Project 2.7 - LEVERAGING R&D FOR THE AUSTRALIAN BUILT ENVIRONMENT

PHASE 2 – CASE STUDIES

Part 4 - Case 3 – From CADD to IPD

Read in conjunction with Part 1, 2 & 3

April 2012

Abbreviations:

3D – Three-dimensional graphical data
4D - Three-dimensional graphical data with scheduling and timeline capabilities
5D - Three-dimensional graphical data with costing capabilities
AIA – Australian Institute of Architects
ACIF – Australian Construction Industry Forum
AMCA – Australian Mechanical Contractors Association
APCC – Australian Procurement and Construction Council
ARC – Australian Research Council
BEIIC – Built Environment Industry Innovation Council
BIM – Building information model/modelling
CADD – Computer aided design/drafting
CIFE – Centre for Integrated Facility Engineering – Stanford University
CSIRO - Commonwealth Scientific and Industrial Research Organisation
IAI - International Alliance for Interoperability (now trading as buildingSMART)
IP – Integrated Practice
IPD – integrated project delivery
IPT – integrated project team
NATSPEC - National Specification System of Australia
PS – Project Services
QDPW – Queensland Department of Public Works
SBEnrc – Sustainable Built Environment National Research Centre

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EXECUTIVE SUMMARY

This case study investigated the evolution that has taken place in the Queensland Department of Public Works Division of Project Services during 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) with the integration of contractors in the design/delivery process.

Incremental development has been driven by the key champions from both the executive and delivery levels within Project Services. Both strategic and day-to-day issues have been addressed throughout the development cycle. Project Services adopted an incremental learning approach driven by a strong and clear vision (Section 6.2). This approach to BIM was implemented on selected projects from 2005 including: Mareeba Courthouse and Police Station (2006); Queensland State Archives (2006); North Lakes Police Station (2008); Dandiiri Contact Centre (2008); and Toowoomba housing (2009/10).

The integrated nature of the Project Services team has enabled this, as has the establishment of working relationships with contractors, subcontractors and consultants willing to participate in the implementation of new work processes and practices. Relationships with external research organisations have also contributed to success. Interactions with national industry organisations and engagement in national forums have also contributed to driving developmental milestones.

Project Services adoption of BIM, IP and now steps towards IPD has been a long term commitment (from the early adoption of CADD) 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.

Based on the analysis of data gathered from 11 interviews, a high degree of focus on several key criteria has contributed to the successful implementation of these initiatives. A strong focus on: product and process development (with a focus on efficiency and productivity); organisational learning; knowledge acquisition and exploitation; strategic decision making including the empowerment of innovation leaders and champions; maximising the use of technology; and supply chain integration, has contributed to performance. Important also, are those areas were little reference was revealed from interview responses. These include the lack of: evaluation institutions and mechanisms; training options appropriate to industry-wide needs; and government guarantees or subsidies for industry-wide improvement.

These findings will be explored further: in conjunction with QDPW Project Services; in the context of the cross-case analysis; and alongside the findings of the audit and analysis of past R&D investment in the Australian built environment.

Further verification (through additional and follow-up interviews) and analysis (through separation of internal and external interviewee findings) of these findings would yield additional knowledge, which may be possible in the context of Case Study 4.

Findings will also be further considered in the context of Phase 4 of the current project, in establishing policy guidelines for future R&D investment in the built environment.

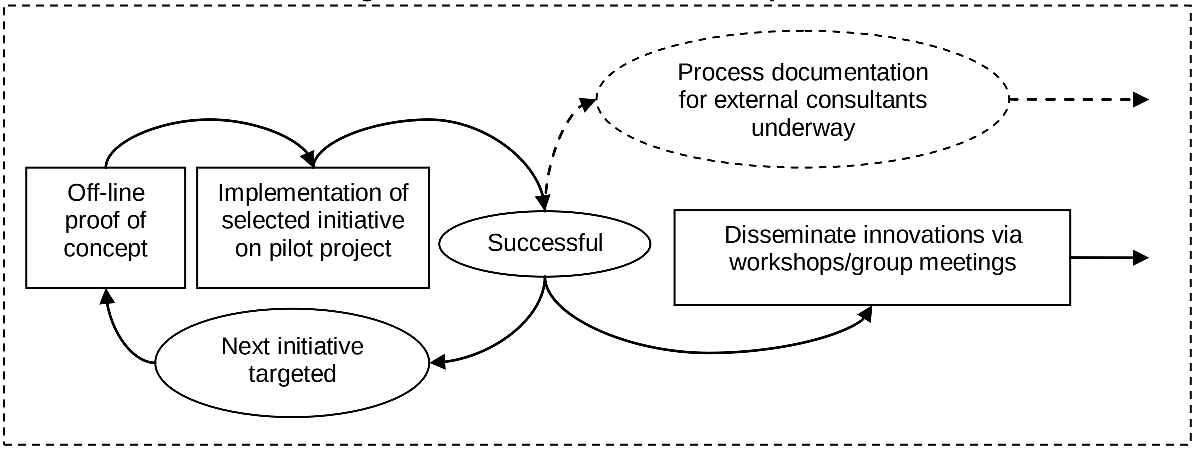
1. The initiative

This case study investigated the evolution that have taken place in Project Services during 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) with the integration of contractors in the design/delivery process.

Incremental development has been driven by the key champions from both the executive and delivery levels within Project Services, based on experience and a sensitivity to the needs of the industry. Both strategic and day-to-day issues have been addressed throughout the development cycle. Strategic support has been provided by the Director and Director-General of the Queensland Department of Public Works (QDPW) throughout this period. Project delivery support has been provided by a team of CADD managers, BIM managers, discipline leaders, principal consultants, project directors and superintendents and strategically selected IT contractors, suppliers and vendors. This Integrated Practice (IP) approach has been critical, with Project Services able to promote integrated decision making across the project team leading to collaborative decision-making. This has laid the ground-work for current steps towards IPD in which the contractor also becomes an integral part of the design team (see CRC CI 2009a for further definition). The ongoing role of internal working groups has provided an important forum for internal discussion and knowledge dissemination.

Project Services adopted an incremental learning approach (Figure 1), driven by on a strong and clear vision (Section 6.2).

Figure 1 – Incremental innovation process



This approach to BIM was implemented on selected projects from 2005 including:

- Mareeba Court House and Police Station (2006) on which the BIM approach was first piloted.
- Queensland State Archives (2006) for which A3D was novated to the contracted (Laing O'Rourke) and a 4D model was developed (enabling rehearsal of the construction sequence). *(See CRC CI 2009a&b for additional detail)*
- North Lakes Police Station (2008) - on which a BIM approach was further developed. In addition, structural steel design was provided directly to the fabricator from Project Services engineers. *(See CRC CI 2009a&b for additional detail)*
- Dandiiri Contact Centre (2008) where the use of a 4D model was further advanced including early energy modelling which led to the building being awarded the highest environmental performance of any Australian building at construction at that time (6*-

92 points). The process of structural steel detailing for the carpark photovoltaics was also an important aspect of this project (resulting in no Requests for Information (RFIs) *(See CRC CI 2009a&b for additional detail).*
- Toowoomba housing (2009/10) where the use of the 3D modelling approach was translated for use on a much smaller scale. 3D models were provided to a select group of tenderers, who where coached as to their application and use. A guaranteed Schedule of Quantities (based on the 3D model) was provided. To date there are no claims associated with the 3D model information provided.

The establishment of working relationships with contractors, subcontractors and consultants willing to participate in the implementation of new work processes and practices has been critical. Relationships with external research organisations including the CRC for Construction Innovation, QUT and RMIT (via ARC Linkage projects) have also contributed to 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 (AMCA). Engagement in forums such as the 2007 Australian Institute of Architects (AIA) conference has also contributed to driving developmental milestones within Project Services and as forums for dissemination.

2. Illustrating the case - interview findings

This report is to be read in conjunction with Part 1 – Overview, which provides details of the research methods and tools used to gather the following data.

Data for this case has been gathered from face-to-face interviews undertaken with 11 people from both within QDPW and from those external to the organisation but with a high level of awareness of the CADD, BIM, IP and IPD initiatives undertaken by Project Services (Table 1).

Table 1 - Interviewees

Role	Case 3
Executive (internal)	1
Champion (internal)	1
Project Leader (internal)	1
Implementer (internal)	1
Allied Agency (internal)	-
Supplier (external)	1
Contractor (external)	2
Consultant (external)	1
Industry Rep. (external)	2
Researcher	1
	11

The following tables (Table 2 – Table 10) provide a summary of data gathered relating to the specific theme of each interview question.

Table 2 – Drivers

Improved business outcomes
Increased production efficiency and outcomes
Better communication and collaboration
New technology
Provide industry leadership
Process improvement
Stimulating and smart work environment
Improve client understanding linked to improving market share

Table 3 – Key implementation activities
Incremental adoption / experimentation
Establishing a shared vision / action plan
Investment in technology – hardware, software and relationships
Patronage of executive management
Training
Updating processes and manuals
Alliance with researchers

Table 4 – New processes - current
Use and sharing of 3D and 4D models
Enhanced collaboration leading to reduced errors and omissions
Development of a shared vision for delivery team

Table 5 – New processes – required
New fee split
New style of training
Application tweaking
Embedding in other business processes
Workflow documentation
New procurement methods
Industry wide data support and naming conventions
Rationalisation of standards
Model server development and use
Better identification of value
Focus on what is needed to build

Three types of impacts are being discussed: (i) impacts on the culture and values of the organisation; (ii) on the supply chain and industry; and (iii) the impact of major external changes on the development and delivery of the initiatives.

Table 6 – Impact on values and culture
Move from engaging a consultant to engaging a consultancy team
Change in contractor culture; build understanding on site
Builders in design process/office
New way of dealing with contracts and copyright
Change in business and project delivery processes
Shared team values required; requires greater trust
Use as design and documentation tool (potential reduction in documentation)

Table 7 – Impact on supply chain and industry
sharing of digital models with consultants, contractors and subcontractors
Development of a national BIM guidelines
Changing relationship between designers, consultants and contractors
Feedback loop to vendors and suppliers regarding object information
Improvement in upfront inefficiencies

Table 8 – Major changes impacting on initiative
reduction in workload due to reconstruction impacted on ability to undertake R&D
CAD vendors pushing next-gen software
Some stalling regarding enabling technologies
GFC bought greater focus on cost-effective delivery
Governments mandating use of BIM

Table 9 – Successes
Incremental change approach
Clear vision and sticking to it
QDPW taking the risk to introduce new methods to industry; leadership
More effective delivery (on both small and large projects)
Motivated team
Green building outcomes
Model quality
Better collaboration tools available
Clearer communication, collaboration, honesty and openness

Table 10 – Barriers
indifference and lack of knowledge
Vendors focus on graphics rather than work ability and object information
Entrenched old business processes (especially procurement)
Resistance to change
Building a shared vision
Commercial realities
Lack of political understanding of the need
Continuity of knowledge and support
Education and training to address skills gaps
Capable software and technology

Table 11 – R&D engagement and activities
Project Services achieved proof of concept via informal R&D process
Formal R&D via CRC CI, SBEnrc and ARC linkages
Informal R&D via pilots, demo project and working groups
Liaison with industry R&D activities via industry associations, vendors and suppliers
Abundant underlying international R&D informing the field

3. Links to theory

The following tables (Table 12 to Table 22) present data coded by researchers against specific criteria related to the three areas of theory identified as significant to this research (i.e. dynamic capabilities, absorptive capacity and innovation). The tables highlight the number of interviewees in five categories (i.e. Majority = >80%; Several = >50% but < 80%; Some = <50% but >20%; Minority = <20%; None) who were considered by the research team to have raised concepts related to the criteria indicated on the following graphs.

3.1. Dynamic capabilities

Teece, Pisano and Shuen (1997) define *dynamic capabilities* 'as the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments' (p.516). Criteria for providing evidence of an organisation's dynamic capabilities have been drawn from several papers in this field including Lawson and Samson (2001), Teese and Pisano (1994), Eisenhardt and Martin (2000), Davis and Walker (2009).

3.1.1. Evidence of dynamic capabilities

Comments during interviews could be attributed to characteristics of the following dynamic capabilities (Table 12). For example, this is useful in the context of WAG's ability to integrate and take advantage of innovations associated with green buildings.

Table 12 – Interviewees who raised issues relevant to organisational dynamic capabilities

Majority	Product & process development Organisational learning External R&D engagement Strategic decision-making Technology transfer
Several	Internal R&D engagement Alliancing
Some	Cost advantage through less waste Product/service differentiation
Minority	IP creation Customer focus
None	Cost advantage through increased market intelligence

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

3.2. Absorptive capacity

Evidence of inbound absorptive capacity

Cohen and Levinthal (1990) introduce 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' (p.128). They argue that absorptive capacity is 'largely a function of prior related knowledge' (p.131) that has been accumulated through effort, as prior knowledge facilitates the assimilation of new knowledge. Key criteria which shed light on the absorptive capacity of an organisation have been drawn from key literature in this field (Cohen and Levinthal 1990, Zahra and George (2002), Nieto and Quevedo (2005), Flatten et al. (2011)).

This is relevant in terms of further understanding WAG's capacity to value, assimilate and take advantage of green building-related knowledge.

Table 13 – Interviewees who raised issues relevant elements of inbound absorptive capacity

Majority	Exploitation of knowledge Assimilation of knowledge into organisation Transfer of knowledge Knowledge acquisition from external sources
Several	Knowledge acquisition – internally generated

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Measures of absorptive capacity

The following measures of absorptive capacity (Table 14) have been derived from Cohen and Levinthal (1990), Zahra and George (2002), Nieto and Quevedo (2005), Flatten et al. (2011).

Table 14 – Interviewees who raised issues relevant to measures of absorptive capacity

Majority	Effort put into development of new products
Several	Capacity to adapt technologies from other sources Noteworthy economies of scale Capacity for technological development High level of technological specialisation
Some	Staff skills - Investment in training Awareness of customer needs Effort put into cost reduction
Minority	Awareness of competitors' technologies
None	Range of staff training

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

3.1. Innovation

Chesbrough (2004) defines the *open innovation* paradigm as an assumption 'that firms can and should use external as well as internal ideas and internal and external paths to market, as they look to advance their technology' (p.23). He proposes that this increases the number of possible sources of innovation.

This approach better enables an organisation (in this instance WAG) to deal with the unknowable, and manage the risks associated with experimentation.

Chesbrough et al. (2005) was used as the source for the *features* of 'open innovation' presented in these case reports. Huizingh (2011) was the source for the criteria used to illustrate the *nature* of open innovation exhibited in the delivery of initiatives. Categories of *factors resulting in benefit from innovation* project and team have been drawn from Ling (2003). Bossink (2004) discusses an extensive array of *drivers for construction innovation*. These have been used alongside interview responses to categorise drivers within each case study organisation.

Features of open innovation

Chesbrough et al 2005 was used as the sources for significant features of open innovation (Table 15).

Table 15 – Interviewees who raised issues relevant to features of open innovation

Majority	Abundant underlying knowledge landscape Purposive outbound flows of knowledge & tech.
Several	Business model focus on converting R&D into commercial value New metrics for assessing innovation capability and performance
Some	Equal importance given to external knowledge, in comparison to internal knowledge Rise of innovation intermediaries
None	Proactive and nuanced role of IP management

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

3.1.1. Nature of open innovation

Nature of open innovation

Key relevant academic literature was used as the source for the following criteria which have been used to illustrate the nature of open innovation exhibited in the delivery of green building initiatives by QDPW Project Services (See Part 1 Overview).

Table 16 – Interviewees who raised issues relevant to inbound innovation

Majority	Exploitation Knowledge Acquisition
Several	Outbound innovation (external exploitation of internal knowledge) Retention
Some	Coupled activities
None	Non-pecuniary Pecuniary i.e. acquiring, sourcing, selling, and revealing

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 17 – Interviewees who raised issues relevant to effectiveness of innovation

Majority	Enhancing technological effectiveness
Several	Number of innovations Less waste
Some	Financial benefits Decreasing risks Lower costs Nonfinancial benefits Access to new markets
Minority	Shorter time to market Other measures…. Stimulating growth

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Benefits of open innovation approach

The benefits of this approach for the project and team have been drawn from key academic literature (See Part 1 Overview). Those identified in Table 18 relate to the working environment.

Table 18 – Interviewees who raised issues relevant to benefits of open innovation approach

Several	Capabilities of the people involved in the innovation Level of interest of project team members Working environment
Some	Formation of task groups

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Drivers for construction innovation

The academic literature discusses an array of drivers for construction innovation (See Part 1 Overview). These have been used to thematically code data from interviews.

The following tables (Table 19 to Table 22) highlight areas where interviewees raised issues relevant to construction innovation in the context of QDPW Project Service's CADD, BIM, IP and IPD initiatives.

Table 19 highlights the environment pressures which are considered to have existed.

Table 19 – Interviewees who raised issues relevant to benefits of construction innovation – environmental pressures

Several	Governmental clients with innovative demands Market pull industry wide
Some	Innovation stimulating regulations
None	Government guarantee for markets for innovative firms Subsidies for innovative applications and materials

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 20 – Interviewees who raised issues relevant to benefits of construction innovation – technological capability

Majority	Technology leadership strategy
Several	Finance the pilot projects
Some	Technology push
Minority	Programs promoting access to technology Technology fusion
None	Product evaluating institutions

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 21 – Interviewees who raised issues relevant to benefits of construction innovation – knowledge exchange

Majority	Lateral communication structures Training of workers on the site
Several	Integrated and informal R & D function Stimulation of research
Some	Effective information gathering Creation of knowledge networks
Minority	Programs promoting collaboration Broad view of risk

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 22 – Interviewees who raised issues relevant to benefits of construction innovation – boundary spanning

Majority	Empowerment and innovation leaders Integration of design and build Innovations from suppliers
Several	Strategic alliances in long-term relationships Explicit coordination of the innovation process Empowerment of innovation champions
Some	Coordination of participating groups Mechanisms sharing financial risks and benefits Involvement of the client – within org

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

4. Discussion

The above data has been gathered and analysed in order to illustrate and better understand the CADD, BIM, IP and IPD initiatives implemented by Project Services and the environment in which they were rolled out.

As per the data presented in the previous section, this has been done in two parts. The first part has been designed to build a better understanding of the initiative themselves and the context in which they were rolled out. This draws directly from responses to each of the interview questions (Table 2 to Table 11). The second part has used a set of criteria from academic theory around dynamic capabilities, absorptive capacity and open innovation to thematically code data (based on Table 12 to Table 22). This has been done to build a deeper understanding of the capabilities Project Services exhibited in the course of these activities, and those capabilities which may not have been evident, but which may contribute to better outcomes for the future.

4.1. Understanding the initiatives

In summary, key *drivers* of these initiatives contain improved business outcomes including:

- increased production and process efficiency – for example in responding to recognised waste in the traditional project delivery processes through implementing on-going steps from CADD to BIM, IP and IPD (as discussed in the joint ACIF/APCC paper (2009, p.2)[1].
- better communication and collaboration – through: (i) the development of effective supply chain networks; and (ii) development and use of the model server
- improving market share – through demonstrating to government clients the added value that this service can provide (such as more effective environmental modelling; potential for facilities management; and less waste in the delivery process)
- creating a stimulating and smart working environment (with the aid of new technology) to maintain a core team of skilled professionals in a public sector environment.
- providing industry leadership – as demonstrated through: Project Service's leadership role within NATSPEC; broad industry recognition of this national leadership role; and active engagement with vendors, suppliers, and contractors to enhance BIM and IPD outcomes.

Key *implementation activities* relating to the application of new initiatives throughout project life cycles included the incremental approach to improvement building on a strong, shared vision for implementation, supported by all levels of management. These efforts (particularly since 2005) have helped highlight the benefits of BIM to the wider industry (this value is highlighted by BEIIC (2010) where they discuss the case for the accelerated widespread adoption of BIM due to its potential to enhance productivity throughout the buildings network. 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 include the use and sharing of building information models, and ensuring a shared vision across the delivery team (enabling new activities such as high level clash detection, energy modelling at the design stage; 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 embed IPD into business and procurement mechanisms including: new procurement methods; fee splits which reflect work flow; and new mechanisms for collaboration.
- new methods of training – Universities and TAFEs are considered to be lagging industry needs
- industry standards - such as national BIM guidelines - as developed by the CRC for Construction Innovation (2009) and NATSPEC (2011).
- product libraries (such as those being developed by AMCA and SBEnrc) and applications which support this new collaborated and integrated environment rather than past CADD based graphical environments.

Importantly this all needs to occur whilst maintaining a focus on what is needed to add value to the process and to build the product.

Impacts were felt both internally on organisational culture and values; and externally on the supply chain. Impacts include the need for changes in delivery processes brought about by the use of new tools and delivery mechanisms such as the shift from engaging an individual

[1] Hartmann and Fischer (2008, p.3) cite a potential 20-30% greater productivity with the use of BIM, and a reduction in Requests for Information (RFIs) and Change Orders (COs) by a factor of 10.

consultant to engaging a consultancy team; having contractors as a part of the design and documentation team; and ensuring shared vision and trust between this larger team. This requires: new forms of contracts; that legal and copyright issues and concerns are addressed; and new methods for on-site operations (see BEIIC 2010, p.xiii). Key supply chain impacts have thus arisen due to these changing relationships. These are starting to be addressed through:

- the sharing of models with an integrated project team - technology has lagged til recently, but is being overcome through the development of model servers and vendors addressing communication issues between products.
- the need for national BIM guidelines to gain consistency for clients, contractors and suppliers. Feedback mechanisms across the supply chain have been important in order to achieve these industry-wide standards.

External impacts upon the ongoing implementation of these initiatives identified by interviewees include: the recent Queensland floods and the subsequent need to fund reconstruction efforts, which impacted on new project funding (on which further process development was to occur); and the GFC (which has resulted in a reduction in funding for capital projects, and increased competition amongst consultants and contractors for work, placing greater focus on cost effective delivery). Whilst the latter may have reduced the amount of capital available, it was considered as beneficial in placing a focus on more cost effective delivery methods. In terms of the technology, some stalling has been experienced with regards to enabling technologies, whilst at the same time vendors continue to push next-generation software, before current versions are fully exploited, requiring project teams into an unwanted upgrade cycle. A final key impact has been the establishment of timescales for mandating BIM deliverables by governments, as seen in the: US General Services Agency in 2005; by the UK Government in 2011; and Queensland State Government in 2007 when they foreshadowed an increasing expectation that consultants and contractors would be required to be able to work with these models.

Key *successes* highlighted include the adoption of the incremental change approach, with process improvements targeted on a project-by-project basis. Importantly, this was set in the context of a clear shared vision for development towards an IP and IPD environment facilitated by the use of BIM and associated technologies. A key part of this has been the preparedness of Project Services to take the risk associated with the use of 3D, 4D and 5D models by contractors and suppliers (for example on North Lakes, the State Archives project, Dandiiri Contact Centre and the Toowoomba housing projects). Similarly the establishment of a collaborative environment based on openness and trust has been critical. This is essential to IPD, and Project Services, 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 benefits have included: (i) successful 'green' outcomes which were leveraged through the development of the building information model and the ability to undertake environmental assessments (to further leverage the investment in BIM and IPD) at an early stage in project development on Dandiiri; and (ii) the ability to rehearse the construction sequence to maximise on-site efficiency.

Potential *barriers* were also identified ranging 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 exists 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 (e.g. technology, training, and process improvement especially in the form of suitable procurement mechanisms) have also impacted the development, as well as the continuity of knowledge and support. Each of these barriers, identified in interview, further reinforce the findings of the BEIIC 2010 (p.xii) report.

In the context of this case study, *R&D engagement and activities* can be described as informal and integrated. This informal approach has been facilitated by the integrated nature of Project Services project teams. Proof of concept was achieved using their own resources, and then they established a number of formal research links to further realise the potential of BIM, and now IPD and visualisation, for use in their organisation and across the industry. Proof of concept was achieved 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. On-going success has been augmented through collaboration with: the CRC for Construction Innovation (now the Sustainable Built Environment National Research Centre); the International Alliance for Interoperability (IAI – now buildingSMART); A3D; and through a series of ARC Linkage projects (in conjunction with QUT and RMIT). However, this formal activity has been integrated on a project-by-project basis, with each project being targeted for specific new outcomes without impacting on time and cost. 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. The business wide adoption of outcomes has been an important driver for these relationships, with outcomes regularly shared with industry through seminars and conferences.

4.2. Exploring the links to theory

Based on an analysis of interview responses, Project Services have embedded dynamic capabilities which have facilitated their approach to the development of CADD, BIM, IP and IPD initiatives. Those capabilities most evidenced from interviews include:

- product and process development – with a focus on efficiency, productivity and waste reduction as realised in a series of pilot projects undertaken since 2006, including North Lakes Police Station, the Queensland State Archives Project, and Dandiiri Contact Centre (for further details refer to CRC CI 2009a&b)
- organisational learning including: both informal and integrated learnings; and more formal lessons through alpha and beta testing products, and the development of the National BIM Guidelines (CRC CI 2009a&b)
- external R&D engagement as highlighted in the previous section.
- strategic decision-making as evidenced in the engagement of a consultant to review activities to date in 2005 and the pursuant development and on-going implementation by Project Services of *The Vision* (Section 6.1)
- technology transfer – examples being: (i) the novation of A3D to Laing O'Rourke on the Queensland State Archives project to develop a 4D model of that project; and (ii) current efforts with the integration of visualisation and CADD software to produce 3D models to facilitate early stakeholder engagement.

Evidence of inbound absorptive capacity is apparent in the exploitation, assimilation and transfer of knowledge, and its acquisition from external sources. Issues identified from the analysis of interview responses regarding measures of absorptive capacity include:

- the capacity for technological development - from CADD (in the 1990's), to BIM (from the mid 2000's), to IP (from late 2000's), including leveraging broader potentials through: 3D to 4D to 5D model development; environmental modelling; brief development; and model server development.
- its adaptation from other sources - CADD was first used by defence and aviation industries in the 1980's; and model server technologies are being adapted from the

telecommunications industry; and visualisation tools now being adapted from the gaming industry.

- a high level of technological specialisation – as evidenced in the specialists engaged within the Project Service's CADD team, and through links with key external specialists.
- noteworthy economies of scale – Project Services is 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.

In terms of issues relevant to 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:

- 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
- the enhanced effectiveness of this technology[2]

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).

Construction innovation drivers were coded according to criteria related to environmental pressures, technological capability, knowledge exchange and boundary spanning. The most commonly coded responses in terms of environmental pressures related to:

- government clients (that is the Project Services team) with innovative demands.
- industry-wide market pull through: (i) contractors such as Laing O'Rourke; (ii) sub-contractors such as the AMCA; and (iii) peak bodies including BEIIC, the Australian Construction Industry Forum (ACIF), the Australian Procurement and Construction Council (APCC), the Australian Institute of Architects (AIA), and TripleM.

In terms of technological capability, reference to a technological leadership strategy was most often coded. This relates to: *The Vision* (Section 6.2) and ongoing commitment to its intent; and also to the leadership provided by Project Services to the broader industry, both state-wide and nationally (especially through NATSPEC).

Regarding the exchange of knowledge, lateral communication structures and on-site training of workers (the Queensland State Archives Project demonstrates Project Services, the contractor and the 4D model developer (A3D) working together on-site to develop the model) were important.

Finally in terms of boundary spanning the most coded references are:

- the empowerment of innovation leaders.
- the integration of design and build as seen in: (i) PS's contribution to the CRC for Construction Innovation project *Off-Site Manufacture in Australia* (Blismas 2007); (ii) practical examples such as the steel fabrication for the North Lakes Police Station from a model provided directly to the manufacturer; (iii) investigation of building life cycle asset management tools and processes (for example ArtrA).
- innovation from suppliers such as that associated with model server development, A3D (4D model development); and making use of 4D modelling for construction rehearsals and the like on the Queensland State Archives project by Laing O'Rourke.

[2] The Australian Mechanical Contractors Association (AMCA) highlighted Cannistraro (2011) potential savings in change orders from 18.42% on 2D projects to 2.68% on collaborative BIM use in their organisation in the US. This is supported in the Australian context by Barda (2011) who highlights the potential for 5-12% reductions in re-work based on ACIF understandings. Quantitative findings in the Australian context are yet to be tracked and reported widely throughout the sector.

The criteria least coded in relation to dynamic capabilities was cost advantage through increased market intelligence (indirect cost benefits exist from improved processes, but these have not been empirically reported). With regards to absorptive capacity this was a range of staff training. This is currently predominantly undertaken as on-the-job training, as universities and TAFE's lag industry needs.
With regards to open innovation criteria least coded criteria include: the proactive and nuanced role of IP management; pecuniary criteria such as the explicit production savings provided by Cannistraro (2011), not yet broadly available for discussion in Australia; and pecuniary interests such as acquiring, sourcing, selling, and revealing. The least coded of the construction innovation criteria are government guarantee for markets for innovative firms and subsidies for innovative applications and materials (though these are supported through their interaction on projects, no formal guarantee and subsidy mechanisms were discussed by interviewees). Materials and product evaluating institutions were also not coded as no formal evaluation mechanisms exist in this field though the following three organisations play a role:

- NATSPEC - through the establishment of National BIM Guidelines
- buildingSMART - providing an active industry-driven forum for discussion of methods and tools
- BEIIC – in reporting on productivity impacts of BIM (2010)

5. Conclusion

Project Services adoption of BIM and now IPD has been a long-term commitment (started with their early adoption of CADD) 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.
There was a high level of focus on several criteria including:
- Product and process development – with a focus in efficiency, productivity and waste reduction
- Organisational learning
- Knowledge acquisition and exploitation including both internal and external, and formal and informal R&D engagement
- Strategic decision making including the empowerment of innovation leaders and champions
- Maximising the use of technology
- Clients with innovative demands
- Industry push
- Supply chain integration

This provides a powerful cross-section of mechanisms through which benefits of innovation can be maximised.

Important also are those areas were little reference was revealed from interview. These include:
- Lack of evaluation institutions and mechanisms - formal industry wide benchmarking and reporting of benefits is lacking and would potentially enable the quantification of cost benefits and performance.
- A range of training options appropriate to industry-wide needs - in a field in which technology (both hard and soft) is rapidly changing, and impacting on procurement and delivery structures and mechanisms.

- Government guarantees or subsidies for industry-wide improvement - which may take the form of mandating of BIM and IPD. BEIIC (2010, p.xii) presents modelling, showing the economic benefits of accelerated widespread adoption of BIM in Australia, and a series of actions to help realise this potential.

The initiatives undertaken by Project Services over the past decade may be considered as providing a proof-of-concept of this direction. Fundamental structural reform may be the next required step to deliver on these potential improvement areas.

These findings will be explored further in conjunction with QDPW Project Services, in the context of the cross-case analysis and alongside of the findings of the audit and analysis of past R&D investment in the Australian built environment.

Further verification (through additional and follow-up interviews) and analysis (through separation of internal and external interviewee findings) of these findings would yield additional learnings, and may be possible in the context of Case Study 4.

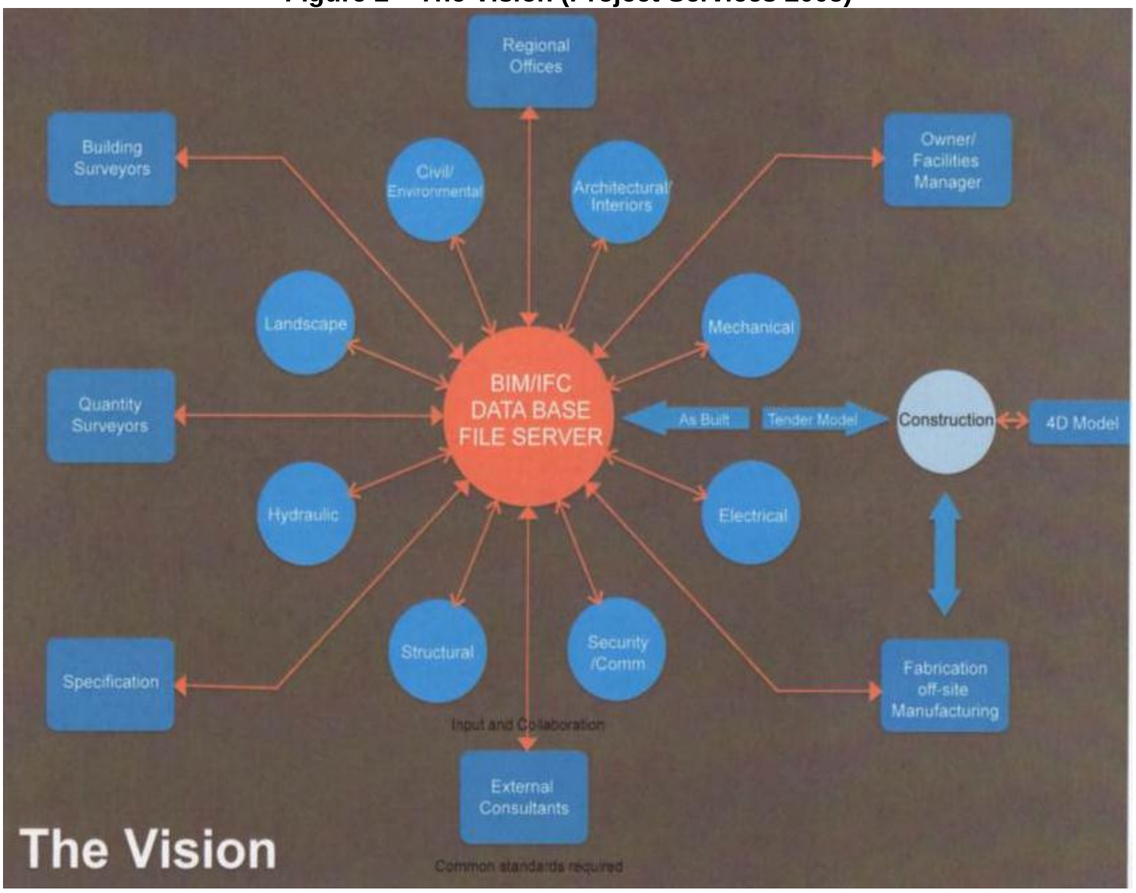
These findings will be further considered in the context of Phase 4 of this current project, in establishing policy guidelines for future R&D investment in the built environment.

6. Appendices

6.1. The Vision

Figure 2 was provided by Project Services. It was established in 2005, and has been the guiding strategy since then for the transition from CADD to BIM and IP to IPD.

Figure 2 – The Vision (Project Services 2005)



6.2. Timeline

The following timeline (Table 23) is an effort to place Project Services development from CADD, through 3D, 4D and 5D modelling, to their current pursuit of integrated project delivery (IPD). It attempts to place this development in the context of significant global and national developments in this field.

Table 23 – CADD to IPD timeline

Date	International	National	QDPW TIMELINE
Mid 1950s	SAGE (semi-automated ground environment) system developed.		
1963	Sketchpad developed by Ivan Sutherland MIT. Steve Fenves dev. STRESS (Structural Engineering Systems Solver) (Karima and Akinci 2010).		
Late '70s	US Dept of Defence provides initial impetus for "interoperability" in CAD.	Pre 1978 – NSW "method building"	State Government Computer Centre using AutoCAD since 1970's.
1980	Commencement of IGES (Initial Graphics Exchange Specification) - Digital Representation for Communication of Product Definition Data, published by U.S. National Bureau of Standards.		
Date??	3D solid modelling tool development –RUCAPS, TriCad, Calma, GDS (Eastman 2008).		
Early '80s	Competing standardisation efforts in Nth America & Europe on "object-based" interoperability.		
Date??	Object based parametric modelling developed for mechanical systems design e.g. Revit, Betley, Graphisoft, Tekla (Eastman 2008).		
Mid '80s	Merger of standardisation efforts to form (STEP). Collaboration in development of STEP (ISO 10303) standards.	Late 70-80's - Pallette Brisbane based 2D CADD software developed.	Purchased 4 GDS workstations – 2 for the Architects (schools design); 2 for Accommodation Services.
1989		Late 80's Commonwealth Government purchased and used 3D software package for multi-disciplinary project delivery.	New Chief Architect appointed. Changes in the branch related to use of CAD. Mostly architects using CAD. Next step was to get the engineers involved.
1991			Purchased AutoCAD for architects/interiors. Engineers already using it.
1992	Gehry Fish sculpture for the 1992 Olympics, Spain using Catia, Dassault Systems 3D modelling and fabrication software (aerospace industry).		Throughout 90's – GDS in use on main frame and mini-computers for briefing and documentation for schools projects. Change of focus to AutoCAD - enabled connection with structural engineers. Work on TAFE colleges.
1993	Intergraph (US) developing full parametric modelling package for design. Too much horsepower needed.		
1994	Publication of first STEP standards.		2 copies ArchiCad purchased (Cairns & Brisbane). Commercialisation of Project Services.
1995	Autodesk starts Industry Alliance for Interoperability due to perceptions of slowness in STEP standard development. CATIA V 5 released. Singapore launched the Construction and Real Estate Network (CORENET).		

Date	International	National	QDPW TIMELINE
1996	Computational Fluid Dynamics - Boeing 777 design.		
1997-2002	Vera Technology Programme (Finland) - management of info. Throughout life cycle of the built environment.		
2000	Release of IFC 2.0 interoperability standard (Washington). Start of IFC 2x development.		
2001	BIM preferred term for “object-based CAD” and “object-based” interoperability.	CRC CI commenced	20 Revit (later taken over by Autodesk) licences purchased.
2002	US General Services Authority – IFC core requirement in building modelling.		
2003	ArtrA software development - 3D Computer Aided Facilities Management system - uses BIM to manage info. & documentation for life cycle bldg maintenance	ActiveFacility - model server R&D commenced.	Expanded use of modelling software by architects.
2004	2004/05 Release of IFC 2x3 - wide support by major architectural CAD vendors.	Quality of documentation became issue. Group set up to look at this incl. Engineers Australia. Outcome - *Getting it right the first time*.	Energised the focus on CAD.
2005	IAI became buildingSMART		Consultant engaged for review of PS activity. Strategy to ‘do it’. “The Vision” established Initial look at using Tekla.
2006		*Open specification for BIM: Sydney Opera House* case study - CRC for CI.	Mareeba Court House - demo project. 2007 RAIA conference driver. Move towards multi-disciplinary model. Look at sustainability - DDS for modelling of performance. Lots of IFC problems. A3D prepared model - State Archives Extension. Built 3D model & paid for 4D model of the bldg.
2007	General Services Agency USA - IFC would be a core requirement in building modelling. American Institute of Steel Construction’s Steel Design Guide - computer based automation etc (Eastman 2008). National Institute of Bldg Sciences release *National BIM Standard*. From Oct 1 - Senate Properties (Finland) require models to meet IFC standards. Applications of BIM and Hurdles for Widespread Adoption of BIM, CIFE.	RAIA conference April 2007 - ICT theme. Building site as a place of assembly – CRC CI publication *Offsite manufacture in Australia* (Blismas 2007).	CADD Steering Committee established. Monthly industry sessions –multi-disciplinary.
2008	Eastman, C. M. (2008). *BIM handbook*, N.J., Wiley.	BIM modelling of Brisbane City Hall commenced. CRC CI project gathering industry requirements for model server.	Tom Fussell Chair of NATSPEC With BDS - use Tekla to develop steel model for fabrication – North Lakes Police Station. ARC Linkage - integrated decision-making & early

Date	International	National	QDPW TIMELINE
			engagement of mech. services. Mech. engineers using Revit Mechanical. Dandiiri Contact Centre – fully integrated model migrated to 4D with A3D. QPWD took the risk.
2009	McGraw Hill Construction - *The Business Value Of BIM: Getting Building Information Modeling to the Bottom Line*.	CRC CI - *National Guidelines for Digital Modelling*. ACIF & APCC - *Integrated Project Teams and BIM in the Australian Construction Industry*. AIA Integrated Practice Group established.	Toowoomba housing projects – 3D model and guaranteed schedule of cost provided to contractor.
2010	Parametric modelling tools - Aviva Stadium, Dublin Karimi, H. A. and B. Akinci, Eds. *CAD and GIS Integration*. London, Taylor and Francis Group. BSRIA BIM and CIBSE BIM conference. McGraw Hill Construction - *The business value of BIM in Europe.*	buildingSMART - MESH Conference. QDPW part of Steering Committee with AMCC - improve the processes; rationalise libraries. BEIIC - *Productivity in the buildings network: Assessing the impacts of BIM* AMCA & KarelCad - models from eng. to fabrication.	Industry partner of ARC Linkage for object libraries. Project Services established QS Working Group. QS's - small projects using Rivet and CostX – 5D.
2011	Senate Properties BIM guidelines 2011-12. *BIM Management for value, cost and carbon improvement: UK BIM Working Party Strategy Paper.* *UK Nat. Building Specification BIM survey findings* released. UK Government Construction Strategy – will require collaborative 3D BIM as a minimum by 2016.	NATSPEC - *National BIM Guide; Project Brief; and Reference Schedule*. buildingSMART – MESH Conference April 2011. 1 Bligh Street– first commercial project in Aust. to implement multi-disciplinary BIM collaboration. Micropower software taken Australian licence for ArtrA – 3D asset and FM system.	Partner in ARC Linkage project on specification and estimation (QUT, NATSPEC) Process documentation for external consultants. Using Affinity & CodeBook to develop project briefs. Model server for use on Carseldine project. Mech. engineers use Revit model in CADuct – model to manufacturer. Working towards IPD on all projects.
2012			Integration of visualisation software (from gaming industry) into delivery process to enhance stakeholder engagement at front-end of project (Urban Circus) Use of Affinity and Codebook for project briefing to develop room data sheets for current project
Next steps			Link with whole of supply chain (for example with use of ArtrA) Address procurement issues Criteria for sharing of models, libraries etc. Model servers to use for FM.

6.3. CADD, BIM and IPD strategies

Table 24 – Relevant CADD, BIM and IPD Strategies in Australia

Initiatives	Date	Aim and Objectives
National		
Getting it right the first time	2004	Quality of documentation became issue. Group set up to look at this incl. Engineers Australia - Driver for focussing on the front end.
Open specification for BIM: Sydney Opera House case study (CRC for Construction Innovation)	2006	The Sydney Opera House was used as a case study of the application of BIM. This was integrated with a task to identify if such a model could support the asset and facility management needs of such a building. A set of BIM standards were developed, with the intent of their potential application to other building.
Offsite manufacture in Australia (Blismas)	2007	This scoping study was led by Project Services. The intent was to look at the state of off-site manufacturing adoption in Australia. It discusses manufacturing principles; drivers and barriers; presents 7 case studies; and provides a proposed action plan.
National Guidelines for Digital Modelling and case studies (CRC for Construction Innovation)	2009	These Australian-based guidelines draw on industry consultation, experience and case studies to promote a set of industry standards based on internationally accepted standards.
Integrated Project Teams and BIM in the Australian Construction Industry (ACIF & APCC)	2009	This paper reviews BIM and IPT, and highlights improvement opportunities in these methods to deliver greater value for money to project stakeholders.
Productivity in the buildings network - Assessing the impacts of Building Information Models (BEIIC)	2010	Reports on the first national survey of BIM adoption, use, costs and benefits in Australia. It provides an analysis of contribution the widespread adoption of BIM could make to the Australian economy.
*National BIM Guide and Reference Schedule (*NATSPEC)	2011	This draft reference document is intended to assist clients and consultants in defining their BIM requirements in a nationally consistent manner.
Queensland		
Consultancy review report	2005	John Mitchell engaged by Project Services to review advances to date and provide advice regarding future directions
The Vision	2005	Project Services prepared this vision to strategically guide development from that time forwards.

6.4. Interview data tables

6.4.1. Understanding the initiatives

6.4.1.1. Drivers

Identified by internal interviewees

- increased production efficiencies
- enable better collaboration and communication in order to achieve performance advantages
- availability of new technology
- providing leadership at both national and state level including influencing the industry and the uptake of new technologies and associated work practices.
- provide a stimulating work environment for staff
- improve client understanding and thus increase market share
- improve business outcomes

Identified by external interviewees

- process improvement
- improved quality of product and increased productivity through (i) a reduction in waste and duplication; (ii) increased confidence in documentation; (iii) the ability to undertake building performance assessments linked to increased sustainability of built outcomes
- improved communication and collaboration including the better integration of design information
- technology as its value is becoming more evident for example through being able to rehearse the construction process and thus increase certainty of outcomes
- the need to innovate and bring change to the industry

6.4.1.2. Delivery

Identified by internal interviewees

- Incremental change on a project by project basis involving learning from mistakes and implementing what works
- establishment of a shared vision
- training in teaching – often by word of mouth
- influencing vendors and not inventing new tools
- model so the implementation – learning from other sectors; learning how to manage the access to the data; and how to validate data
- patron each by executive management
- alliance with research is
- upgrading of manuals

Identified by external interviewees

- Development and use of the 4D model including (i) Getting the correct information into the 3D model (ii) turning it into a 4D environment through use of the schedule (iii) using it construction sequencing and visual status reports
- training – getting the team to adopt technology and benefit from it
- experimentation
- the staged sequencing from small and simple projects to significant ones
- investment in the right technology
- establishing an action plan based including product acquisition, implementation strategy, and an integrated approach
- developing new processes for the use of the 4D model and integrating these into business procedures

6.4.1.3. New processes – both current and required

Identified by internal interviewees

- sharing and use of three and 4D models with contractors leading to improved collaboration and reduction in errors and omissions
- incremental steps the development from simple or complex building types
- new fee split required to reflect new work processes
- new style of training required
- application tweaking required
- development of a shared vision of the internal team
- implementation as part of other processes for example the Gateway review

Identified by external interviewees

- the workflow required to maximise advantages; needs to be documented; tied to the front end of the project
- different procurement methods required to maximise advantages
- industry-wide data support and naming conventions required
- new approach to training required
- standards around 3D, 4D and BIM models need rationalisation
- increased collaboration required bringing together various disciplines
- development and use of model fileserver clash detection, design optimisation, coach checking and compliance
- needs to be able to better identify value to industry and government
- need to keep focus on what tradesmen need to build with

6.4.1.4. Impacts

Three types of impacts are being discussed: (i) impacts on the culture and values of the organisation; (ii) on the supply chain and industry; and (iii) the impact of major external changes on the development and delivery of the initiatives.

Culture and values-based impacts

Identified by internal interviewees

- from engaging a consultant to engaging the consultancy team (with issues of risk is and ownership)
- changing culture within contracting organisations; lack of understanding industry of integrated project delivery and BIM processes
- builders in the office assisting with design of documentation
- needing a new way to deal with contracts; fear of litigation; managing an understanding Copyright
- change in business and project delivery processes required
- need a shared values across the team

Identified by external interviewees

- training of management and operatives
- greater reliance on trusting relationships required; more collaborative and less adversarial
- changes to procurement required; getting rid of lowest price mentality; project managers and directors protecting commercial position because of skinny margins; creating an open environment in which people can see what's going on in the 4D model
- guys on-site need to see the benefits also
- design rather than a documentation tool; consultants may feel creativity is being stifled
- reduction in documentation

Impacts on the supply chain and industry

Identified by internal interviewees

- Sharing of models and training consultants and contractors
- contractors now sharing 4D models with sub-contractors
- development of a national BIM guidelines
- sharing process documentation and models with external consultants
- engagement of consultancy teams rather than individual consultants
- reduction in variations

- feedback loop to vendor's; push back now to suppliers to provide more information in objects
- can only really be delivered on the D&C projects

Identified by external interviewees

- changing relationship between designers, contractors and subcontractors
- improved clash detection
- industry is shifting towards smart environment with improved safety and planning
- improvement in upfront inefficiencies
- downstream supplier is getting conflicting messages regarding them deliverables
- sub-contractors have embraced technology especially steel and mechanical

Major impact of external changes

Identified by internal interviewees

- no major impact because of strong vision and direction
- reduction in workload due to reconstruction impacted on ability to undertake R&D on new projects

Identified by external interviewees

- major push by CAD vendors of next-generation software
- some stalling in terms of enabling technology, hardware issues
- GFC impacted on new projects, providing critical focus on cost-effective delivery, became one of the largest contributors to the real application and uptake of BIM in a broad sense
- early losses when people jumped onto the bandwagon
- governments mandating the use of BIM in the UK, the United States Gen services Administration and Project Services

6.4.1.5. Successes

Identified by internal interviewees

- adopting an incremental change approach; proof of concept achieved
- establishing a clear vision and sticking to it
- taking the risk in order to provide industry leadership; working with the supply chain
- decrease in team size, increase in production speed or increase in deliverables for example facility management, 4D modelling, cost modelling and brief modelling
- motivated team of people
- Dandiiri being awarded a six star green star rating

Identified by external interviewees

- Project Services seen as a leader in BIM both state-wide and nationally
- raised the profile of the construction industry to attract new talent
- clients getting more and with greater confidence by the same dollar
- reduction in variations
- now able to be implemented on a number of small projects; now onto third fourth and fifth generation projects
- excellent model quality

- approached by Project Services to going out to tender with models reference only initially and migrating this to form part of the contract
- improvements in technology and hardware to enable better collaboration tools
- better and clearer communications; increased collaboration, honesty and openness

6.4.1.6. Barriers

Identified the internal interviewees

- indifference and lack of knowledge regarding integrated project delivery, BIM processes, intellectual property, accountability, contractual and legal issues, copyright issues, litigation issues and ownership – relates to clients, consultants, and contractors
- vendors getting products to work correctly with increased focus on information and costing elements rather than graphics
- entrenched business and project delivery processes and associated resistance to change
- building a shared vision of the integrated project delivery and BIM futures
- commercial realities
- lack of political understanding of the need for integrated project delivery and BIM
- continuity of knowledge and support (when key people move on)

Identified by external interviewees

- education and training, skills gaps; requires design and construction skills along with CADD skills; skills gap in translation from 2D to 3D to 4D
- capable software, technology (for example Internet bandwidth, constant upgrades); lack of compatible product data; no consistency information exchange protocols; need for guidelines
- redefinition of processes to maximise advantages; new fee scales required
- procurement (including insurance and legal liability issues) and acquisition strategies
- overcoming industries history of trying new things; overcoming cynicism; perceived cost penalties; lack of industry-wide uptake
- lack of appreciation by middle and senior managers as to investment required; development of 4D model labour-intensive; takes time to implement

6.4.1.7. R&D

Identified by internal interviewees

- Project Services took initiatives to a proof of concept phase (e.g. North Lakes police station) then intellectual partner was needed to contribute to further development.
- Formal research links established through the CRC for CI and ARC linkage projects.
- CRC for CI projects include Estimator, design checker, spec writer, 12 D site works, LCA design and the National BIM guidelines. Project Services involved in development, alpha and beta testing, and presentations of trials.
- ARC linkage projects BIM Specification and Cost Planning (July'10-Jun'13) and Assimilation of Building Services in Early Stage Design (Dec '08-Dec '11). Former with QUT and the latter with RMIT and QUT. Provided an important opportunity for Project Services to have significant import into both the research questions and methodologies.

- Ph.D. students being present in the office.
- Research being undertaken by industry associations and suppliers. The Australian Mechanical Contractors Association
- Suppliers such as Autodesk (Autodesk Lab), KarelCAD and Bentley undertake research relating to product development.
- Incremental implementation of projects can be considered as informal research and development; no specific budget allocations were available for this activity. Projects were targeted which would provide an opportunity to implement current state understandings and to learn from these experiences

Identified by external interviewees

- Abundant international platform informs CRC research including European research into BIM server development; 4D research at Stanford University; AEC three in the UK and object libraries; Salford University in the UK; the technical University Dresden (structural); the technical University of Munich; Tampere University of technology; VTT Finland; University of technology Sydney (regarding construction processes and BIM.

6.4.2. Links to theory

6.4.2.1. Dynamic Capabilities

Table 25 – Summary of comments relevant to dynamic capabilities from interviews

Product & process development	– Incremental approach to adopting initiatives – integration of new software into business processes – internal CAD steering group – upgrading is manuals, procedures, processes, document management system, naming conventions and library development – development and implementation of Vision – reduction in overall delivery time or increasing what is delivered – development and use of model server – getting appropriate technology including software and hardware – changing perceptions – working with industry associations and NATSPEC – changing the way work is done with contractors and subcontractors – future development required – further impacts on business processes of technology – new procurement and contractual arrangements – new fee structures – resolution of software and workflow issues – standardisation of object data – use of asset and facility management – development of KPIs – production of digital as-builts
Organisational learning	– Transition from 2D office 6-7yrs ago – development and implementation of the Vision – formation of CAD steering group – incremental application on projects, learning from mistakes; pilot and demonstration projects as proof of concept – training and teaching by word of mouth – the John Mitchell 2005 study – involvement in ARC linkages and the CRC CI and SBEnrc – involvement with industry organisations and associations – adopting new smart work practices as example to the industry – driver in becoming tech. savvy; group of people in PS who understood the technology – involvement in ARC linkages and the CRC CI and SBEnrc – involvement with industry organisations and associations
Strategic decision-making	– Engagement of John Mitchell from 2005-2007 – development of the Vision

	– Chief Architect as champion supported by Director and Director-General – strategic project by project implementation – making use of gov. resources and purchasing power to drive initiatives across industry – sustain market share and show government leadership – strategic focus on model server – announcement Project Services would require BIM on all projects – high level work to reinvent contractual arrangements
Technology transfer	– Sharing models with contractors initially for reference then as part of contract (through Solibri and Navisworks) – use of diverse software e.g. energy modelling, CADDuct, Tekla – alpha and beta testing of CRC CI project outcomes – model server technology adopted from other industries e.g. telecommunications – BIM adopted from manufacturing aerospace and defence industries – Future implications/innovations – immersive virtual reality design tools – science tablet devices with augmented reality – 3D laser scanning for digital as- builts
Internal R&D engagement	– Formation of CAD Steering group – incremental approach to adopting initiatives; experimentation – interactions with researchers – Project Services took initiatives to proof of concept on informal basis
External R&D engagement	– Involvement with ARC linkage projects – involvement with CRC CI and SBEnrc – engagement with AMCA & A3D who have invested heavily in R&D collaboration with vendors with own R&D programs – future implications/innovations – ARC linkages preferred method – more control over questions and methodology
Alliancing	– sharing models with contractors initially for reference only – discussions with tripleM and AMCA – research alliances with CSIRO, CRC CI (now SBEnrc), IAI (buildingSMART), A3D – sharing E-tendering system with the Master Builders Association – working with Laing O'Rourke to implement 4D model on the State Archives Building
Cost advantage through reduction in waste	– Gaining efficiencies over the life of the building – gaining efficiencies in translation from design to construction to operational model – reduction/elimination of waste and duplication of effort (rework); get it right first time – address inefficiencies in construction industry; construction industry is the single biggest industry in the world and in any country yet it is the least efficient and profitable
Product/service differentiation	– Entrenched business and project delivery processes will have to change, facility owner will be looking to consultants to get their model
Customer focus	– Collaboration through IP (and IPD) in the development of BIM models has the potential for customers and facilities management – measuring the value of 4D still needs work
IP creation	– 4D modelling tools developed by A3D as utilised by Project Services

Table 26 – Number of interviewees who discussed issues considered related to organisational dynamic capabilities

	Reported in:
Product & process development	11 of 11
Organisational learning	10 of 11
Strategic decision-making	10 of 11
Technology transfer	9 of 11
Internal R&D engagement	8 of 11
External R&D engagement	8 of 11
Alliancing	8 of 11
Cost advantage through reduction in waste	5 of 11
Product/service differentiation	3 of 11
Customer focus	1 of 11
IP creation	1 of 11
Cost advantage through increased market intelligence	0 of 11

6.4.2.2. Evidence of absorptive capacity

Table 27 – Details cited from interviews of evidence of inbound absorptive capacity

Exploitation of knowledge	– Next step to go upstream with more complex projects and become standard practice – ambition to have no variations – seen as benefiting Project Services in their internal processes – production efficiencies including performance advantages and speed – 3D has improved collaboration - drastic improvement in errors and omissions – size of team is reducing, speed of production is increasing, overall delivery time decreasing or increase in what is delivered – on site layout time reducing for mechanical sub-contractors – facilitated because Project Services have all disciplines under one roof – development model fileserver to design optimisation capabilities – way of motivating the office – not just using 4D software for bids and tendering but the construction – getting six star green star rating on Dandiiri – contractors no longer scared to play in the patch – State Archives Project three months ahead of schedule – training in BIM in Project Services Architectural Academy – announcement that BIM deliverables will be required on all projects – industry is learning of the impacts were efficiencies exist, using them information to pre-planned, pre-purchased and prefabricated
Transfer of knowledge – predominantly outbound	– Incremental application to projects – sharing models with contractors and consultants – publication of guidelines to consultants – design direct to sub-contractors for fabrication – engagement and feedback loops with suppliers/vendors – impact state-wide and nationally, PS consistent voice nationally in last 3 to 5 years – presentations at industry forums and conferences – providing industry leadership, encouragement to industry to use them and IFC, training and assisting where they can – novation of A3D to Laing O'Rourke on the state archives Project
Assimilation of knowledge into organisation	– CAD Steering Committee, involvement of the discipline leaders, the IPD workgroup and IT team – incremental application on pilots and demonstrator projects; experimentation – 6 to 7 years ago Project Services was a 2D office, it is now a 3D office – active involvement of John Mitchell 2005 to March 2007 – presentation Australian Institute of Architects conference (2007) and buildingSMART (2007) conferences
Knowledge acquisition externally	– Involvement with 2 ARC linkages, CRC CI, SBEnrc, industry associations, and NATSPEC – interactions with CSIRO and IAI – engagement of expert suppliers – John Mitchell 2005 report – novation of A3D (State Archives Project) to Laing O'Rourke – attendance at summits, forums etc e.g. BEIIC buildingSMART, Autodesk
Knowledge acquisition – internally	– CAD Steering Committee as forum for discussion – achievements on pilot projects, progress by lessons learned – background research and experimentation – PS took things to a proof of concept stage internally

Table 28 – Number of interviewees who discussed issues considered related to evidence of absorptive capacity

	Reported in:
Transfer of knowledge – predominantly outbound	11 of 11
Exploitation of knowledge	11 of 11
Knowledge acquisition – externally	9 of 11
Assimilation of knowledge into organisation	9 of 11
Knowledge acquisition – internally	7 of 11

6.4.2.3. Measures of absorptive capacity

Table 29 – Details cited from interviews of measures of absorptive capacity

Measures of absorptive capacity	**As evidenced in Project Services**
Effort put into development of new products	– Development 4D model, IP and IPD – cost design analysis; environmental analysis – tools developed by the CRC CI e.g. estimator, design checker, spec writer, 12 D site work, LCADesign, and National BIM guidelines – PS role in strategically directing development and becoming a consistent national voice for last 3 to 5 years – commissioning of John Mitchell report (2005) and subsequent action plan, product acquisition, and implementation on small-scale projects across all disciplines – presentations at the AIA and buildingSMART conferences (2007) – pilot projects from 2005 to current – product development work with e.g. A3D (4D modelling products), Exactel (costEX), ActiveFacility (model server)
Noteworthy economies of scale	– BIM new standard practice on public housing, next step police stations – the size of the Qld State Gov.'s work represents a large proportion of the Aust. construction spend; PS are the largest gov. agency in Aust. thus can tap into new techniques/processes: government is has the resources to drive the sorts of initiatives
High level technical specialism	– Number of specialists in particular fields within PS regarding model server, CADD application managers, specialist IT team – involvement of John Mitchell from IAI – engagement of A3D to develop first 4D model; pilot project undertaken with Laing O'Rourke (expertise in BIM from the UK)
Capacity for technological development	– Ever evolving space; industry still developing; model file servers still developing – need for more object information; needs to be pushed back to suppliers – shift towards a smart environment with 4D modelling - improved safety and planning, clash detection and construction sequencing – Internet and computing power could be one of the biggest handicaps – next breakthrough in the business model – use of tech. such as laser scanning, immersive virtual reality design, 3D printers, cloud for building analysis, tablet devices with augmented reality, Trimble laser and GPS-based assessment systems
capacity to adapt technologies from other sources	– BIM around in other sectors e.g. manufacturing, aerospace, petrochemical and defence long time - construction industry haven't been able to afford it – working with the AMCA, KarelCAD and Bentley – use of costEX, CADDuct, Tekla, energy modelling software – model server from telecommunications industry – tech. from other sectors - bldg performance analysis, immersive virtual reality design & 3D printing
Awareness of competitors technologies	– Sub-contractors and contractors working with PS aware of array of 4D technologies and software
Staff skills and investment in training	– Role of Project Services Architectural Academy – lots of time and effort involved; continued improvement required
Effort put into crossed reduction	– Production efficiency as a driver both in Project Services and industry – reduced waste leads to easier finance and reduced finance risk – 3D model design direct from design office to the factory for prefabrication
Awareness of customer needs	– Sub-contractors and contractors responding to PS vision and needs as the customer; and that chasing inefficiency was a part of PS motivation

Table 30 – Number of interviewees who discussed issues considered related to measures of absorptive capacity

	Reported in:
Effort put into development of new products	11 of 11
Noteworthy economies of scale	8 of 11
Capacity for technological development	7 of 11
High level technical specialism	7 of 11
Capacity to adapt technologies from other sources	6 of 11
Awareness of customer needs	5 of 11
Staff skills and investment in training	5 of 11
Effort put into crossed reduction	3 of 11
Awareness of competitors technologies	2 of 11
Range of staff training	0 of 11

6.4.2.4. Features of open innovation

Table 31 – Details cited from interviews of significant features of open innovation approach

Significant features of 'open innovation'	As evidenced in Project Services
Purposive outbound flows of knowledge & technology	– Sharing of 4D models with contractors; novation of A3D to Laing O'Rourke – talking to Tasmanian Government Industry Training Board – Tom Fussell chair of NATSPEC (development of BIM guidelines) – PS train and assist as much as they can with contractors and subcontractors; PS focused on making models accessible to all – looking hard at places where the design can drive the manufacture – presentation at 2007 AIA and buildingSMART conferences – PS galvanised the use of BIM in Queensland - seen by others as an equal leader in Australia – e-tendering system made available to Master Builders – Project Services Architectural Academy
Abundant underlying knowledge landscape	– Association with ARC Linkage projects, CRC CI & SBEnrc, NATSPEC, AMCA, vendors, IAI & buildingSMART, A3D – alpha and beta testing of CRC CI projects – internal IT team, CAD Steering Committee, IPD group
New metrics for assessing innovation capability and performance	– Use of 4D model for the green assessments, energy modelling; achievement of 6* rating for Dandiiri; use of cloud to do power, water usage and occupancy rate options – use of robotic GPS– traditional layout would have taken 2 men 1 week/floor, now taking 1 man half a day – reduction in variations; see US data on reductions in change orders provided by interviewee BIM 05; clash detection through early-stage coordination – UK Ph.D. on KPIs 4D – see Dawood paper
Business model focus on converting R&D into commercial value	– Informal R&D – overhead code that allows development of a percentage of project that we know we can absorb; each project should advance strategic approach a little – initially went out to tender with 4D models for reference only, and slowly migrated this to models as part of the contract; next step is the model producing the built quantities and being tagged with cost information – working with structural steel design and the sub contract or to use 3D model fabrication
Rise of innovation intermediaries	– Involvement with CRC CI & SBEnrc; ARC Linkage projects; IAI & buildingSMART – feedback loop to vendor's and suppliers
Equal importance given to external knowledge, in comparison to internal knowledge	– PS took things to a certain stage themselves as proof of concept, then an intellectual partner required – external involvement with 2 ARC Linkage projects; CRC CI; NATSPEC; buildingSMART; ActiveFacility; A3D; AMCA; subcontractors; and vendors – internal formation and development of CAD Steering Committee, IPD group, BIM managers, CAD software specialists

Table 32 – Number of interviewees who discussed issues considered related to features of open innovation

	Reported in:
Purposive outbound flows of knowledge & technology	9 of 11
New metrics for assessing innovation capability and performance	8 of 11
Business model focus on converting R&D into commercial value	6 of 11
Abundant underlying knowledge landscape	6 of 11
Rise of innovation intermediaries	5 of 11
Equal importance given to external knowledge, in comparison to internal knowledge	3 of 11
Proactive and nuanced role of IP management	0 of 11

6.4.2.5. Nature of open innovation

Table 33 – Details cited from interviews of nature of open innovation

Nature of open innovation	**As evidenced in Project Services**
Inbound innovation (internal use of external knowledge)	
Knowledge Acquisition	– Engagement with ARC linkages; CRC CI, SBEnrc, NATSPEC, AMCA, TripleM, vendors, CSIRO, IAI and buildingSMART, BEIIC – PS represented on a number of industry initiatives, forums where you have dialogue, board of that spec, PS presents as many high-level professional development forums and seminars
Exploitation	– Project Services has had impact both it's a state level and nationally – PS is trying to push IPD at a high level because technically we can handle the issues that we need to change the contracts with both subcontractors and contractors – size of teams reducing, speed of production increasing, or an increase in what is delivered – vendors need to provide more information in objects, pushing back to suppliers – when not trying to invent new tools but for example influence Exactel in the development of costEX to allow collaboration of data – all disciplines under one roof and so have a very real opportunity to get this working – embedded in project delivery processes – application on projects including the State archives Project – using the 4D model to show what the program is doing instead of traditional cant charts – getting six stars of the Dandiiri contact Centre – the UK and the United States Gen services authority have already mandated BIM, Project Services made an announcement a few years ago that this will also happen here – State archives Project was three months ahead of schedule
Outbound innovation (external exploitation of internal knowledge	– Sharing of 4D models with contractors consultants and subcontractors; – Tom as chair of NATSPEC driving the development of national BIM guidelines – PS providing advice to Tasmanian government industry training board – working with triple M – feedback loops to vendor's – presentation at Institute of architects and building smart conferences in 2007 – making e tendering system available to Master builders
Retention	– Staged sequencing from small and simple pilot projects – push each project a little higher – lots of time and effort put into training; word of mouth training – formal groups meeting on a monthly basis – alpha and beta testing of the CRC CI projects; – upgrading of manuals
Coupled activities	– Working with suppliers and vendors to develop compatible product data, information exchange protocols

Nature of open innovation	**As evidenced in Project Services**
	– external research involvement – establishing national BIM guidelines – new compliance and certification processes – need to change business (procurement, fee scales) and financial systems workflows
Effectiveness	
Enhancing technological effectiveness	– Development of national BIM guidelines – incremental approach – more information in objects from vendors and suppliers; BIM compatible product ; off-the-shelf tools that talk to each other – gaining efficiencies in the life of building – model server data transfer between consultants and contractor – looking for places where design can drive manufacture – improved communication and collaboration – new procurement methods and business models – models for design optimisation, construction sequencing and clash detection – government drive motivates industry
Number of innovations	– Project Services now a 3D office – increased collaboration through IP and IPD – increasing what is being delivered e.g. FM,4D models, brief, environmental and cost modelling
Less waste	– Increased production efficiency through improved coordination, variation reduction – 4D model of clash detection – better program monitoring
Decreasing risks	– Fear of litigation not valid - process does not add faults – smart environment - improved safety and planning; ability to rehearse project – enables better risk, cost, quality management, communications, collaboration and predictability
Access to new markets	– Use of 4D models to win work – 4D modelling software for use in other sectors – contractors now working with BIM deliverables to increase market share
nonfinancial benefits	– Increase in what is being delivered to client e.g. cost briefing and environmental modelling – production efficiency is a driver – improved communications
financial benefits	– Reduction in waste and duplication of effort – 4D models for clash detection – greater on-site technologies e.g. tremble lasers and GPS-based system; prefabrication
Lower costs	– Production efficiency e.g. size of team reducing, speed of production increasing
Other measures	– 4D enables greater predictability and certainty – sustainability drivers important
Stimulating growth	– PS impacted at the state and national level – mandating the use of BIM
Shorter time to market	– Speed of production increasing

Table 34 – Number of interviewees who discussed issues considered related to nature of open innovation

	Reported in:
Inbound innovation (internal use of external knowledge)	
Knowledge Acquisition	11 of 11
Exploitation	10 of 11
Outbound innovation (external exploitation of internal knowledge)	7 of 11
Retention	6 of 11
Coupled activities	4 of 11
Pecuniary re acquiring, sourcing, selling, and revealing.	0 of 11
Non-pecuniary	0 of 11
Effectiveness	
Enhancing technological effectiveness	11 of 11
Less waste	7 of 11
number of innovations	7 of 11
Decreasing risks	4 of 11
Lower costs	3 of 11
financial benefits	3 of 11
nonfinancial benefits	3 of 11
Access to new markets	3 of 11
Stimulating growth	2 of 11
Other measures….	2 of 11
Shorter time to market	1 of 11

6.4.2.6. Benefits of open innovation approach

Table 35 – Details cited of benefits of open innovation approach

Category of factors	As evidenced in Project Services
Capabilities of the people involved in the innovation	– PS has a critical group of people who understand the technology – IT team incl. BIM manager, 2 CADD software specialists – alpha and beta testing of software – engagement with ActiveFacility and A3D – Chief Architect as key driver – passionate team
Working environment	– Useful for motivating the office - providing intellectual stimulation – requires collaboration – progress by lessons learnt; training and teaching by word of mouth – drives work to front-end project – forgetting what tradesman need to build with – engagement with PS Architectural Academy
Level of interest of project team members	– Shift from acceptance to recognising the benefits; some would rather be left alone – core team engage in 'playing' in own time – PS passionate and follows through – middle management and senior management disconnect – you can't be a PM to manage a project in the traditional sense
Formation of task groups	– formal groups meeting on a monthly basis as forum for discussion – Steering committee and IPD group – NATSPEC committee - development of national guidelines

Table 36 – Number of interviewees who discussed issues considered related to benefits of open innovation approach

	Reported in:
Level of interest of project team members	7 of 11
Working environment	7 of 11
Capabilities of the people involved in the innovation	7 of 11
Formation of task groups	4 of 11

6.4.2.7. Drivers for construction innovation

Table 37 – Details of construction innovation drivers

Innovation driver	
Environmental pressure	
Governmental clients with innovative demands – within org	– Driven by government - impact on state and national; dramatic results; galvanised BIM use in Queensland – PS had the vision to make changes for the benefit of the industry – potential facility management – key driver inefficiency in construction industry - PS want to do something about – engagement with A3D and Laing O'Rourke on the State Archives Project – 15 years ago it was about showing government leadership; 5 to 6 years ago about achieving organisational outcomes
Market pull – industry wide	– Very real industry push for BIM – push for elimination of waste and duplication of effort – Laing O'Rourke commenced work in BIM 12 years ago in UK
Innovation stimulating regulations – across industry, between and within org	– Development of a national BIM guidelines – PS work needs to be followed by legislative processes and rules – governments mandating BIM on all projects
Technological capability	
Technology leadership strategy – between and within the organisations	– Stated leadership at all levels of the Dept of Works executive - wanted organisation to be tech savvy; announcement to market of BIM deliverables on all projects (2008?) – The Vision (2005) - PS had the vision to make changes to the benefit of the industry – PS encourage industry to use BIM; train and assist where able – government is always one of the key drivers - has got the resources to drive these sorts of initiatives where only very progressive private companies will invest – PS seen by others is equal leader in BIM in Australia – method of working with industry (discussed elsewhere)
Finance the pilot projects – industry wide	– PS novated A3D to Laing O'Rourke on the Archives Project – incremental application from small and simple projects to more sophisticated ones – not an actual cost code but a determination on the percentage that can be absorbed to pilot new processes without impacting on deliverables – PS have purchasing power to do demo projects
Technology push – industry-wide, between organisations and within the organisation	– Push by vendors to move to next-generation software – PS train and assist industry to use BIM – push back to suppliers to provide more object data – novating A3D to Laing O'Rourke on the State Archives Project – tech. staff need to have right tools
Technology fusion – within org.	– See Autodesk lab products
Programs promoting access to technology – industry wide	– PS working with suppliers and subcontractors
Knowledge exchange	
Training of workers on the site – between and within orgs	– Working on-site with contractors; contractor then sharing models with subcontractors – PS providing models to tenderers – staged sequencing from small and simple to sophisticated projects - progress by lessons learnt – formal groups meeting on a monthly basis as forums for discussion – training and teaching by word of mouth – John Mitchell working with the project team – on-site learnings for both contractors and PS on State Archives projects – PS Architectural Academy
Integrated and informal R & D function – between orgs	– Incremental project by project implementation; staged sequencing including experimentation – did a fair amount of background research – lots of collaboration between CSIRO and IAI – sponsoring Ph.D's

Innovation driver	
	– internal working groups – involvement with industry organisations e.g. forums – PS Architectural Practice Academy
Stimulation of research - industry wide	– PS took to proof of concept then stronger intellectual partner was needed – involvement with ARC linkages, and past CIC CI projects – engagement John Mitchell (IAI and buildingSMART) – A3D sponsored Ph.D. at Teeside University
Creation of knowledge networks – industry wide	– Working with the AMCA, KarelCAD, Bentley, Exactel – involved in two ARC linkage project – internally with CADD Group and IPD workgroup – feedback loop to vendors and suppliers
Effective information gathering – between orgs	– Involvement with ARC, CRC CI, and SBEnrc – internal specialists in each field
Broad view of risk – between orgs	– PS carried risk to demonstrate outcomes to clients and contractors – fear of litigation and managing copyright is a barrier
Programs promoting collaboration – industry wide	– Main driver is collaboration – sharing models with contractors and consultants – leveraging up with vendors and suppliers
Lateral communication structures - between and within the organisation	– PS management including each of the discipline leaders and internal CADD specialists - These people formed the CADD Steering Committee - Now also IPD Group; PS good environment for collaboration – needed research partner to progress beyond proof of concept - researchers including CRC CI, ARC Linkage projects (and associated PhDs); Teeside Uni (via A4D) – NATSPEC engagement – working with suppliers including ActiveFacility, A3D, John Mitchell; vendors; and contractors (i.e. Laing O'Rourke) – engagement with sub-contractors and associations e.g. TripleM, AMCA – influence vendors – coordination Big Rooms – BIM, IP and IPD embed integrated team approach; enable visioning and process to be revealed, allow other stakeholders to see what is happening; need to commence working with supply chain as soon as possible – links through summits and breakfasts; BEIIC; buildingSMART
Boundary spanning	
Innovations from suppliers - between and within org	– Involvement with the AMCA, KarelCAD and Bentley – development of costEX with Exactel – use of Tekla, energy modelling software, ArchiCAD, Revit, CADDuct etc – use of Solibri and Navisworks for collaboration – association with A3D, ActiveFacility, IAI – Autodesk lab – building performance analysis in the cloud for power and water usage and fiddling with occupancy rates
Integration of design and build – within org	– Sharing of 4D models with contractors and subcontractors – novation of A3D to Laing O'Rourke – providing performance requirements to mechanical contractors for design and fabrication based on the model – looking at places where the design can drive manufacture – consultants forced into greater discipline – Laing O'Rourke mandating BIM had a snowball effect across other contractors
Empowerment and innovation leaders – between and within org	– Note – PS as innovation leader – PS supported by Director and Director-General – PS believed in what we were doing; not reading from the script; passionate about it; needed to understand broader issues and the internal mandate – PS seen as state and national leader – novation of A3D to Laing O'Rourke
Explicit coordination of the innovation process - between and within org	– Working with contractors on development of 4D models – working with suppliers and subcontractors – involvement of discipline leaders - internal innovation – incremental approach – together they tried to nut out how they'll do a thing on a certain project without impacting deliverables such as time and cost – identification and pushing the pilot projects that would not have happened without senior management support

Innovation driver	
Strategic alliances in long-term relationships – industry wide, across and within org	– Research partnerships with the CRC CI and SBEnrc; ARC linkage projects – model server collaboration – collaboration with John Mitchell (IAI) from 2005 to 2007 – involvement with A3D
Empowerment of innovation champions - between and within org	– Note - BIM manager and CADD managers as innovation champions; discipline leaders – leadership by Chief Architect; support of Director and Director-General – creation of CADD team and IPD team – engagement of technical specialists e.g. John Mitchel, ActiveFacility, A3D – involvement in research projects to alpha and beta test new tools – acknowledged that PS has group of people who understand the technology and critical in informing the direction
Mechanisms sharing financial risks and benefits – within org	– sharing 4D models with contractors - PS would take the risk to demonstrate benefits to contractors and clients; models for reference only and later as part of contract – next breakthrough will be changing the business model which comes back to risk management – holy grail is IPD – shared gain no pain – equal risk
Involvement of the client – within org	– On local hospital handed back 4D model to client to assist with understanding the benefits – State Archives Project contractor and clients representative in day to day discussions – PS as client – believed in what they were doing; wanted organisation to be tech savvy
Coordination of participating groups – between and within org	– Sharing of models with contractors and subcontractors – working with tripleM on North Lake police station – use of file server for internal coordination between disciplines – PS management as Director and leader – superintendent's rep on State Archives Project heavily involved with contractor in development of model

Table 38 – Number of interviewees who discussed issues considered related to drivers for construction innovation

	Reported in:
Environmental pressure	
Governmental clients with innovative demands	8 of 11
Market pull – industry wide	6 of 11
Innovation stimulating regulations	3 of 11
Government guarantee for markets for innovative firms	0 of 11
Subsidies for innovative applications and materials	0 of 11
Technological capability	
Technology leadership strategy	9 of 11
Finance the pilot projects	8 of 11
Technology push	4 of 11
Programs promoting access to technology	1 of 11
Technology fusion	1 of 11
Product evaluating institutions	0 of 11
Knowledge exchange	
Lateral communication structures	11 of 11
Training of workers on the site	9 of 11
Training of workers on the site	9 of 11
Training of workers on the site	9 of 11
Integrated and informal R & D function	8 of 11
Stimulation of research	7 of 11
Creation of knowledge networks	3 of 11
Effective information gathering	3 of 11
Programs promoting collaboration	2 of 11
Broad view of risk	2 of 11

	Reported in:
Boundary spanning	
Integration of design and build	10 of 11
Innovations from suppliers	10 of 11
Empowerment and innovation leaders	9 of 11
Explicit coordination of the innovation process	7 of 11
Empowerment of innovation champions	6 of 11
Strategic alliances in long-term relationships	6 of 11
Involvement of the client	5 of 11
Mechanisms sharing financial risks and benefits	5 of 11
Coordination of participating groups	4 of 11

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