to examine any underlying dimensions and to determine whether the data could be reduced (by combining variables into summated scales) the 7 items that made up the customer profile construct were subjected to principal component analysis (PCA). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.551, exceeding the minimum acceptable value of 0.5 (Hair et al, 2005), and the Bartlett’s Test of Sphericity was significant (p=0.000), indicating suitability of the data for factor analysis. The ratio of sample size to number of variables was almost 10:1, where the recommended minimum ratio is commonly considered to be 5:1 (Hair et al, 2005), lending further support to the factor analysis.

The factor analysis of the 7 customer profile variables produced a 3 factor solution that explained 66.89% of the variation. All 3 factors had eigenvalues greater than 1 and interpretation of the scree plot also suggested that 3 factors should be extracted. Only items that loaded on a single factor with loadings greater than 0.65 were retained, based on good practice guidelines defined by the sample size (Hair et al, 2005). Of the original items 2 failed to load substantially on any of the factors and were subsequently removed from the analysis. The factors were interpreted as follows:

- Factor I, which accounts for 26.56% of the variance, comprised of 2 items from the original construct which are concerned with the strength and quality of relationship with the customer and the frequency of interaction experienced. The factor was considered conceptually clear and was named commitment. Cronbach’s alpha for this factor as a composite scale on the sample was 0.72 indicating acceptable levels of homogeneity and reliability.
- Factor II accounted for 20.25% of the variance, but included only a single item concerned with customer attitude towards risk. Items relating to customer technical competence and willingness to sponsor new ideas also loaded on the factor (0.621 and 0.543 respectively), but did not meet the required level of loading (>0.65). Cronbach’s alpha for this factor was unsatisfactory and was therefore not included in the path analysis.
- Factor III accounted for 20.08% of the variance and comprised of 2 items, the first representing the customer’s actions towards setting tough and ambitious targets and the second concerning the level of experience in construction. The factor demonstrates the role of the customer in terms of ‘pulling’ innovation and understanding the nature and complexities of the industry, and was therefore named leadership. Cronbach’s alpha was 0.75.

5.2 Path Analysis

The data was checked for normality and absence of multicollinearity. In addition to examining the normal probability plot for each variable, statistic tests of normality based on skewness and kurtosis values (Hair et al, 2005) revealed no statistically significant deviations. All of the factors in the model were represented by either single variables or summed scaled measures, resulting in a single indicator per factor. The recommended ratio of sample size to
number of variables should be between 5:1 and 10:1 (Hair et al, 2005); in this study the ratio was 1:5.31 and therefore falls within acceptable limits.

The results from the survey were evaluated using path analysis, a simple extension of hierarchical multiple regression (Pedhazur, 1982). This technique aims to provide estimates of the magnitude and significance of hypothesised causal relationships between sets of variables in the input model. As presented earlier in this paper, the input model (Figure 2) depicts the variables and predicted causal relationships identified in the literature. Path analysis can then be applied to compute a path coefficient for each connection between variables to provide a steer on which casual hypotheses from the input model are better supported by the data. This is achieved by conducting multiple regression analysis on each endogenous variable in the model, predicting the dependant variable from all directly related explanatory variables. The standardised beta weights from these multiple regressions are the path coefficients used in the path analysis output diagram, see Figure 3.

The path coefficients can be interpreted in exactly the same manner as betas derived from multiple regression analysis. For the purposes of interpretation, the squared value of a path coefficient provides the proportion of the dependent variable’s variance that is caused by the explanatory variable (i.e. explanatory variable X describes n% variation in dependant variable Y). Path coefficients from extraneous variables and those with an absolute value less than 0.1 have been omitted for visual clarity.
6 DISCUSSION

This study has provided a unique insight into the relationships and significance of a number of variables and their influence on innovation magnitude and mode in the context of a construction firm. In particular, the study has highlighted the complexity and role of innovation mode as a mediating factor for innovation performance in the construction context, which has received limited attention in previous research efforts.

In this study innovation was typically seen as a short-term, internal and reactive activity, which was dealt with on a more informal, ad-hoc basis – interwoven into the day-to-day problem solving nature typical of the construction sector. There were also examples of teams and individuals adopting a longer-term, proactive and formal approach towards the exploitation of innovation, although such approaches were observed less frequently across the sample. This provides empirical evidence for the existence of different modes of innovation in construction beyond the more formal R&D and ‘pipe-line’ management approaches. Furthermore, the findings suggest that the mode of innovation itself influences perceived levels of innovation, with teams and individuals adopting a longer-term focus combined with a more informal approach towards the exploitation of innovation reporting greater innovation success in the workplace.

Achieving a long-term focus for innovation is a challenge in the construction context, since most innovation activities are bound by individual project timeframes and budgets. Professionals concerned with the management of innovation will need to find ways to encourage a longer-term view, one that is frequently reviewed and communicated across teams, that stretches beyond the needs and limitations of an individual project. Part of the answer might be through the provision of an organisational climate that encourages both task orientation and participatory safety, both shown in this study to significantly influence innovation focus.

The results showed that organisational support for innovation was the strongest predictor of innovation and was the only climate dimension that directly and significantly influenced levels of innovation. Where teams perceived greater organisational support for innovation they were found to be more likely to proactively initiate activities with the goal of achieving innovation. These proactive events, by their nature, allow for longer-time scales and therefore increase the likelihood of successful exploitation, as previously discussed.

In practical terms organisational support for innovation should form a priority for firms seeking to improve their innovation outlook, but the findings suggest that managers need to exercise caution and provide balanced solutions that support both formal and informal modes of innovation. Failure to support informal methods of innovating was found to have a negative impact on perceived levels of innovation in the study. The majority of existing guidance for the management of innovation focuses on formal methods of delivery, much of it inspired from practices well established in the manufacturing sector, and more guidance for the support of informal modes is called for.

In contrast to previous research (Dulaimi et al, 2005) it was found that higher levels of perceived complexity were moderately associated with increased levels of innovation. It is anticipated that the increased number of technologies and interactions present in more complex environments provide more opportunities for the development and application of new ideas, technologies and processes. On a more general note, it seems that employees of
technical businesses tend to thrive on complex challenges – particularly when the problem to solve has been carefully defined and the associated risk is managed. Managers and strategy makers might wish to seek to benefit from this attribute, and purposefully select, refine, communicate and engage the workforce in ‘off-line’ collaborative problem solving projects for the ‘big issues’, as defined by the business and its customers. Risk was found to have an influence on the method of innovation, encouraging a more formal and structured approach when perceived risks were higher, which is in keeping with logical reasoning.

The level of customer commitment, measured in terms of strength of relationship and frequency of interaction, had a direct impact on team innovation levels. Trust, transparency and understanding between parties are frequently cited as key enablers for innovation in construction literature and the data supports these assertions. Surprisingly, the variables associated with customer experience and demand for innovation did not reveal a significant relationship with the level of innovation, despite their reference in the literature (Blayse and Manley, 2004). These variables did however influence the method of innovation, where customers who articulated a greater demand for innovation and had previous experience as construction customers encouraged teams to adopt a more formal approach to innovation. It is thought that this is perhaps a result of teams attempting to demonstrate and measure innovative activities to meet the expectations of more demanding customers.

7  CONCLUSIONS

Construction firms have recognised the need to manage innovation more actively and conscientiously to remain competitive in today’s dynamic and challenging business environment. This is not a task to be underestimated. Innovation in construction is complex, multi-faceted and sensitive to underlying cultural and climatic forces. Such forces are notoriously difficult to manage in construction organisations, where teams are often fragmented and of a temporary nature. A fundamental step towards the true achievement of improved management of innovation requires a better understanding of the dynamics of innovation at the firm and project level, equipping managers and strategy makers with the knowledge required to support innovation from grass roots through to the board room.

This paper has reported on an empirical investigation of the role of organisational climate, customer profile, risk and uncertainty on levels of innovation in proximal teams and the various modes of innovation that prevailed in a major UK construction, facilities and associated services firm. The resultant model reveals both the magnitude and relationships between the variables selected for investigation, contributing to current knowledge of the hidden dynamics of innovation in the construction firm. This insight is hoped to provide some important clues for those who seek to improve the innovation outlook of their firms.

However, there is still much to learn and more research is required. Our future work will focus on further developing and refining the model, addressing the need for more rigorous and extensive analysis of the influencing factors of innovation magnitude and mode, and providing practical guidance for managers and strategy makers in construction who have the ambition of making innovation thrive in their organisations.

7.1  Limitations

As with most forms of statistical analysis there are a number of limitations that need to be expressed. The data collection relied on responses based on perceptions rather than actual practices and as such the self-reporting may have potentially exposed results to bias, although
established practices to mediate for this were adopted. The size of the sample was small (n=69) but sufficient to meet the aims of this research. As with any study using a small sample caution should be exercised when generalising the results, but the findings do provide useful directions for future work. It is recommended from this study that future research is conducted in different project settings for cross comparisons and further development of the model in order to draw more robust conclusions.

The application of path analysis to evaluate relationships amongst variables has become a popular technique. Within a given path diagram, path analysis can tell us which are the most important and significant paths in a given diagram, and this may have implications for the plausibility of any causal hypotheses, but path analysis cannot tell us which of two distinct path diagrams is to be preferred or establish the direction of causality between correlated variables (Everitt and Dunn, 1991).

8 REFERENCES


APPENDIX 5  QUESTIONNAIRE A
Questionnaire A (first research cycle)

The survey should take about 10 minutes to complete.

Please read each question carefully and feel free to be frank! There are no right or wrong answers and everything you submit will remain anonymous.

We want to hear your opinion, so please do not confer with others taking part in this survey.

Thanks for your support and we look forward to your feedback.

1) The term 'innovation' is often difficult to define and can mean different things to different people. We'd like to hear your definition of innovation. Please tell us what innovation means to you in the space below...

Thinking in terms of your team, to what extent do you agree with the following statements?

2) People struggle to come up with ideas in this team [r]

3) The team is always quick to spot a promising idea

4) We are always able to exploit our best ideas in this team

5) I am satisfied with the level of innovation in this team

6) What are the top 3 things that are impeding innovation in your area?
   * ...
   * ...
   * ...

7) What are the top 3 things that are promoting innovation in your area?
   * ...
   * ...
   * ...
8) What level of practical support is available to you for attempts to try out new ideas and improve the way we work?

- No support
- Poor support
- Satisfactory support
- Good support
- Excellent support

9) How good are your leaders in communicating the vision and need for change?

- Very poor
- Poor
- Satisfactory
- Good
- Very good

10) What’s your perception of the division’s enthusiasm for innovation? - Do you think we want to do things better?

- Visible discouragement of trying new ideas
- Some discouragement of trying new ideas
- Neither encouragement nor discouragement
- Some encouragement of new ideas
- Active demand and encouragement if new ideas

11) Do you have goals and targets for innovation?

- No goals or targets set
- Irregular goals or targets set
- Regular goals and targets set
- Detailed and regular goals and targets set

12) To what extent are people encouraged and recognised for ideas and entrepreneurial actions?

- Not at all
- To a small extent
- To a moderate extent
- To a great extent
- To a very great extent

13) How would you rate people’s empowerment to try new initiatives?

- Very poor
- Poor
- Average
- Good
- Very good

14) How effective are people at borrowing and implementing ideas from outside your area?

- Very poor
- Poor
- Average
- Good
- Very good
15) Is there time or resource for people to be creative and try new things in your team?

- Very poor levels of time and resource
- Poor levels of time and resource
- Satisfactory levels of time and resource
- Good levels of time and resource
- Very good levels of time and resource

16) Please provide any general comments you may have on innovation

END
APPENDIX 6  QUESTIONNAIRE B
Questionnaire B (second research cycle)

The survey should take about 20 minutes to complete.

Throughout the survey we have used the term ‘team’, by this we mean the immediate group of people you work with on a regular basis in order to perform your role – for example, this could be your current project team or business department.

Please read each question carefully and feel free to be frank! There are no right or wrong answers and everything you submit will remain anonymous.

We want to hear your opinion, so please do not confer with others taking part in this survey.

Thanks for your support and we look forward to your feedback.

Please tell us a few details about you and your team (this is to help us with the analysis of results and to ensure that we get feedback from a representative sample – your individual responses will remain anonymous)…

a) How would you describe your level of responsibility?
   - Director
   - Senior Management
   - Management
   - Non-management

b) What is your age group?
   - 24 years or less
   - 25-34
   - 35-44
   - 45-54
   - 55 years or more

c) The term 'innovation' is often difficult to define and can mean different things to different people. We'd like to hear your definition of innovation. Please tell us what innovation means to you in the space below...
Thinking in terms of your team, to what extent do you agree with the following statements?

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) People struggle to come up with ideas in this team [r]</td>
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<tr>
<td>2) The team is always quick to spot a promising idea</td>
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<tr>
<td>3) We are always able to exploit our best ideas in this team</td>
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<tr>
<td>4) This team has been successful in introducing new technologies/materials that have made a positive impact</td>
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<tr>
<td>5) This team has introduced or significantly improved work processes or techniques</td>
<td>[ ]</td>
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<td>6) The team often find inventive solutions to solve problems</td>
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<tr>
<td>7) I am satisfied with the level of innovation in this team</td>
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</tr>
</tbody>
</table>

8) What are the top 3 things that are impeding innovation in your area?

- ...
- ...
- ...

9) What level of practical support is available to you for attempts to try out new ideas and improve the way we work?

- No support
- Poor support
- Satisfactory support
- Good support
- Excellent support

10) How good are your leaders in communicating the vision and need for change?

- Very poor
- Poor
- Satisfactory
- Good
- Very good
11) What's your perception of the division’s enthusiasm for innovation? - Do you think we want to do things better?

- Visible discouragement of trying new ideas
- Some discouragement of trying new ideas
- Neither encouragement nor discouragement
- Some encouragement of new ideas
- Active demand and encouragement if new ideas

12) Do you have goals and targets for innovation?

- No goals or targets set
- Irregular goals or targets set
- Regular goals and targets set
- Detailed and regular goals and targets set

13) To what extent are people encouraged and recognised for ideas and entrepreneurial actions?

- Not at all
- To a small extent
- To a moderate extent
- To a great extent
- To a very great extent

14) How would you rate people’s empowerment to try new initiatives?

- Very poor
- Poor
- Average
- Good
- Very good

15) Is there time or resource for people to be creative and try new things in your team?

- Very poor levels of time and resource
- Poor levels of time and resource
- Satisfactory levels of time and resource
- Good levels of time and resource
- Very good levels of time and resource

**Still thinking in terms of your immediate team, to what extent…**

<table>
<thead>
<tr>
<th>Question</th>
<th>Not at all</th>
<th>To a small extent</th>
<th>To a moderate extent</th>
<th>To a good extent</th>
<th>To a great extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>16) Are you clear about your team’s objectives?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>17) Do you think your team's objectives are clearly understood by other members of the team?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
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<tr>
<td>18) Do you think your team’s objectives can actually be achieved?</td>
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<td>☐</td>
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<tr>
<td>19) Do you think other team members agree with these objectives?</td>
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<tr>
<td>20) Are team members prepared to question the basis of what the team is doing?</td>
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<tr>
<td>21) Does the team critically appraise potential weaknesses in what it is doing in order to achieve the best possible outcome?</td>
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<tr>
<td>22) Do members of the team build on each other's ideas in order to achieve the best possible outcome?</td>
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<tr>
<td>23) Are team objectives modified in light of changing circumstances?</td>
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</table>

**In your experience of working in this team, to what extent do you agree with the following statements?**

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</thead>
<tbody>
<tr>
<td>24) People in this team are always searching for new ways of looking at problems</td>
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<tr>
<td>25) In this team we take the time needed to develop new ideas</td>
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<tr>
<td>26) People in the team co-operate in order to help develop and apply new ideas</td>
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<tr>
<td>27) Assistance in developing new ideas is readily available</td>
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<tr>
<td>28) We have a 'we are in it together' attitude</td>
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<td>29) People keep each other informed about work-related issues in the team</td>
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<td>30) People feel understood and accepted by each other</td>
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<td>31) There are real attempts to share information throughout the team</td>
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<td>32) People in this team are prepared to take a risk</td>
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</tbody>
</table>
Thinking about how ideas are typically implemented from your experience, please answer the following questions…

33) Ideas are often generated in response to an event or in anticipation of an opportunity. In general, when are ideas generated in your team?

- Almost always reactively, in response to an unforeseen event
- Mostly reactively
- Mostly proactively
- Almost always proactively, in anticipation of a future event

34) Do ideas in your team typically deal with short or long term goals?

- Almost always short-term, dealing with the ‘here and now’
- Mostly short-term
- Mostly long-term
- Almost always long-term, focused on the future

35) Where is the typical driving force for new ideas in relation to your immediate team?

- Almost always internally, driven by the VINCI team
- Mostly internally
- Mostly externally
- Almost always externally, driven by those outside the VINCI team

36) How would you broadly describe your teams’ typical approach towards the generation, selection and application of new ideas?

- Almost always informally, on an ‘as required/ad hoc’ basis
- Mostly informally
- Mostly formally
- Almost always formally, with a clear and consistent structure

Thinking about your customer, to what extent do you agree with the following statements (if you work in a business department or do not regularly engage with customers and feel that this question is not applicable to you please proceed to the final question)?

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>37) The customer is able to discuss our work at a technical level with us</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>38) The customer is not very experienced [r]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>39) We are set demanding and ambitious targets by our customer in this team</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>40) The customer is always prepared to actively sponsor new ideas</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>41) The customer is very risk averse [r]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tbody>
</table>
42) We have a strong and healthy relationship with our customer in this team
☐ ☐ ☐ ☐ ☐ ☐

43) We interact with our customer on a regular basis
☐ ☐ ☐ ☐ ☐ ☐

44) In general, how complex is the work conducted by your team?
☐ Very low complexity
☐ Low complexity
☐ Typical complexity
☐ High complexity
☐ Very high complexity

45) In general, how much risk can be associated with the work conducted by your team?
☐ Very low risk
☐ Low risk
☐ Average risk
☐ High risk
☐ Very high risk

And finally, feel free to provide any general comments you may have on innovation and this survey

_________________________________________

END

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\textsuperscript{1} Items 16-23 and 24-32 from Team Climate Inventory (Anderson & West, 1998)