

# Modelling, Collaboration and Integration: A Case Study for the Delivery of Public Buildings

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## Abstract

An evolution in the use of digital modelling has occurred in the Queensland Department of Public Works Division of Project Services over the last 20 years from: the initial implementation of computer aided design and documentation (CADD); to experimentation with building information modelling (BIM); to embedding integrated practice (IP); to current steps towards integrated project delivery (IPD) including the active involvement of consultants and contractors in the design/delivery process. This case study is one of three undertaken through the Australian Sustainable Built Environment National Research Centre investigating past R&D investment. The intent of these cases is to inform the development of policy guidelines for future investment in the construction industry in Australia. This research is informing the activities of CIB Task Group 85 R&D Investment and Impact. The uptake of digital modelling by Project Services has been approached through an incremental learning approach. This has been driven by a strong and clear vision with a focus on developing more efficient delivery mechanisms through the use of new technology coupled with process change. Findings reveal an organisational focus on several areas including: (i) strategic decision making including the empowerment of innovation leaders and champions; (ii) the acquisition and exploitation of knowledge; (iii) product and process development (with a focus on efficiency and productivity); (iv) organisational learning; (v) maximising the use of technology; and (vi) supply chain integration. Key elements of this approach include pilot projects, researcher engagement, industry partnerships and leadership.

**Keywords:** digital modelling, Building Information Modelling (BIM), Integrated Project Delivery (IPD), Queensland Project Services, Australia

## 1. Introduction

This case study investigated the incremental adoption of digital modelling technologies and processes in the Queensland Department of Public Works Division of Project Services (QPS). Implementation has occurred over the last 20 years from: the initial implementation of computer aided design and documentation (CADD); to the experimentation with building information modelling (BIM) from the mid 2000's; embedding integrated practice (IP); to current steps towards integrated project delivery (IPD) including the active involvement of

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consultants and contractors in the design/delivery process. Improved productivity has been the key driver for this initiative.

This illustrative case study is one of three undertaken through the Australian Sustainable Built Environment National Research Centre (SBEnc) investigating past R&D investment to inform the development of policy guidelines for future investment in the construction industry in Australia. Major challenges exist for the Australian construction industry in effectively leveraging R&D investment due to: the disaggregated nature of this industry (DIISR 1999, Hartmann and Fischer 2008, Eastman et al. 2008); the predominance of small to medium sized enterprises (the Australian industry employs some 950,000 people through 250,000 firms); intense competition; a history of limited investment in R&D and new technologies; and a project-based culture focussing on short-term business cycles (Newton et al., 2009).

In 2004 Engineers Australia established a Task Force to investigate the problem of poor documentation and its causes (Engineers Australia, 2005, p1). This showed: declining standards of project documentation correlated with a 24% decrease in design fees over past 12 to 15 years; the majority of variations were due to poor design and documentation; and that there was strong industry support for a solution. They also found that poor documentation practices have led to: an inefficient and non-competitive industry; cost overruns, reworking, extensions of time; high stress and low morale in the industry; adversarial behaviour impacting on reputations; and a decline in safety standards (p3). The Task Force identified that the cost of 'leaving things as they are' included: poor documentation 'contributing an additional 10 - 15% or more to project costs in Australia' and estimated costs of substandard project documentation equating to financial losses 'exceeding AU\$2 billion in the Queensland construction budget every year – and probably six times this or AU\$12 billion nationwide' (p4). One solution identified by this report was the 'adequate and effective use of technology' (p5). Complementing this report, the CRC for Construction Innovation (the predecessor to SBEnc) through its Construction 2020 initiative identified a series of eight "visions" for the future of Australia property and construction industry. Vision 5 *Information and communication technologies for construction* addressed the use of communication and data transfer technologies within construction to improve efficiency and effectiveness. Vision Six *Virtual prototyping for design, manufacture and operation* was to facilitate the *try before you buy* opportunity across the project life-cycle (Hampson and Brandon, 2004).

This paper investigates how digital modelling and IPD can provide productivity and other benefits throughout the project supply chain through: design visualisation; improved documentation; enhanced supply chain collaboration; more effective cost estimating; and improved building performance.

## **2. Conceptual framework**

Implementation of digital modelling in QPS has been achieved through an incremental learning approach driven by a strong and clear vision with a focus on developing more efficient delivery mechanisms through the use of new technology coupled with process change. Through this approach, QPS has been able to build the capacity for knowledge

uptake, assimilation and exploitation in both their own organisation, and that of their supply chain. In addition they have sought input from external sources of innovation and knowledge, and shared this knowledge openly throughout their supply chain.

## **2.1. Organisational capabilities**

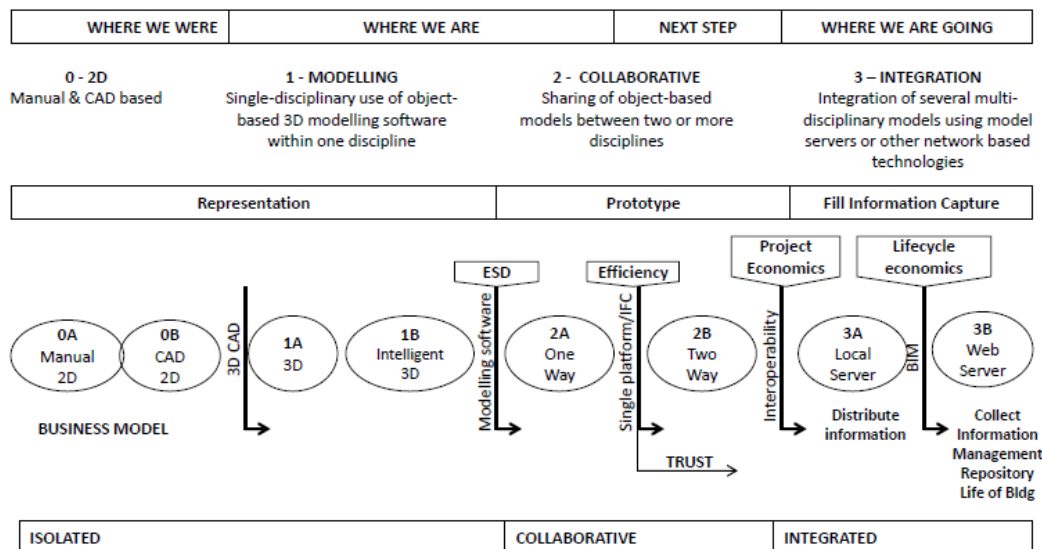
Academic theory used to contextualise gathered data includes: (i) dynamic capabilities; (ii) absorptive capacity; and (iii) open innovation. Teece, Pisano and Shuen (1997) discuss *dynamic capabilities* 'as the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments' (p516). Criteria used to code and analyse data have been drawn from papers in this field including Lawson and Samson (2001), Teece and Pisano (1994), Eisenhardt and Martin (2000), and Davis and Walker (2009). Cohen and Levinthal (1990) introduced the concept of *absorptive capacity* as a 'firm's ability to recognise the value of new, external information, assimilate it, and apply it to commercial ends' (p128). Zahra and George (2002) propose absorptive capacity is a dynamic capability and discuss four dimensions of this capability, namely: knowledge acquisition, assimilation, transformation and exploitation (p186). Measures of absorptive capacity used to code and analyse data have been derived from Cohen and Levinthal (1990), Zahra and George (2002), Nieto and Quevedo (2005), and Flatten et al. (2011). Chesbrough (2004) defines *open innovation* as the use of external and internal ideas and pathway to market to advance their technology and general value. Chesbrough proposes that this approach better enables an organisation to deal with the unknowable, and manage the risks associated with experimentation. Chesbrough (2005) defines a series of features of 'open innovation' which have been used in the analysis of case findings. Additionally Huizingh (2011), Ling (2003) and Bossink (2004) have been used to derive categories for the nature of open innovation; deriving the benefits of open innovation; and the drivers for construction innovation respectively.

## **2.2. Digital modelling**

BIM has been identified as one answer to current industry fragmentation and inefficiencies as it 'incorporates a methodology based around the notion of collaboration between stakeholders using ICT to exchange valuable information throughout the lifecycle.' (Jordani, 2008 in Arayici et al. 2009, p2). Such implementation however requires 'an examination, and potential reengineering, of all impacted processes and a reassessment of the role of practitioners in each of those processes' (Owen et al. 2010, p233). Benefits of BIM implementation are being continuously defined and evaluated. McGraw Hill (2008, p42) highlights benefits including: (i) competitive advantage; (ii) cost, quality and schedule control; (iii) potential to focus on the building owner's life-cycle; (iv) enhanced opportunities for off-site manufacture (including pre-fabrication); and (v) greater opportunities for collaboration across and throughout the building life-cycle, by way of IPD' (pp42-43). Integrated project delivery (IPD) requires greater team collaboration across the supply chain, including design consultants, contractors and sub-contractors (CRC CI 2009a). Cohen et al. (2010) describe characteristics of IPD as: early involvement of key participants; shared risk and reward; multi-party contract; collaborative decision making and control; liability waivers among key participants; and jointly developed and validated project goals' (p5). Figure 1 illustrates the

evolving stages of BIM and IPD implementation as described by the CRC for Construction Innovation (2009).

However, substantial challenges exist to the uptake of BIM. These include lack of awareness of life cycle benefits; lack of relevant training and a lack of industry data standards (DIISR 2010).



**Figure 1 - Implementing BIM (adapted from CRC CI 2009)**

Cohen (2010) identified further challenges including the need for project team members ‘step outside the boundaries of traditional roles into a more fluid, interactive, and collaborative process’ (p7) which impacts on traditional roles, project sequencing and the blurring of lines between design and construction and traditional project delivery. Owen et al. (2010) in the concept of ‘Integrated design and delivery solution’ (IDDS) identify the need for ‘a team approach; support for innovation and tolerance of failure in a team; strong lateral linkages and decentralized decision making; networks of commitment; and new forms of contracting, transparency and risk management (including insurance models)’ (p233).

Measuring benefits is also the subject of much literature (Dawood and Sikka 2005, Eastman et al. 2008, McGraw Hill 2008, Arayici 2009, and Coates et al. 2010). An important issue to highlight is to understand benefit aligned to various parties at different stages in the project life cycle (British Standards Institute 2010, p2).

### 3. Case study method

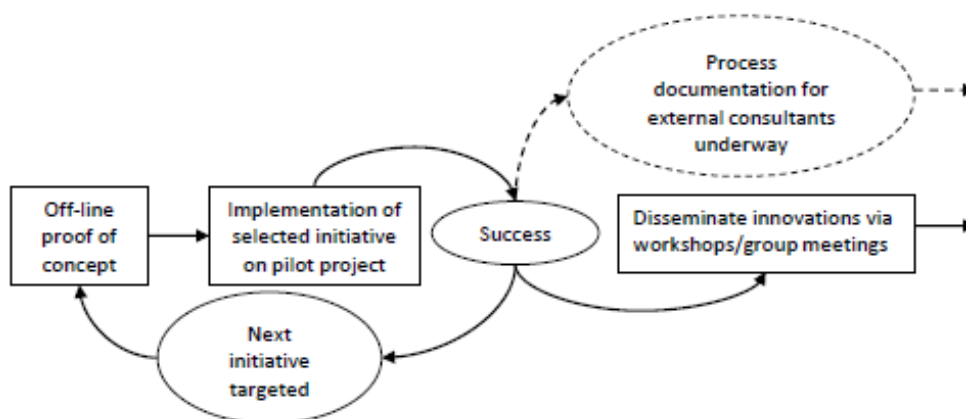
Multiple sources of information were used to inform this case study including: (i) meetings with key agency staff; (ii) project, program and organisational documentation; (iii) formal interviews; (iv) academic literature in the field; and (v) industry reports and presentations. The primary source of data was the formal interviews. Eleven interviewees were identified from within QPS and from those external to the organisation but with a high level of awareness of the initiatives undertaken by QPS. People from each of the following categories were selected including: internally an executive, champion, project leader, and

implementer; and externally a supplier, contractor, consultant, industry representative and a researcher. Formal interviews carried out from August to November 2011.

Data from interviews was subsequently coded by a research team member to build an understanding of the organisational capabilities evident in the implementation of these initiatives (and highlighting those not evident which may contribute to enhance outcomes in the future). Thematic coding and analysis was undertaken in two parts. Firstly key themes were established based on an analysis of the interviewees' direct responses to each question identifying drivers, barriers and successes for each of the cases. Secondly, responses were coded against criteria derived from dynamic capability, absorptive capacity and open innovation theory. The thematic grouping and coding was verified (via random sampling) by an alternate research team member to ensure the reliability and trustworthiness.

## 4. Findings

The incremental adoption of digital modelling technologies and processes within QPS (Figure 2) has been driven by the key champions from both the executive and delivery levels within QPS, based on experience and sensitivity to the needs of the industry.



**Figure 2 – Incremental implementation process**

Both strategic and day-to-day issues have been addressed throughout the development cycle. Strategic support was provided by Departmental executives, with project delivery support provided by a team of CADD and BIM managers, discipline leaders, principal consultants, project directors and superintendents and selected IT consultants/contractors, suppliers and vendors. An integrated practice approach has been critical, with QPS able to promote integrated decision making across the project team leading to more productive collaborative decision-making. This has laid the ground-work for current steps towards IPD in which the consultant/contractor also becomes an integral part of the design team. The ongoing role of internal working groups has provided an important forum for internal discussion and knowledge dissemination. This approach was implemented on selected projects from 2005 (Table 1).

**Table 1 – Project implementation time-line**

Mareeba Court House and Police Station	2006	BIM approach first piloted.
Queensland State Archives , Brisbane	2006	4D model consultancy novated to contractor. Benefits included ability to rehearse construction sequence improving construction productivity.
North Lakes Police Station	2008	BIM approach further developed. Structural steel design provided directly to the fabricator improving fabrication productivity.
Dandiiri Contact Centre, Brisbane.	2008	Use of a model for energy modelling. Building awarded highest environmental rating of any Australian building at that time. Structural steel detailing for carpark photovoltaics resulted in no Requests for Information.
Toowoomba housing	2009	Use of 3D modelling on a smaller scale. Models provided to a select tenderers, who where coached in their application and use. Guaranteed Schedule of Quantities was provided

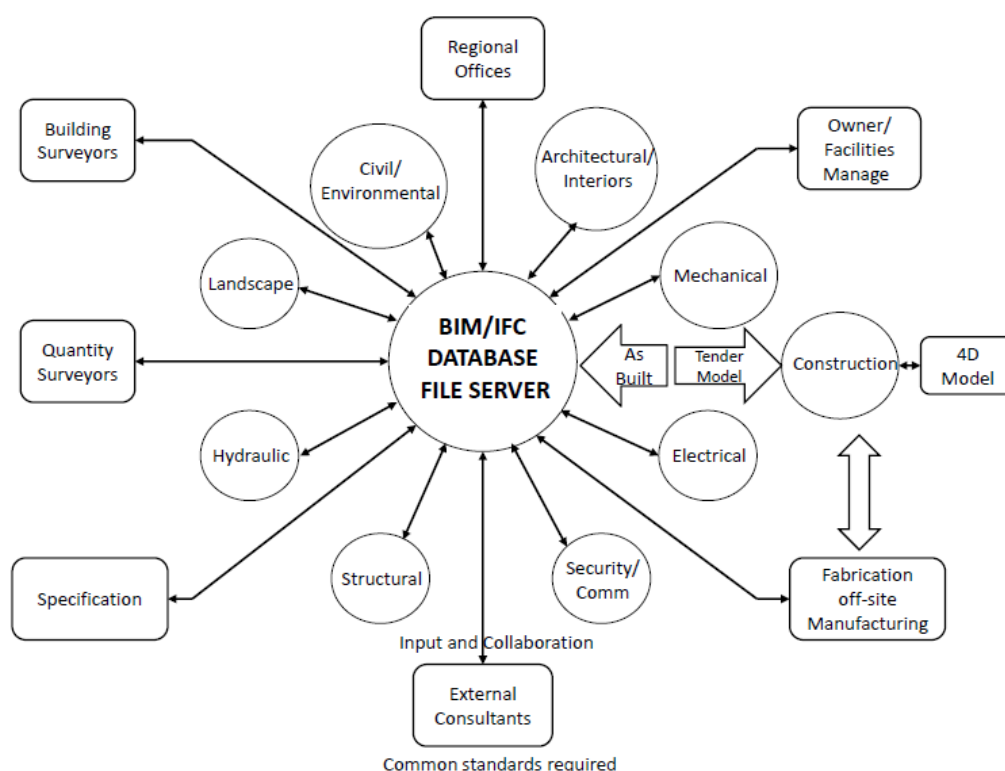
The establishment of collaborative working relationships with contractors, subcontractors and consultants willing to participate in the development and implementation of new work processes and practices has been critical. Relationships with external research organisations including the CRC for Construction Innovation, and universities QUT and RMIT (via Australian Research Council (ARC) Linkage projects) have also contributed to the pathway of success. Of importance also has been the relationships established with national industry organisations such as NATSPEC, and industry associations including buildingSMART and the Australian Mechanical Contractors Association. Engagement in forums such as the 2007 Australian Institute of Architects national conference has also contributed to driving developmental milestones within QPS and as forums for dissemination. These initiatives have been further recognised through winning industry awards for innovation (including the 2011 Australian Institute of Architecture, Queensland - Award for Sustainable Architecture and 2010 Engineers Australia Excellence Awards, Queensland - Hawken Award for Engineering Excellence).

#### **4.1. Analysis of the implementation**

Key **drivers** of these initiatives include: (i) increased production and process efficiency providing additional project value for same fee while maintaining timelines; (ii) better communication and collaboration through the development of effective supply chain networks; (iii) improving market share through demonstrating to government clients the added value that this service (such as environmental modelling, potential for facilities management); (iv) creating a stimulating and smart working environment to maintain skilled professionals in a public sector environment; and (v) providing industry leadership as demonstrated through: Australia’s national building specification NATSPEC (<http://www.natspec.com.au/>); broad industry recognition of this national leadership role; and active engagement with vendors, suppliers, and contractors to enhance outcomes.

Key **implementation activities** included an incremental approach to improvement building on a strong, shared vision for implementation (Figure 3) supported by all levels of management. These efforts (particularly since 2005) have helped highlight the benefits of BIM to the wider industry. An investment in both training and technology underpins this advancement, with associated process improvement. Links with researchers were important to underpinning these developments as they moved beyond the *proof of concept* stage.

New **processes** required to deliver on these initiatives included the use and sharing of building information models, and ensuring a shared vision across the delivery team. This enabled new activities such as high level clash detection, energy modelling; and rehearsals of the construction sequence with both programming and safety benefits. A significant number of **required new processes** were also identified including the need to: (i) embed IPD into business and procurement mechanisms (the UK Cabinet Office (2011, p16) highlights the tension between ‘seeking a more collaborative, integrated model’ which at the same time maintain competitive tension and value for money) including new procurement methods; (ii) develop new methods of training; develop new industry standards such as National BIM Guidelines (CRC for Construction Innovation 2009 and NATSPEC 2011); and (iii) develop product libraries (such as those being developed by AMCA and SBEnrc) and applications which support this new collaborative and integrated environment.



**Figure 3 – The Vision (Project Services 2005)**

**Impacts** were felt both internally on organisational culture and values; and externally on the supply chain. McGraw Hill (2008, p5) note that ‘seven in 10 users say that BIM has had at least a moderate impact on their internal project practices; and two-thirds of users say that BIM has had at least a moderate impact on their external processes. Impacts felt by QPS included: the need for changes in delivery processes such as the shift from engaging an individual consultant to engaging a consultancy team; having contractors as a part of project team; and ensuring shared vision and trust between this larger team. This still requires: new forms of contracts; that legal and copyright issues and concerns are addressed; and new methods for on-site operations (see also Allen Consulting Group 2010, pxiii). Key **supply chain impacts** have thus arisen due to these changing relationships include the sharing of models with an integrated project team. Feedback mechanisms across the supply chain have been important in order to achieve these industry-wide standards.

Key **successes** include the incremental change approach, with process improvements targeted on a project-by-project basis. A key part of this has been the preparedness of QPS to take the risk associated with the use of digital models by contractors and suppliers (for example on North Lakes, the State Archives Project, Dandiiri Contact Centre and the Toowoomba housing projects). McGraw Hill (2008, p33) highlight some of the key risks including: errors and accuracy issues; liability and legal issues; inexperience; and the ownership of the model. The establishment of a *collaborative environment based on openness and trust* has been critical. This is essential to IPD, and QPS, as a multi-disciplinary design office, have been able to take on this approach as part of their on-going leadership in this field. This has led to a motivated team of individuals with a commitment to quality outcomes. Additional successes include: (i) 'green' outcomes leveraged through the use of the 3D model; and (ii) the ability to rehearse the construction sequence to maximise on-site efficiency and construction safety (Queensland State Archives Building), and facilitating off site manufacture (North Lakes Police Station).

Potential **barriers** identified range from indifference and a lack of knowledge, to a resistance to change along with entrenched business practices. This has been a challenge in terms of establishing a shared vision. A lack of political engagement is also evidenced, especially when compared to that which has grown for green buildings. Also acknowledged is the need for pressure to be brought to move beyond a 'promising early start' with BIM technology. Software and technology capabilities have also inhibited development, along with suppliers' focus on graphics rather than object data. Associated skills gaps still need to be addressed. The commercial realities of associated costs such as technology, training, and process improvement especially suitable procurement mechanisms (see Hartmann and Fischer 2008) have also impacted development. Each of these barriers, identified in interview reflect the findings of the Allen Consulting Group report (2010, pxii) and challenges identified in the international literature (McGraw Hill 2008, Eastman 2008).

**R&D activity** can be described as *informal and integrated*. Proof of concept was achieved using their own resources through an on-going series of pilot projects, where innovation was achieved within the project budgets, and with existing resources, and outcomes disseminated via an informal mechanism. They then established a number of formal research links to further realise the potential of BIM, IPD and visualisation. Collaboration has occurred with: the CRC for Construction Innovation; the SBEnrc; the International Alliance for Interoperability (now buildingSMART); and through a series of ARC Linkage projects (in conjunction with QUT and RMIT). Additionally links with contractors, vendors and suppliers; and industry-wide organisations such as NATSPEC, have been an important part of the integrated approach to R&D.

#### **4.2. Analysis of associated organisational capabilities**

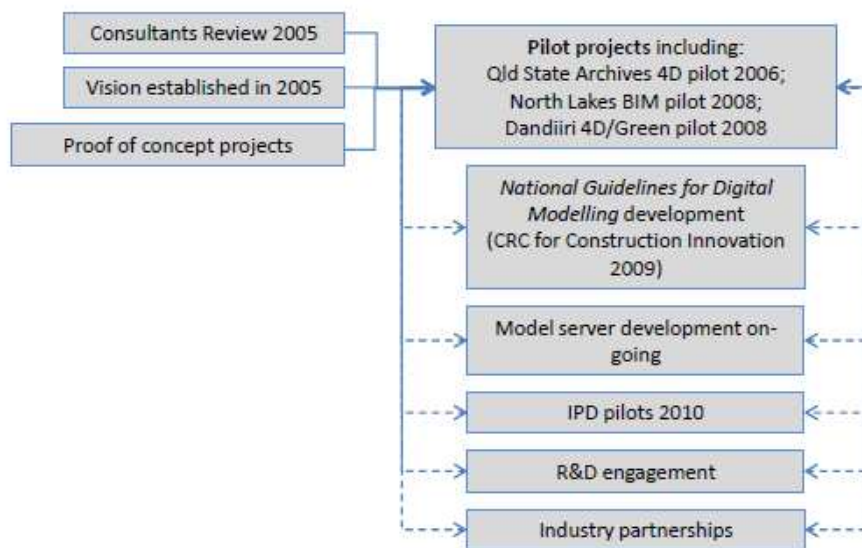
Evidence of **inbound absorptive capacity** is apparent in the exploitation, assimilation and transfer of knowledge, and its acquisition from external sources. The capacity for technological development is demonstrated in the evolution from CADD to BIM to IP including leveraging broader potentials through digital model development; environmental modelling; brief development; and model server development. This capacity is also



evidenced in its ability to adapt knowledge through a high level of technological specialisation – as evidenced in the specialists engaged within the QPS’s CADD team, and through links with key external specialists. QPS have also taken advantage of noteworthy economies of scale being a fully commercialised business unit within the Queensland Department of Public Works with a strong multi-disciplinary team delivering much of the State’s building infrastructure.

Regarding **features of open innovation** the majority of interviewees shed light on an abundant underlying knowledge landscape and outbound flows of knowledge and technology. Regarding **the nature of this open innovation**, inbound innovation is evident in: (i) knowledge acquisition and its exploitation - through informal, formal and integrated R&D activity which is actively embedded into project outcomes and translated into broader industry benefit; and (ii) the enhanced effectiveness of this technology. **Benefits of an open innovation approach** for the workplace are apparent in the capabilities of the people involved (including software-specific specialists and discipline leaders with the ability to integrate new techniques into project delivery process); and the level of interest of team members (enhanced through alpha and beta testing new products and methods).

Base on these findings the following pathway to innovation has been identified (Figure 4).



**Figure 4 – Pathway to innovation**

## 5. Conclusions

Findings of the analysis are two-fold. Analysis of the implementation revealed several key drivers including a central focus on productivity with the coupled requirement for new implementation activities and processes. This included a number of drivers yet to be implemented such as embedding IPD into business and procurement mechanisms. The incremental adoption approach was validated with beneficial outcomes on several projects on which specific aspects of BIM were implemented. Significant barriers were experienced in line with barriers and challenges identified in current literature in this field, including a lack of knowledge and an indifference or even resistance to change. This was countered within

Project Services by the establishment of a strong vision which guided implementation from 2005.

Analysis of organisational capabilities reveal an organisational focus on several areas including: (i) strategic decision making including the empowerment of internal innovation leaders and champions; (ii) the acquisition and exploitation of knowledge; (iii) product and process development (with a focus on efficiency and productivity); (iv) organisational learning; (v) maximising the use of technology; and (vi) supply chain integration. Key elements of this approach include pilot projects, external researcher engagement, industry partnerships and leadership. Additional areas where there was a high level of focus on several criteria including: clients with innovative demands; industry push; and supply chain integration. Together this provides a powerful cross-section of mechanisms through which benefits of innovation can continue to be maximised.

Queensland Project Service's adoption of BIM and important formative steps towards IPD has been a long-term commitment driven by key champions and leaders within that organisation, with executive support. The criteria discussed above illustrate areas in which this activity has been successful and areas from which potential future benefit could be obtained. These findings are reinforced by industry and academic literature including (Allen Consulting 2010, UK Cabinet Office 2010, and Owen 2012).

Whilst QPS have not formally tracked performance the following criteria can be considered as important, based on case study findings: reduction in RFIs; ; improved client understanding through visualisation; improved productivity (delivery on time, enhanced product for same budget); integrated practice (reduction in clashes); supply chain collaboration; staff retention (through skills enhancement and workplace satisfaction).

The leading initiatives undertaken by Queensland Project Services over the past decade may be considered as providing a proof-of-concept of this direction. This leadership has established the basis for industry reform that is advancing towards more productive delivery of public buildings in Australia.

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