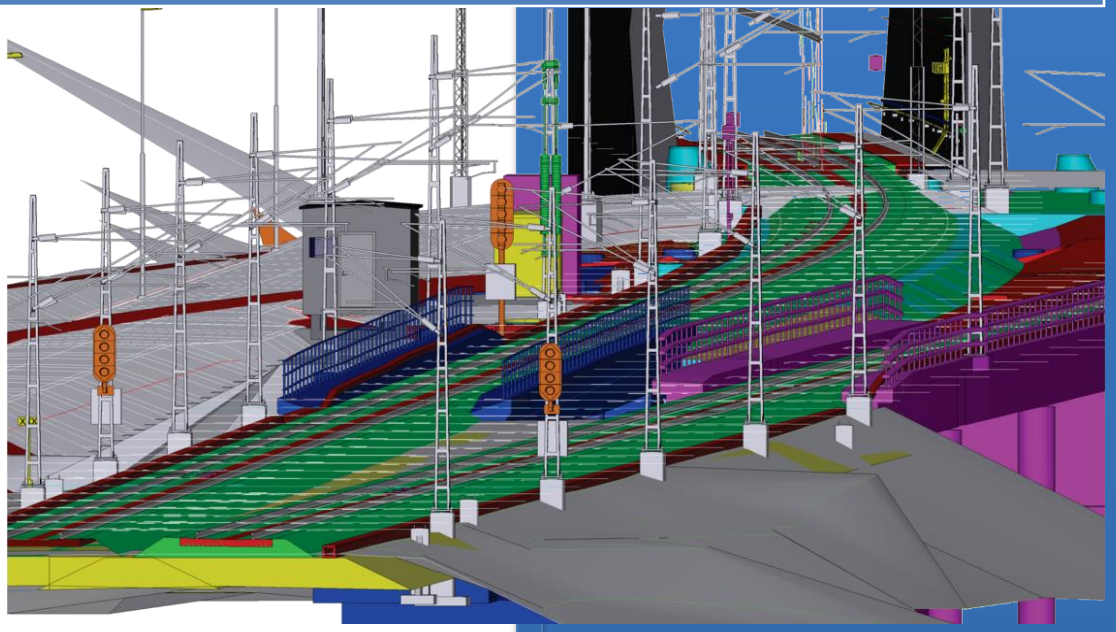
Sustainable Built Environment National Research Centre

Integrated Project Environments



Sustainable Built Environment National Research Centre

July 2014

BRIEFING REPORT FOR INDUSTRY

Contents

Acknowledgement: the image on the cover of this document was provided by Trafikverket.

Introduction to the Project

Integrated Project Environments: Productivity Gain through Industry Transformation

This research will contribute to realising productivity benefits of digital modelling and integrated project delivery for the Australian construction industry through the use of building information modelling (BIM) in the delivery of transport infrastructure projects. This project addresses procurement, process improvement and technology required to improve BIM and VDC uptake. Data was collected through interviews in Australia and Sweden, one of the acknowledged global leaders in this field.

BIM has been identified as an important emerging and transformative enabling technology, with the potential to streamline processes throughout the constructed facility lifecycle. The Australian Productivity Commission (2014) highlights that more widespread adoption of BIM could enhance productivity across the industry and have a significant positive impact on the cost of infrastructure.

The Research

This report is based on an analysis of findings from: (i) desk top research undertaken in 2013/2014; and (ii) 21 interviews carried out in late 2013 of a cross-section of the industry, including: clients, asset owners and procurement managers; design BIM managers; contractor project managers; supply chain, technical and industry experts; and representatives of industry-based associations. These industry professionals have an average 10-20 years working in the construction industry in Australia and Sweden in small and medium size enterprises (SMEs) as well as large organisations.

This section focuses the creation and development of a national strategy for Australia and how this was achieved in Sweden. It is contextualised using information found in academic and industry reports.

This research aims to:

1. Inform a national strategy for the adoption of BIM
2. Develop guidelines for new contractual frameworks
3. Inform a strategy to reduce skill gaps especially for SMEs

within the context of Integrated Project Delivery in Australia.

Industry Outcomes

1. Recommendations for policy makers to achieve a nationally consistent strategy
2. Recommendations for modifications of current procurement and contractual frameworks to allow more collaborative and BIM-enabled project environments.
3. A dissemination strategy that includes providing informative material to different levels of the supply chain through work with organisations such as CCF and EA, as well as through our partner organisations and our media resources (e.g. YouTube channel and industry publications).

About this Report

The present report summarises the research outcomes from SBEnrc Project 2.*24 Integrated Project Environments: Productivity Gain through Industry Transformation*. It is based on three in-depth reports available at www.sbenrc.com.au

(i) Research Report 1 – Towards a National Strategy;
(ii) Research Report 2 – Document Review; and
(iii) Research Report 3 – Reducing the Skills Gap.

About the Research Team

Dr Keith D. Hampson

Over the past 20 years Keith has made a notable contribution to building collaborative innovation networks between industry and research globally. He is committed to crafting a more effective construction industry by promoting better education, applied technology and innovative practices. Keith serves as CEO of the SBEnrc and its predecessor, the CRC for Construction Innovation.

Dr Judy A. Kraatz

Judy is a Registered Architect with her doctorate in urban development. Her research is informed by over two decades as a design architect; leading multi-disciplinary teams delivering city-wide solutions; and integrating sustainability into curriculum and practice. Judy is currently a Senior Research Fellow at Griffith University.

Adriana X. Sanchez, MSc

Adriana's experience focuses mostly on sustainable water and transport infrastructure management. Special areas of interest include procurement, risk management and translating policy into tangible outcomes. She has a Masters in sustainable resource management, conducted research on four continents and is a Research Associate at the SBEnrc.

About the Sustainable Built Environment National Research Centre

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to the CRC for Construction Innovation (http://www.construction-innovation.info). Established on 1 January 2010, the SBEnrc is a key research broker between industry, government and research organisations servicing the built environment industry.

The vision for the SBEnrc is to be an enduring world-class research and knowledge broker in sustainable infrastructure and building design, construction and management to enhance the performance of Australia's built environment industry.

Important Concepts

Integrated Project Delivery - IPD is a delivery method. It is not tied to a single type of contract but rather forms a set of principles that can be applied to a variety of contractual arrangements (AIA, 2007). Ideally, IPD brings the expertise of key actors from construction management, trades, fabrication, suppliers and product manufacturers to owners and design professionals earlier in the design and delivery process. This allows the production of a design that is optimised for quality, aesthetics, constructability, affordability, timeliness and seamless flow into lifecycle management (McGraw Hill Construction, 2008).

Building Information Modelling - BIM can be described as *a set of interacting policies, processes and technologies generating a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle"* (Succar, 2009). Mature BIM is a *socio-technical system* that can be used to improve team communication throughout the project life cycle, produce better outcomes, reduce rework, lower risk, and improve both predictability of outcomes and operation and maintenance of the asset. These are some of the benefits identified by the US infrastructure sector (McGraw-Hill Construction, 2012).

Peak Body - for the purpose of this research peak bodies are defined as: non -profit umbrella organisations that *provide information dissemination services, membership support, coordination, advocacy and representation, and research and policy development services for its members and other interested parties* (Cheverton, 2005).

Informing a National Strategy

Recommendations and Roadmap for Policy Makers and Australian Peak Bodies

Why IPD and BIM?

Digital technologies such as BIM are considered enablers of IPD and agents of change that allow the lateral and longitudinal integration of disciplines, industry participants and construction phases including design, fabrication, assembly and delivery (BEIIC, 2012).

IPD leverages the power of modelling to facilitate collaborative decision making (McGraw Hill Construction, 2008). The 3xPT Strategy Group, formed by the Construction Users Roundtable (CUR), AGC and AIA, concluded that project information that supports the analysis, visualisation, communication, and decision-making during the IPD process is best represented and shared though BIM (3xPT Strategy Group, 2007). Furthermore, AIA (2007) states that although IPD projects can be carried out without the use of BIM, the full potential benefits of both are only achieved when used in conjunction. Succar (2009) goes one step further, stating that IPD is the ultimate goal and final maturity stage of BIM implementation.

The British Standards Institution has pointed out that *BIM technology is considered invaluable to the delivery of a construction project since it provides a common single and coordinated source of structured information throughout the lifecycle of a project* (BSI, 2013).

The use of BIM promotes clearer, more accurate, up-to-date communication by consolidating currently disparate project information. It allows all team members to contribute to the establishment and population of the databases underpinning the planning, design, construction and operation of the asset (APCC & ACIF, 2009).

> *If clients had a digital model of all their roadworks, they would be able to understand exactly what their maintenance requirements would be for the next 20 years. They can therefore manage their budgets for the next 20 to 30 years. They can predict with far greater accuracy what they're trying to do, they could resolve design issues, they could plan their infrastructure growth far more effectively*
>
> **Australian Contractor**

Models also allow for more accurate costing estimations in earlier project phases (AIA, 2007). It has also been argued that the adoption of BIM has the potential to increase the productivity of the construction sector, in Australia, by up to 9% with high benefit/cost ratio (Brewer, Gajendran, & Le Goff, 2012). This would for example lead to an increase in Australia's GDP of up to AUD 7.6 billion for the period 2011-25, based on the building network alone (Allen Consulting Group, 2010).

The Australian Industry

In Australia, the transport infrastructure sector represents nearly 5% of Australia's Gross Domestic Product (GDP) and provides over one million jobs across 165,000 companies. *It is a critical input to national productivity* (SCOTI, 2012). The responsibility for planning, funding, constructing, maintaining and operating transport infrastructure is shared between the three levels of government (federal, state and local). This means that, although there is generally good collaboration between levels, the complex intergovernmental arrangements for transport infrastructure management create the potential for a number of issues (Newman, et al., 2012), contributing to a lack of national standard practices and strategies that could support the widespread uptake of IPD and BIM. This is reflected in the fact that the only goal-seeking system found is also a polity, where decisions made are based on consensus from all members.

The Swedish Industry

> *Sweden is known to be strong in a number of technologies related to the built environment such as BIM application in construction projects. Firms in the built environment industry have since long ago relied on open innovation. Open interaction between firms is often aimed at stabilising accepted practice or developing it as an industry standard. This applies in particular to BIM as a support for virtual design and construction, where many parties are involved and need to change their practices simultaneously.*
>
> (Bygginnovationen, 2013)

The Swedish Government has adopted a series of four major pilot projects for the implementation of BIM, aligned with the European Union's V-Con initiatives. With this the Swedish Transport Administration, Trafikverket, expects to benefit from the productivity gains of such implementation (Rijkswaterstaat, 2012). Trafikverket is currently using BIM to design and build large and complex projects, such as the Stockholm Bypass and the new City Line in Stockholm (WSP, 2013). Trafikverket has stated that they expect to achieve significant financial and time savings by avoiding the project planning issues that would otherwise only be detected at the construction phase, reducing the number of audits and time needed, and using sections of the tender documents as models (Trafikverket, 2013b).

SMEs have a prominent position in Sweden's government development and funding programs (Kadefors & Bröchner, 2014). This is probably due to the fact that in 2008 only 2% of Swedish construction companies had 50 or more employees and these represented only one third of the total share of the Swedish market (OECD, 2008).

In Sweden, we see [migrating to BIM] as a way of surviving also to help out and mining future competence flows back to us… Making sure that the competence is still there in ten years, fifteen years, seven years, five years

Swedish Contractor

Sweden has recently carried out a deregulation process where functional specifications are being commonly used by clients instead of traditional regulation. This process has led Sweden's two largest contractors, Skanska and NCC, to prioritise the procurement of technically qualified and experienced staff. This strategy has ultimately led to the formation of a strong and close relationship between industry and Sweden's knowledge brokers and providers (Miozzo & Dewick, 2004).

Peak Body Role

Peak Body Classification

In order to identify the role of umbrella organisations it is important to understand their identity: who they are, what is their purpose and objective and what do they want to be. This report makes use of the peak body's vision, objectives and organisational structure to classify them within the three identities defined by Young (2001):

(i) Goal-seeking Systems: There is a coordinated effort across the organisation to achieve common system-wide goals. These organisations rely on hierarchical authority and unified command and control.

(ii) Economies: The organisational goal is to meet the economic needs of their members more efficiently than in the open market. The organisation is an economic actor that aims to determine what services it can provide to its members for a fee; this is done through a negotiation process with their members and therefore relies on reciprocity and exchange among participants.

(iii) Polities: The organisation is used as a forum for member organisations to meet and work towards a common position, strategy and collaborations. The purpose of these organisations is to facilitate discussion and debate, to reach common understandings and strategies, and perhaps to manifest collective action on those strategies. Therefore, such organisations rely on persuasion and consensus building.

Peak Bodies in Australia

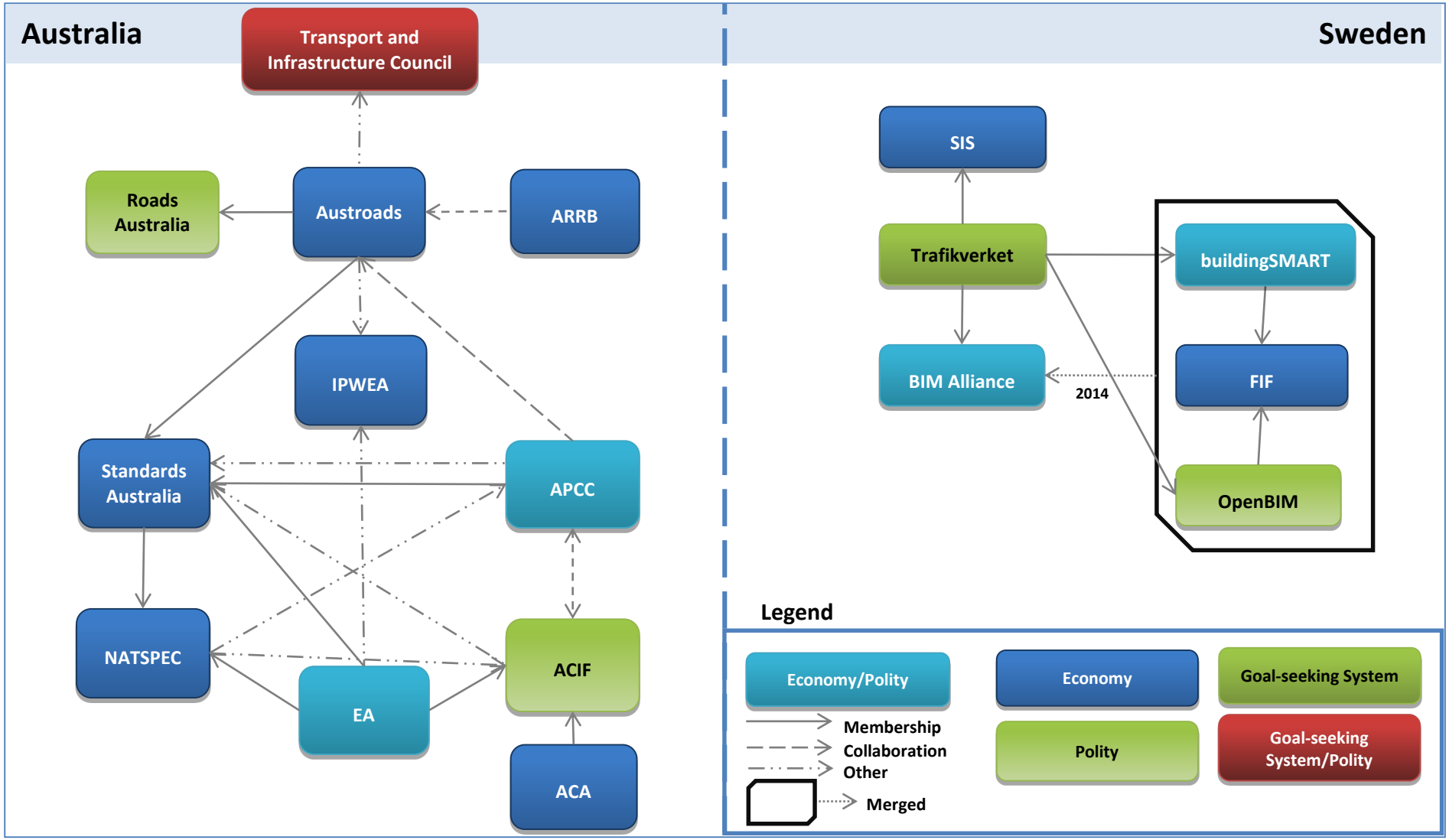
Peak bodies *flourished in Australia in the 1970s and 1980s.* However, their impact and spheres of influence have been limited by a shrinking level of power since the 1990s made worse by forced amalgamation and de-funding. This has led to most peak bodies focusing on policy development and advocacy being identified as polities and economies (Cheverton, 2005).

As explained by Maddison & Denniss (2005) this reduction in the peak bodys' power to influence policy came about mainly due to the change in the government's discourse in relation to the role of these groups in Australia observable since 1996.

Therefore, the power to generate change and the authority of peak bodies in Australia now *rests on the willingness of the affiliates to cede and abide by such levels of authority* brought by a balance between *power over* (so members follow the same vision) and *power for* (collective power to achieve collective interests) (Brigden, 2000).

Young (2001) also suggests that the type of peak body is related to the goal congruence among members, transaction cost and efficiency (i.e. *if congruence is high, the goal-seeking system (bureaucracy) minimizes transaction costs; if congruence is low, the economy (market) is efficient; if congruence is between these extremes, the polity (clan) is efficient).* The lack of organisations that can be classified as purely goal-seeking systems in Australia's construction industry would suggest a lack of harmony between key players and a fragmented industry.

Australian and Swedish Peak Body Maps



Industry Views

Six key themes were identified from interviewees with a cross-section of representatives from the transport infrastructure industry as relevant to the development of a national strategy for BIM uptake and IPD implementation:

(i) Lead agent role
(ii) Client role
(iii) Mandates
(iv) Pilot Projects
(v) Metrics
(vi) Standards.

Lead Agent Role

The ability of information technology to transform organisations and entire industries[1] is widely accepted where the context is characterised by change. The relationship between new technology and the institutional environment is important because implementation of new standards and processes may require changes to agreements which can in turn affect the economic performance of the industry (Crowston & Myers, 2004).

While collaborative decision making and stakeholder engagement is generally necessary to achieve such transformation, it is also necessary to have a steering agent responsible for developing overall guidelines and frameworks for operation of an industry sector. This also requires a common communication platform for performance and productivity improvements and measures associated with technology uptake.

> *The purchaser, that is the client, is the key driver for these things and procurement is the key driver of change*
>
> **Australian Contractor**

In the UK for example, the government has taken a clear leading role for the adoption of BIM in close collaboration with industry peak bodies. They used procurement tools to facilitate a timetable for SMEs and larger firms to adopt BIM as the technology of choice in design, construction and materials manufacturing (BEIIC, 2012). The government has put in place a program to require collaborative 3D BIM (*with all project and asset information, documentation and data being electronic*) on its projects from 2016 (UK Cabinet Office, 2011).

In Australia there are a number of organisations with different roles affecting the uptake of BIM and new information technology. However, there is no umbrella organisation coordinating efforts across the nation that would lead to a harmonized implementation of BIM/VDC in infrastructure construction. Furthermore, there is no coordination or connection between design manuals and minimum standards across agencies. Based on the interviews, it is considered that either

[1] Industry being not only suppliers and clients but also the regulatory framework and industry associations which form the institutional environment (Crowston & Myers, 2004).

Commonwealth Government or a body composed of all the state and territory transport infrastructure agencies and industry, is in the best position to address this need and provide direction and consistency across state boundaries.

Client Role

In Australia the key clients for the delivery of road and rail infrastructure are primarily the various State government agencies including New South Wales Roads and Maritime Services (NSW RMS), Queensland Transport and Main Roads (QTMR), and Main Roads Western Australia (MRWA).

In Sweden, the central Swedish Transport Administration (Trafikverket) is the primary client for the delivery and maintenance of road and rail infrastructure. The road network includes 98,400 km of state roads; 41,000 km of municipal streets and roads; and 76,100 km of private roads. The railway network includes 11,900 km of railway line, 90% of which is electrified (Malm, 2012).

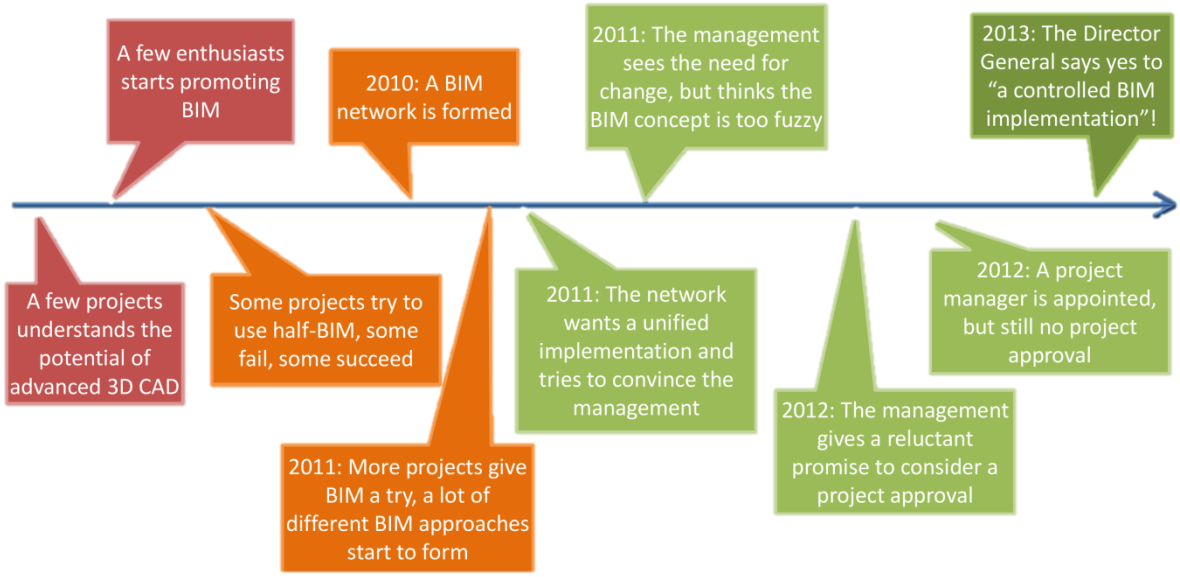


Figure 1. Rough timeline for Trafikverket BIM mandate (Albertsson & Nordqvist, 2013).

The Australian interviews clearly identified the leadership role that can be potentially played by clients. Clients themselves also recognised the importance of their role in facilitating greater productivity through the use of data associated with BIM/VDC. Additionally, both clients and suppliers highlighted the importance of having informed and involved clients that know exactly what they need in order to capitalise on the potential benefits from using BIM and IPD.

> *Clients need to understand what they want and set certain boundaries before they bring contractors on board*
>
> **Australian Designer**

In Sweden, the need for clients to specify functionality was a key issue, and also for the provision of different types of contracts to reflect these new requirements. There was acknowledgement of the emerging lead role of Trafikverket, built on past initiatives of industry.

Mandates

> *BIM mandates by US, UK and other government entities demonstrate how enlightened owners can set specific targets and empower design and construction companies to leverage BIM technologies to meet and exceed those goals, also driving BIM into the broader project ecosystem in the process.*
>
> (McGraw Hill Construction, 2014)

In Sweden, although the government has not officially mandated BIM, it has asked their agencies to raise their productivity which has led Trafikverket to take a clear leadership role and require BIM from 2015 (Trafikverket, 2013a).

Research showed that although a mandate by the central government can promote the accelerated uptake of new technologies, there are other ways in which public clients can take a leadership role. It should also be highlighted that in both British and Swedish cases the government agencies have the support of industry peak bodies which provide a forum for stakeholders and services that back the government actions.

> *There's got to be some, I don't like using the word mandate, but there's got to be some level of impetus for it… it can be as I said just half a dozen projects over the next three years spread across four agencies'*
>
> **Australian Industry Expert**

The Australian interviews showed that there seems to be little demand for a formal mandate without a period of testing and piloting the use of BIM/VDC. It was however acknowledged that a mandate from a single government agency could lead the industry as a whole towards a higher uptake of BIM/VDC and the realisation of significant benefits from more integrated systems.

Pilot Projects

Pilot projects can be used *to* validate and demonstrate the readiness of outputs. Exemplar projects can help increase acceptance and accelerate the uptake of well-designed collaborative BIM processes (Mitchell, Plume, Tait, Scuderi, & Eastley, 2012).

> *Get the schema first, get the cycle going and get some learnings out of it and then we can say "okay we've proved this. It works and these are the things we need to do to get it to work"*
>
> **Australian Client**

Countries such as Finland, Norway, Sweden, the USA, the Netherlands and the UK have all implemented a set of pilot projects which preceded the mandate start date. Trafikverket is also part of the EU funded *Virtual Construction for Roads (V-Con)* initiative which aims *to improve the efficiency and effectiveness of the National Road Authorities by improving data exchange in the civil infrastructure sector* (Rijkswaterstaa).

Interview results showed that there is an incremental approach to implementation through testing activities on pilot projects being undertaken in Australia by some agencies. This incremental approach to BIM uptake was the subject of a case study in 2012/13 of the implementation of digital modelling in buildings in the Queensland Department of Public Works (Kraatz & Hampson, 2013).

Most Australian interviewees highlighted that pilot projects are an important factor in increasing acceptance of new technologies and ways of working. Contractors, designers and client alike explained that pilot projects help to understand implementation issues as well as quantify benefits. Some of the interviewees also mentioned that pilot projects can be used as learning tools by disseminating the outcomes and learned lessons.

Metrics

Although BIM and more integrated models promise many benefits, there are very few metrics available that can objectively measure and quantify the productivity improvement and other intangible benefits.

> *Without such metrics, teams and organizations are unable to consistently measure their own successes and/or failures. Performance metrics enable teams and organizations to assess their own competencies in using BIM and, potentially, to benchmark their progress against that of other practitioners. Furthermore, robust sets of BIM metrics lay the foundations for formal certification systems, which could be used by those procuring construction projects to pre-select BIM service providers*
>
> (Succar, Sher, & Williams, 2012)

We'll see increases in productivity that need to be measured across several projects… it's very hard to determine what the measures might be on a single project evaluation

Swedish Industry Expert

The lack of agreed and readily available metrics for assessing the benefits of BIM/VDC implementation was largely acknowledged by the interviewees and is commonly mentioned as an issue to make the business case for BIM/VDC.

Publically available information of this kind is an important element in demonstrating the medium to long-term benefits of adoption of digital modelling. While firms do establish and report on internal KPIs such as those to monitor time-savings, return on investment, error reduction, there is no national or global standard for the gathering and reporting of such data which is then made available more broadly to enable policy settings and drivers to be set in place.

Standards

Standards Australia (2013) highlight the importance of standards at the macro-economic level and their direct relationship to productivity through more: (i) safety; (ii) international competitiveness and trade; (iii) interoperability of technologies and processes; and (iv) reduction of information asymmetry. This report also emphasises the role of standards in facilitating the diffusion of new technologies throughout the industry (Standards Australia, 2013).

> *Good standards provide clear requirements that set minimum conformity specifications and strike the right balance between too many and too few varieties; this works in the best interests of both the product supplier and the consumer… standards serve many purposes. They enable trade, improve safety, facilitate efficient use of resources, reduce time, improve quality, permit compatibility and aid integration. Businesses and consumers benefit from them the world over*
>
> (National Building Specification (NBS), 2014)

In Sweden Trafikverket is central to setting the standards for projects, given their significant market share in the delivery and maintenance of road and rail assets. However, contractors, designers and academics have been actively involved in the development of these standards and OpenBIM has served as a forum for these discussions.

> *There are enormous benefits from having a much more consistent set of standards across Australia… so I would certainly strongly support the adoption of a national standard or Australian standard for this*
>
> **Australian Contractor**

In Australia, contractors and designers alike expressed frustration with the diversity of standards already in place between the different states and strongly support the development of national standards. Some mentioned that this hindered information sharing not only between industry sectors but even within the same organisation between different offices. Australian Standards was commonly identified as the peak body ideally suited to developed national standards if the individual states decided to adopt them.

The Australian Productivity Commission also highlighted the need for a coordinated approach to the establishment of technical standards around BIM. They recommend that this should be done in consultation with industry and other private sector procurers but spearheaded by Australian Government agencies. This would in turn *ensure that the greatest benefits from the adoption of BIM are realised* (Australian Government Productivity Commission, 2014).

The availability of national standards would therefore avoid duplication across the industry and allow the use of libraries that would in turn reduce the cost burden of adoption and make the transition more *accessible to* small and medium-sized enterprises.

Conclusions, Recommendations and Milestones for Australia

Specific recommendations for the industry are:

(i) The development of a national strategy for the adoption of integrated project environments in Australia will require the leadership and coordination of a lead agent to engage with other lead industry associations and disseminate information.

(ii) Leverage on the fact that main transport infrastructure clients are state and territory government agencies. As such, these organisations are in a unique position to influence the uptake of new technologies and processes.

(iii) Use pilot projects, monitored and evaluated to build a knowledge base especially in terms of productivity benefits and processes associated with the uptake of BIM and IPD.

(iv) Recognise the fact that a national mandate has been shown by international comparators to provide the industry with the incentive to develop a pipeline of coordinated actions.

(v) Build consensus on standard performance indicators and metrics to prove the business value of BIM and IPD in terms of project, business and industry-wide productivity gains.

(vi) Develop national standards to provide a framework for a nationally consistent approach for uptake that reduces macro-economic burden of adoption and increases productivity.

An analysis of peak bodies was undertaken in terms of roles, processes, spheres of influence and impacts on the industry, with a special focus on the uptake of new technologies and processes.

The three main differences found between Australia and Sweden were:

(i) **The level of complexity:** the Australian peak body map shows a high level of complexity with a diversity of types of interactions between the different industry peak bodies.

(ii) **The type of goal-seeking systems:** Australia does not have a distinct goal-seeking system, suggesting a lack of harmony between key players and a fragmented industry.

(iii) **The level of input and type of interaction between the different peak bodies:** Australia seems to have a more unidirectional approach than Sweden when interacting with industry peak bodies. Here the peak bodies identified as a goal-seeking system only receive input from the other peak bodies but do not provide an active contribution to the development of outputs and strategy. This limits the relevance and impact of those efforts. In Sweden, Trafikverket has established bi-directional liaisons with polities and economies that jointly act as supporting and leading agents.

In Sweden, these differences have enabled Trafikverket to undertake a wider implementation of BIM with the support of the industry and academia for the development of standards and tools. It was also found that the three-tiered level of government, the competitive market economy and the style of governance chosen by Australia act as limiting factors for a widespread uptake of BIM spearheaded by a clear leading agent.

However, the Transport and Infrastructure Council could take this leadership role and drive the industry transformation effort supported by the forum and expertise provided by TISOC and Austroads. Based on the Swedish experience it would seem that this process can be most efficient if a bi-directional line of communication is established between TISOC and Austroads. Thus, actively engaging all transport authorities in the development of outputs that would be submitted to TIC for discussion and approval.

The research team used the findings from this research to develop a series of recommendations and a roadmap for the development and implementation of a nationally consistent strategy for the uptake of IPD and BIM.

Proposed Milestones for Adoption of Integrated Project Environments

2014	**Australian Productivity Commission** recommended considering BIM for complex infrastructure	Leadership
	APCC-ACIF established the Education and skills program for PTI and BIM	
	TISOC agrees to National Pilot and Lessons Learned Program	
2015	**Austroads - SBEnrc** develop guidelines for program including standards and metrics in consultation with industry with support from APCC, ACIF, NATSPEC, State Agencies and other industry bodies	Metrics
	Working Groups formed to develop program and lessons learned; State agencies choose strategic projects and coordinate lessons learned across Australia	Pilots
2016	Evidence-based recommendations are made to **TISOC** by **Working Group**	Client Role
	Education and Skill providers coordinated BIM curriculum finalised	Skills
2017	**TISOC** advices Transport and Infrastructure Council based on results	Client Role
	Transport and Infrastructure Council agrees on IPD/BIM strategy	Mandate
2018	**EEA, CCF, TAFE and Universities** already providing relevant courses with input from other industry associations such as ACA, MBA, and FMA, among other	Skills
	Standards Australia publishes BIM – IPT standards with support from APCC, ACIF, NATSPEC, State Agencies and industry stakeholders	Standards
2019	**BIM is rolled out** industry wide based on proven benefits and a prepared industry	BIM Uptake

Contract Practices for Integrated Project Environments

Recommendations from a Contract Documentation Review

Contract Practices, BIM/VDC and IPD

Traditional infrastructure construction delivery models have been described as hierarchical, fragmented, linear and prone to promoting adversarial behaviour across the supply chain (NASFA, et al., 2010). Integrated Project Delivery (IPD) is a business model for the integration of all design and construction stakeholders involved in the delivery of new construction projects. IPD is not tied to a specific set of contractual arrangements or technologies, but is rather a set of principles that can be applied to a range of circumstances (AIA, 2007). However, it leverages on digital information technologies such Building Information Modelling (BIM) and Virtual Design and Construction (VDC) to unlock the full potential of both IPD and BIM/VDC (McGraw Hill Construction, 2008).

> *The coupling of BIM with IPD enables a level of collaboration that not only improves efficiency and reduces errors, but also enables exploration of alternative approaches.*
>
> (Porwal & Hewage, 2013)

For these more collaborative models to be most effective the different actors must be engaged, preferably from the earlier design phases. However, *existing procurement methods have not sufficiently addressed the key issues of open collaboration using BIM* (Sebastian, 2010). Traditional forms of contract do not facilitate an open multi-disciplinary approach with the early engagement of contractors and sub-contractors as would be required in an IPD-BIM framework for industry development. The problem is well recognised within the UK industry:

> *The strategy also challenges industry business models and practices. It will replace adversarial cultures with collaborative ones; and will demand cost reduction and innovation within the supply chain...rather than innovation that is focussed on the bidding process*
>
> (UK Cabinet Office, 2011).

According to the Australian Built Environment Industry Innovation Council (BEIIC) the principles of integration and collaboration will come to define how the industry is organised (BEIIC, 2012). With growing adoption of these principles the skilling of the workforce and definition of new contractual clauses will represent key steps towards more integrated project environments. This will foster more efficient and profitable linear infrastructure construction projects that also exhibit less risk to the supply chain as a whole.

AIA (2007) suggests that in order to minimise the likelihood of adversarial behaviour, clients must carry out careful contract drafting, clear and unambiguous definition of incentive milestones, and due diligence in team selection.

The 3xPT Strategy Group report (2007) (informed by cross-functional teams including owners, architects, contractors, subcontractors, consultants, attorneys and insurers) recommended that contractual agreements adhere to the following general rules:

- Use of contractual terms that drive collaboration to the maximum extent possible, thereby appropriately allocating risk and reward
- Consideration of value-based compensation with outcome-based incentives and disincentives aligned across the team
- Collaborative management of project contingencies
- Cooperation with insurance companies and agencies to develop new risk management approaches and tailored insurance products (3xPT Strategy Group, 2007).

Recently, there have been several attempts to develop collaborative contract forms that are compatible with the use of IPD and BIM/VDC (Sherman, 2013). The Australian Institute of Architects (2010) suggested that these existing international standards could be analysed and modified for the Australian environment in order to develop national standards and protocols that could be implemented in the near future. However, these efforts are still being tested internationally and none had been systematically reviewed for the Australian context until now.

With the right type of contract for these systems, *best value for money* is obtained when awarded to *the responsive and compliant bidder, that is willing to fulfil the terms of the contract, for the lowest dollar value with innovative ideas* (Porwal & Hewage, 2013).

The Review

This review highlights the findings of an analysis of contract documentation carried out based on 14 key topics of those outlined by the 3xPT Strategy Group Integrated Project Delivery (IPD) Principles for Owners and Teams report. Documents include contract agreements, manuals and guidelines issued by: Queensland Transport and Main Roads (QTMR), New South Wales Roads and Maritime Services (NSW NRMS), Main Roads Western Australia (MRWA), UK's Chartered Institute of Building (CIOB), the American Institute of Architects (AIA), AEC (UK) Committee and NATSPEC.

The review of Australian contract agreements focused on Design and Construct (D&C), Early Contractor Involvement (ECI) and General Conditions of Contract documentation which was publicly available or provided by participating organisations.

New South Wales Roads and Maritime Services (NSW RMS), Queensland Transport and Main Roads (QTMR), and Main Roads Western Australia (MRWA) are three of the four largest road construction clients in Australia. They contribute to 84% of the almost AUD7 billion invested by the State/Territories governments in the roads sector in 2012 and are currently responsible for almost 70% of the roads in the country (Figure 2) (Sanchez, Lehtiranta, Hampson, & Kenley, 2013).

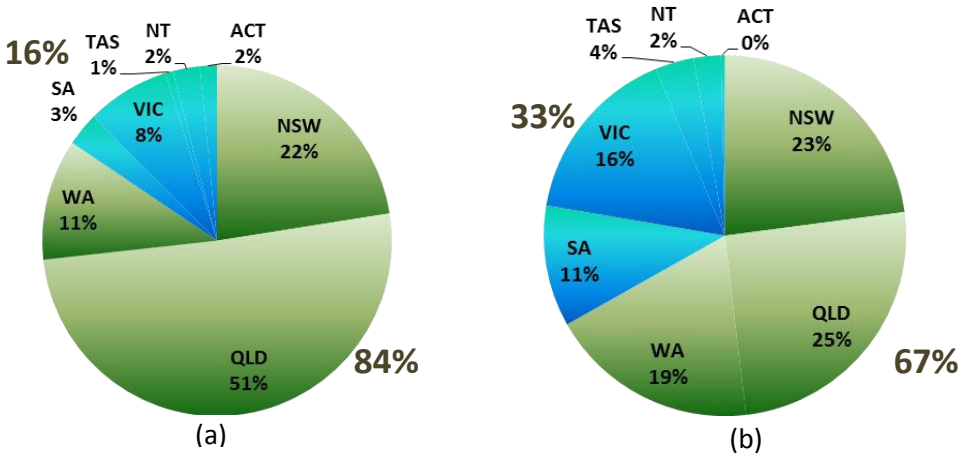


Figure 2: (a) total road expenditure by state/territory, by level of government, 2011-12 prices — State/Territory; (b) total road length by state/territory (2011-12) (BITRE, 2013).

With the exception of the AEC (UK) which only covered 9, all organisations cover 11-13 topics. However, the key difference between these organisations was the level of detail to which each topic is addressed and whether the way in which they are addressed is compatible with IPD principles and BIM/ VDC.

It was found that many current practices in Australian transport agencies are compatible with IPD and BIM/VDC. However, new issues must be considered in order to facilitate more integrated project environments and the use of new digital technologies that foster collaboration.

ECIs and D&Cs

ECI contracts are similar to the Construction Manager – Constructor (CMc) contract, which has been argued to be particularly well suited for IPD and the use of collaborative digital technologies such as BIM/VDC (AIA, 2007). These contracts are characterised by integrated planning, design and construction process with early contractor and consultant involvement, potential to incorporate innovative ideas and construction methods, and the client retaining a strong influence in the planning and design stage (CEIID, 2010). In Queensland, an ECI is described as a negotiated D&C contract with significantly more efficient use of resources during the tender phase (QTMR, 2009a).

In traditional D&Cs the client prepares a design brief, outlining the functions and key use requirements for the works. Then seeks tender for completion of the detailed design and construction of works (CEIID, 2010). These contracts are normally characterised by the contractor bearing the responsibility for the design consultants' contract, and the construction of the works. The client has limited control over the final design (NSW Government, 2008).

In general, ECIs were found to be the most IPD-compatible contract model when compared to D&Cs. QTMR for example includes the possibility of bringing in the sub-contractors at an earlier stage of the project (QMTR, 2009f). This team is normally formed by at least the client, head contractor and designer. In NSW RMS' ECI all participants are *causally responsible for the acts and omissions (including breaches of this document) of the other as if those acts or omissions were its own* (NSW

RMS, 2013). This would encourage a no-blame culture by sharing the risk of non-performance; one of the basic principles of IPD (AIA, 2007). ECIs also include the development of "relationship management plan" which aims to create a more collaborative culture based on shared core values and relationship goals (QTMR, 2009b; QTMR, 2009c). The ECI workshops also contribute to this end and fall under the Level 1 described by the ACIF-APCC Project Team Integration Workbook (2014), where Level 2 includes all senior staff of the contractor, designer, and sub-contractors and Level 3 are on-site job captains, foremen and supervisors. These are just a few of the characteristics of the ECI contract that were found to be compatible with IPD.

Design and Construct (D&C) models can also be used for IPD. However, traditional D&Cs require a certain level of design completion before tender, with the owner usually participating in those earlier stages and reducing their input and involvement later on, creating clear silos of responsibility and risk (AIA, 2013). Nevertheless, D&C contracts can be made more "IPD-friendly" by for example: (i) increasing client's involvement (and reflecting this in the project agreement); (ii) changing the compensation model to link financial benefits to project goals that can promote greater collaboration; and (iii) using open book accounting for project cost to foster client's collaboration throughout the life-cycle of the project; and (iv) including clauses that address risks in such a way that the BIM models can be integrated throughout the project phases.

The following sections comprise a suite of recommendations for: (i) modifications/expansion of current documentation, roles, processes, and outputs; and (ii) new considerations on the same topics, plus metrics and classifications. The analysis of how these recommendations are specifically addressed by different organisations can be found in the Research Report 2: *Document Review*.

Recommendations for Modifications/Expansion of Current Contract Practices

Documentation

Contract Agreement - Current contract agreements can be used by adding new documentation as addendums (e.g. BIM and data sharing protocols) and adding clauses that: (i) require all subsequent agreements to include the developed protocols; (ii) reflect confidentiality and authorship of each model element as per data sharing protocol; and (iii) require that all parties include a copy of the latest version of the protocol in the model itself.

Scope of Works and Technical Criteria – modify currently used SWTC to include similar considerations as those in the CIOB Working Schedule and Planning Method. Alternatively, adding a section titled BIM Execution/Management Plan (such as that of AEC UK), where contributions from subcontractors should also be considered.

D&C Deed Schedule - Link to clearly defined Levels of Development (LOD) and Model Elements in the Execution Plan. Breaking down the model into its component parts or *elements* simplifies the task of assigning responsibilities for managing and coordinating the BIM development to appropriate project participants, and assigning the LODs (AIA, 2013). This is similar to the levels of development of the design documentation used by NSW RMS but should be defined not only in technical terms and levels of detail but also in terms of authorised uses.

Contract Program/Preliminary Design Report - Include newly developed performance metrics (Key Performance Indicators - KPIs) and success criteria specific to working in integrated teams and using BIM. This metrics should also be aligned with the asset management system needs.

Relationship Management Plan - Use to establish collaboration standards across all project types that motivate collaboration and as basis for project integration evaluation (already used by QMTR in their ECI).

Roles

Project Verifier - Expand the responsibilities of this role to include BIM coordination and verification (existing NSW RMS and MRWA role) while continuing as an independent external consultant. This would be an alternative to creating a completely new role (e.g. section 6.2.3).

Design Manager - Expand responsibilities to include BIM coordination activities across design and construction phases (existing role in MRWA across the two phases).

Processes

Tender Selection Criteria - Expand non-price criteria to include past performance in integrated project environments and more interactive contract models, technical skills of the project team as well as commitment to an integrated approach. ECI-type workshops can be a tool for this evaluation.

Bonus Clauses - Expand benefit sharing clauses to other types of contracts and agencies (already used by QTMR and NSW RMS). Base these on clear KPIs and defined success criteria related to project goals. Linking financial benefits with project goals can increase collaboration and integration across the project.

Integrated Project Environment Workshop - Include efforts to: (i) facilitate all parties involved understand and agree to limits of use (through for example authorised uses); (ii) encourage and protect the ownership of the data which often gains value with file sharing and collaboration; and (iii) create commitment to a more integrated and collaborative way of working (currently branded as “pre-start conference” or “kick-start workshop”).

Indemnification - Review indemnification language included in the contract documents closely with legal and insurance counsel to avoid uninsurable obligations.

Skill Development Plan/Enterprise Training Management Plan - Use as tools to reduce the skill gaps on a project-by-project basis.

Regular Update Meetings - Use for project health check, address changes to protocols and works, and should comprise at least: client representative, contractor’s design manager, contractor representative, subcontractors (if relevant) and the project verifier (if required)

Risk Apportioning - Agree upon risk apportioning in the contract agreement; ideally shared equally among all participants to encourage a no-blame culture and open collaboration.

Outputs

Systems for Design Development and Data Management - Select based on project specific considerations such as scale, cost and level of effort needed for new users; as long as the output is

compatible with asset management systems. Open source systems or most commonly used software might have preference. See NATSPEC (2011) for more technical recommendations.

Submissions **-** Require in PDF format, instead of requesting all approved submittals and other required documents in paper-based formats. Drawings to be submitted in native and IFC formats while as-built drawings can be delivered as PDF files with fully bookmarked pages and design intent models in PDF and DWG format.

Final Submission - Clean data for final submission so only asset management and monitoring relevant information is required as specifically detailed by the client at project inception. Avoid language such as "all relevant data" in the contract agreement, payment schedule and milestones. This would significantly reduce storage needs and post-contract data handling, and facilitate future accessibility of the relevant information.

Recommendations for New Considerations for Contract Practices

Documentation[2]

BIM Protocol - Develop at the earliest project stage possible. This document can be added to contract agreements as an addendum that redefines relevant terms. To include: (i) a strategy to manage changes (processes to document the receipt and agreement of changes); and (ii) methodologies and technologies. Other items to be specified may include: agreed parameters regarding BIM platform(s); administration and maintenance; source of "truth" for all data; interoperability criteria; data transfer protocols; level of detail development by phase, and tolerances for BIM authoring tools; data integration; and collaborative team workflow environments, among other. To avoid compliance issues this should be a contractually binding document not just a guide.

Data Sharing Protocol (internal and external) - Addressing confidentiality, data security (this can also be done through a separate data security protocol for complex projects); setting adequate user rights to prevent data loss or damage during file exchange, maintenance, and archiving; authorised uses of the data; identifying clear ownership of the model elements throughout the project life-cycle; transmission, use, storage and archiving the data. To avoid compliance issues this should be a contractually binding document not just a guide.

Metrics and classifications

Levels of Development - To be defined in both technical terms and in terms of roles, responsibilities, data dates, KPIs and success criteria (for more detail see sections 5.1.1 and 8.3 of Research Report 2), for each Model Element and project phase.

Skills Matrix - Include all relevant parties (incl. subcontractors) to assign responsibilities related to primary functions to different roles. This matrix is to be informed by the personal expertise needed for each individual task at each stage of development and related to primary functions: strategic (creation of standards, training, implementation, etc); management (execution plan, model audit,

[2] For specific recommendations on how to develop these protocols please refer to Research Report 2. For simple projects these protocols can be integrated into a single document.

model coordination and content creation); and production (modelling and drawings); clearly assigned to different roles.

Roles[3]

BIM Project Coordinator - To helps set-up the project, audit the model and coordinate contributions to the model and protocols. A case may exist for this role to be carried out by an independent entity similar to the Project Verifier.

BIM Technical Discipline Coordinator - To lead meetings such as MRWA's trade coordination meeting with subcontractors. This role would facilitate the coordination of technical disciplines for BIM development, standards and data requirements; lead the technical discipline BIM team in its documentation and analysis efforts; coordinate internal and external BIM training as required; and facilitate team "buy-in" for project overall goals, systems and integrated/collaborative approach.

BIM Strategic Coordinator - May manage several small projects and hand-offs from service suppliers and between phases as well as managing knowledge transfer across projects and actors.

Processes

Element Ownership and Handing-off Procedures - Clearly define these issues to enable the use of current insurance arrangements, by having clearly defined authors responsible for evaluating, mitigating and resolving any potential conflicts found by any other user.

Culture **-** Encourage a collaborative no-blame culture by defining as part of core values, maintaining open communications and apportioning risk adequately.

Common Data Environments **–** Establish to facilitate collaboration and data management. The system classification proposed by AEC (UK) (Work in Progress (WIP); Shared; Published; Archive) offers a structured and easy way of organising the data and information. Additionally, user manuals and information such as what the system is intended to achieve and how the system will impact the role of the project participants can improve acceptance by the project team.

Outputs

BIM Outcomes (As-built) and Metrics - Aligned with the system requirements of facility and asset managers as well as traditional and BIM specific metrics.

[3] In small projects several of these roles can be carried out by the same individual.

Reducing the Skills Gap

Recommendations to knowledge providers and intermediaries

Skills, IPD and BIM

As we move towards a more integrated industry numerous reports have raised skilling the construction workforce in the use of new digital technologies (such as BIM) as one of the key challenges to be faced by Australia in the near future (buildingSMART Australasia, 2012; AMCA, 2012a; Australian Institute of Architects, 2010; AMCA, 2012b).

The former Built Environment Industry Innovation Council (BEIIC (2012) further highlighted that clients, contractors, sub-contractors, architects and consultants are all struggling to come to terms with BIM, requiring::

(i) Investment in knowledge transfers and curriculum change policies across the vocational education and training (VET) sector

(ii) Support from higher education and the industry for widespread adoption of new digital technologies (BEIIC, 2012).

Past research has identified three types of skills needed (Li, et al., 2008):

1. *Technical*: require the modeller to understand construction processes, to have a strong hands-on knowledge of digital modelling systems and software
2. *Human*: to work with other people of the integrated construction team. Especially the process modeller needs to be self-aware, understanding and sensitive to the feelings and thoughts of others to maintain a healthy interpersonal relationship with the rest of construction team
3. *Conceptual*: to understand the schematic representations for process, product and resource models. These schematic models provide a theoretical underpinning for construction virtual design technology.

Coordination to Provide Leadership and Address Complexity

The need for direction and transitional funding for curriculum development and training at a vocational level in the context of a national framework for the implementation of BIM and IPD by the building design sector is required (Giangregorio & Goss, 2008). This still applies, and further, is critical to the broader construction industry in Australia in order to maximise the benefits of these emerging processes and technologies. These two groups are however just two elements of this complex network involved in delivery of innovation in this industry.

> *Trafikverket have an internal education program, and seminars to inform us (industry) about how BIM, the benefits of BIM in house building and in infrastructure building*
>
> **Swedish Consultant**

Seven key stakeholder groups in industry innovation have been formerly identified (Fien & Winfree, 2012) including: government; private enterprise; industry and professional associations, accrediting bodies and unions; industry CPD providers; manufacturers and suppliers; tertiary education, both VET and universities; and research organisations. They also highlight that it is necessary for *senior decision makers in the built environment industry and associated further education sectors* to develop capacities including those that: attract and train people skilled in collaboration; re-engineer industry roles to enable IPD; align accreditation with re-engineered roles and skills; and support small and medium businesses to reskill around new industry practices (Fien & Winfree, 2012).

The significant array of participants involved in the delivery of transport infrastructure in Australia adds to this complexity. These organisations thus have a role to play in how the industry adopts new processes and technologies.

> *We're partnering with universities to gain content and the response has been an overwhelming to: contribute specialist expertise from within universities; and access the specialist expertise from other universities and from industry people. The universities are very excited that we will be having a neutral platform where (with information) available to all of their students…*[Some] *universities* [however] *are more reluctant to get on board and change their curriculum, with the view that if they put in digital modelling then they need to eliminate something else in the curriculum; also because this is a rapidly changing field*
>
> **Australian Industry Association Manager**

Diffusion, Uptake, and SMEs

Five barriers to the adoption of digital information technologies have been raised in the academic literature (Hollenstein, 2004; Comin & Hobijn, 2006; Miozzo & Dewick, 2002):

(i) Investment costs and unfavourable financial conditions.
(ii) Human capital restrictions - general shortage of highly skilled workers, insufficient training, etc.
(iii) Information barriers.
(iv) Managerial barriers - e.g. insufficient awareness of managers and deficient strategic orientation.
(v) Sunk cost barriers - which may imply high substitution costs.

Other issues which can assist with adoption include:

- Sponsorship and standardisation can facilitate the widespread adoption of new technologies (Katz & Shapiro, 1986).
- Change management variables such as motivation, training and technical support, supervisor support and open discussion categories (Peansupap & Walker, 2005).
- Knowledge sharing and learning literature to provide the basis for the development of skills among users, and skill and knowledge transfer through communities of practice.

It is also important to note that meta-governors[4] can prevent systematic patterns of exclusion by bridging barriers faced by groups such as Small and Medium-sized Enterprises (SMEs) (Sørensen & Torfing, 2009). Intermediary programmes which address cultural, financial and accessibility issues, have the potential to assist here (Parker & Hine, 2013). Barriers identified by Lange, et al. (2000) include:

- *Cultural:* that is, attitudes towards skills development. Cultural barriers are one of the greatest hurdles affecting SMEs attitudes towards training and skills development. These can be reduced through the use of on-the-job and/or more informal training where the direct link between cost and benefit is more visible.
- *Financial:* being the cost or perceived cost of training and learning. Effective network management can help to reduce these barriers by: (i) lowering the transaction costs of networking through the provision of adequate support and resources; and (ii) empowering the network actors through the funding of individual or collective learning in terms of participation in courses, seminars and conferences, the invitation of guest speakers to network meetings, or the organization of future workshops with external moderators (Sørensen & Torfing, 2009).
- *Access:* for example when training programs are only provided by a few institutions, the transport cost and down time might effectively restrict access to these skilling programs.
- *Provision*: where training is only provided as a response to a particular need instead of as part of an ongoing program. Reducing these barriers will require a greater degree of formal training that provides employees with access to learning in a more convenient and timely fashion (e.g. online learning).

> *If there were government agencies who decide to use BIM, then professional organisations such as CCF and EEA would probably try to pool resources and develop a bit of a collective on this and see how [they] can take what [they] know and what [they]'ve been working on…Their role should be more of support or endorsement once an agreement is reached, and also the technical capability that they bring to the table*
>
> **Australian consultant**

Giangregorio and Goss (2008) identified a series of recommendations based on roles, to address skills needs improved uptake of BIM and IPD including:

- *Government:* create awareness of the benefits of leveraging benefits through contracts and work collaboratively to remove institutional barriers
- *Industry:* develop relationships and reward the of delivering integrated solutions, and promote technology and processes that leverage this behaviour
- *Business:* work with financial organisations and insurers to build understanding of IPD such as reduction in risk and errors

[4] Meta-governance refers to the need of formal public organisations to exercise some control over devolved and decentralised decision-making organisations. In this sense, meta-governors are actors (often public organisations) who exercise some level of control over devolved and decentralised decision-making organisations (Badie , Berg-Schlosser, & Mo, 2011).

- *Professional Associations:* provide information, guidelines and continuing professional development
- *Educational and Training Institutions:* integrate BIM and IPD as a part of curriculum

Industry Views

In Australia, interviews indicated that for SMEs to embrace technology then the investment decision needs to be there. They need not necessarily support it, but they need the opportunity to be given the opportunity to engage. Incentives that would work for SMEs must then include a level of inclusiveness that's beyond the perceived tokenism of the process. There needs to be some confidence that clients are really committed to the process. For example, if client groups were looking for a particular system or software to be used across all range of their projects, then they would need to help smaller contractors and smaller organisations to have that capacity. Industry associations can also provide support, for example, whilst Engineers Australia (EA) has not specific business support programs for SMEs, they have a special strategy for the small organisations for accessing continuing professional development (CPD) through Engineering online at a good rate.

In Sweden, interviewees identified that *buying-up* is part of the reason behind the trend of consultants becoming larger. They explained that this happens because of the high cost associated with being at the cutting edge and having the expertise and skill. There are some special kinds of consultants in Sweden that are trying to introduce BIM in smaller companies, that is, specialists coming out from research.

SMEs find adapting to the changes of particular clients more difficult than larger companies. They have different clients and have to use different types of software and different types of processes. For SMEs this is a significant challenge [this is mostly based on the building sector]. SMEs and smaller sub-consultants can be part of the process if they have access to open formats. These allow the easier exchange and transfer of data with small innovative SMEs being an important part of the up-skilling of the industry.

Knowledge Intermediaries

> *Technological knowledge intermediaries, aim to efficiently mediate technological knowledge transfer by creating shortcuts between the source and the recipient technologies.*
>
> *(Lim & Park, 2010)*

Knowledge intermediaries play a role in education and training for industry skill development as well as developing a firm's ability to understand, analyse and acquire knowledge from external sources. These services facilitate industry change by ensuring that firms have access to skills, new knowledge and new knowledge networks as well as ensuring that firms understand the organisational changes required to introduce new technology (Parker & Hine, 2013).

These knowledge intermediaries, also known as exchange agents, have a strong influence on the speed of diffusion and uptake of new products and services by industry. They play an active role in the diffusion process, including: (i) support in decision-making of whether to adopt or not; (ii) as a specification writer or standard setter; and (iii) as an evaluator of the technology once it is in the

market (Howells, 2006). Knowledge intermediaries also contribute in the development of the organisational learning capabilities (Parker & Hine, 2013).

Thus, identifying these knowledge intermediaries can accelerate technological knowledge flow and also provides strategic insight for technology planning (Lim & Park, 2010). They can facilitate interactions between knowledge providers (including research institutions, universities and training organisations) and industry, assisting the exploitation and acquisition of new technology (Parker & Hine, 2013).

We (contractor) linked to several universities, SBUF, Stanford via CIFE… a couple of weeks ago we arranged a VDC certificate course for 29 people … we actually arranged a special edition for ourselves in Helsinki where we brought Martin Fischer and John Kunes over for a week and we had a four day start up course - and now we will have up to 12 months of reporting to CIFE and then two days to finish off and hopefully all 29 participants will received a VDC certificate

Swedish Contractor

Large contractors often play a mediator role in the interface between sources of new technologies and the institutions adopting them (e.g. clients, regulators and professional institutions). Therefore, unless contractors acting as mediators are convinced of the merit of the new technology and have the skills to learn, apply it in future projects, and incorporate it into the system, technology diffusion is likely to be slow (Miozzo & Dewick, 2002).

Professional associations can also be seen as key agents in technology diffusion since their members may act as *boundary spanners;* through their involvement, members are able to learn about new technological developments. These types of associations often see their role in the dissemination of knowledge in the industry as a key aspect of their functions. This is particularly important for SMEs and therefore it is crucial for these firms to have significant representations in professional associations (Swan & Newell, 1995). Therefore, it is paramount to include professional associations such as the Civil Contractor Federation (CCF) and Engineers Australia (AE) in the strategic planning.

There's not a sufficient supply of people skilled in BIM, there's a great shortage in Australia… We (contractor) are engaging the consultants and then trying to up skill our guys through exposure to the consultants… and making the facilities available and helping guys up skill themselves

Australian Contractor

SMEs face barriers to investment in new technology, particularly in terms of time and financial resources, given that new technologies are disruptive to business processes and require the development of new organisational capabilities (Lange, Ottens, & Taylor, 2000). In this context, the role of external knowledge intermediaries in supporting SMEs to acquire the necessary skills and capabilities to use new technologies and to assist in the adoption of new technologies could be critical.

Industry Views

In Australia, interviewees observed a very powerful push for endorsement from Construction Skills Queensland (CSQ), Engineers Australia, Civil Contractors Federation (CCF) and major contractors towards increasing productivity in the industry. This can be realised in part through a more skilled labour force and government endorsement. This is more about providing the upper levels of the workforce with skills to improve productivity rather than labour market and apprenticeship/traineeship programs. This approach is considered to create a pull as opposed to trying to push by bringing in significantly larger cohort in at a much lower skill level.

In part, it is expected to be a trickledown effect from major to mid-size projects once the technology becomes more main stream. This would lead to more wide spread uptake, with significantly more technology being embraced than ever before (i.e. continuous business improvement model). It also requires a *schedule* for adoption so that contractors can plan to include it in their investment pipeline. If this adoption could be considered as *R&D* for tax purposes or business support for medium-sized enterprises this would potentially lead to greater uptake.

It was found that although not everyone is a member of those organisations, having professional organisations endorse the movement provides more exposure and awareness. This is important to agree on what they want BIM to look like (such as a road map) and then the potential is to reach significantly more people. Coupled with this is the need for organisations such as Standards Australia to develop standard forms of contract and the like. Professional associations such as CCF and EA could influence the uptake of more collaborative models and new technologies.

Coordinated National Approach to Filling the Skills Gap

As part of a national strategy, policies are needed to promote broad access to these skills and competencies and especially the capability to learn. Such policies should address: (i) providing broad-based formal education; (ii) establishing incentives for firms and individuals to engage in continuous training and life-long learning; and (iii) improving the matching of labour supply and demand in terms of skill requirements (OECD, 1996)

National programs should address the need to *re-shape* the roles and responsibilities of professionals as well as to *re-skill* the current workforce (BEIIC, 2012). However, at present one of the major challenges that formal education might face in this respect is the limited number of users with sufficient *technical* expertise to serve as source of training.

Fien and Winfree (2012) note the importance of a *well coordinated and collaborative approach to the development of priority knowledge and skills*. When referring to SMEs specifically, public policy initiatives aiming to increase the availability of technical and industrial competence in new technology are of great importance to this sector, with the potential to positively impact the level of innovation in SMEs, business capability development and commercial competitiveness (Parker, 2007).

The development of *human*[5] skills might be of special interest to SMEs to facilitate their growth, most of all when involved in complex supply chains. The effect of government-supported training programs for SMEs in this space has been said to be beneficial for business performance but often rejected by smaller firms. Micro firms in particular might also lack the time and clarity over their training needs to engage in such programs (Iles & Yolles, 2002). Thus, knowledge intermediaries might have key roles in the reduction of the skill gap in SMEs.

In Australia, there are a number of universities and TAFE institutes currently developing and implementing BIM training programs in Australia (Brewer, Gajendran, & Le Goff, 2012) (a partial list of this is provided in Appendix B). However, up until now there has not been a unified strategy to skill the workforce. In terms of attempts to increase the level of information and technology diffusion throughout the industry, there have also been several awareness initiatives organised by professional associations such as the Australian Institute of Architects, Consult Australia, The Australian Institute of Building (AIB), and the Facilities Management Association (Brewer, Gajendran, & Le Goff, 2012).

However, ACIF and APCC have recently commenced a new project in 2014 including development of a draft strategy for *Education and Skills Program for PTI and BIM* for industry and clients (ACIF, 2013). The Australian Mechanical Contractors Association (AMCA) also launched the BIM-MEP^{AUS} initiative, focused on training and education. The group is *working with Government, universities and training organisations to coordinate and develop a range of courses targeting needs at all industry levels* (AMCA, 2012b).

In Sweden, the BIM Alliance has undertaken a study of BIM courses on offer at all levels in the country and Chalmers University also is currently capturing data on all educational and vocational educational courses on offer. English overviews are not yet available. Of note however is the higher level of reported incidents of industry/academia training collaborations to develop skills through industry placements. Additionally there is a growing number of courses related to BIM and IPD. See Andersson (2013)for more information.

Building Business Capability – Beyond Skills Development

> *Business capability development provides firms with the ability to create, develop and modify intangible assets such as skills and knowledge.*
>
> *(Smedlund, 2006)*

Firms require such capability to learn or absorb knowledge from the external environment in order to gain benefit from, for example, new technologies (Hollenstein, 2004). Songer, et al. (2001) suggest that firms need to develop a business model that fully integrates the capability to use new information technologies as a transformation tool to both recognise the impact on the organisation, and to make it possible to quickly integrate these changes throughout the organisation.

[5] These are skills needed to work with other people in the integrated construction team. Especially the process modeller needs to be self-aware, understanding and sensitive to the feelings and thoughts of others to maintain a healthy interpersonal relationship with the rest of construction team (Li, et al., 2008).

APCC (2013) further identify a significant return on investment from training and development. They propose that if 20% of payroll cost is invested in professional development and this investment delivers a 1% savings, then the return on investment could be 2,500%.

In Australia, interviews undertaken as part of this research revealed that there needs to be wider acknowledgement and understanding of the skilling that is required, and that this involves a change in mind-set along with skills. There is an apparent need for further alignment between industry and traditional educational providers as to required skills (including need for collaboration skills).

Alternate delivery methods need to be further investigated to facilitate learning pathways (especially for SMEs). Universities are positively responding to optional pathways through: development of Masters courses; or delivery through skills agencies and industry associations. This may help to overcome difficulties and time lags in updating curriculum in professionally accredited courses. TAFE has been very active in this space recently, providing courses in digital building.

In addition, industry associations should be (and in some instances are) formulating plans to up-skill their members. For example Engineering Education Australia[6] (EEA) provides professional development for the whole range of engineering sectors and construction including a recent graduate program for engineers around communications, collaboration, team work; and a series of short webinars sessions on BIM including international guest speakers being hosted by the Victoria division (James, 2013; Engineers Australia, 2013; Kulatunge, 2013; Chater, 2013).

There was also acknowledgement that a composite approach to training may be most appropriate including: training courses and workshops; mentoring, coaching, and sharing ideas with colleagues; and then actually doing it and experiencing it.

A co-contribution/co-investment model tends to be more effective in the project management engineering/senior site-supervisor type space, where this new technology would more likely reside. One interviewee highlighted that they need to justify your training investment as being relevant to the enterprise and what the enterprise does, so flexibility is needed.

> *Through this network of Swedish Built Environment universities we try to organize education, because we see each of us is too small actually to start developing new courses. So we need to collaborate… There are 4 universities that have these kinds of Masters students and Civil engineering*
>
> **Swedish University Professor**

In Sweden, Vinnova[7] is financing a national group of representatives from the Swedish construction industry (including clients, contractors, and university researchers) to develop recommendations around BIM competencies required for the next 5, 7, 10, 15 years. In addition, the OpenBIM[8] (now the BIM Alliance) program was a valuable external entry point for linkages between industry and educational institutions.

[6] http://www.eeaust.com.au/
[7] VINNOVA – Sweden's Governmental Agency for Innovation Systems - http://www.vinnova.se/en/
[8] http://www.bimalliance.se/about_bim_alliance

Trafikverket have its own internal education program, and provides seminars to inform industry about BIM. These include dissemination of information about the benefits of BIM for both small and large scale infrastructure projects. Other companies pay for employees to attend external classes. However, the primary skill required remains construction knowledge.

Overall the industry is being well served by universities, for example Lund, Chalmers, Lulea, and KTH provide courses in this area. Sweden also has a long-term tradition of PhD students going into senior levels of technology development in industry. This started in the 1980s, when the Swedish National Construction Industry R&D Organisation (SBUF)[9] started. There are also adjunct professors that work in both academia and industry.

Dissemination Strategy

As part of the development of this roadmap, dissemination avenues were also considered to address the skills gap at the various layers of decision-making. This research proposes a three tiered dissemination strategy (

Figure 4) for research findings to build understanding of BIM, IPD and the requisite skills upgrade required within the industry. This hierarchy may also be useful in terms of the design of courses to up-skill people of various levels of decision-making.

Additionally, SBEnrc is building a playlist on YouTube with informational videos about BIM that target all three tiers (Figure 3).

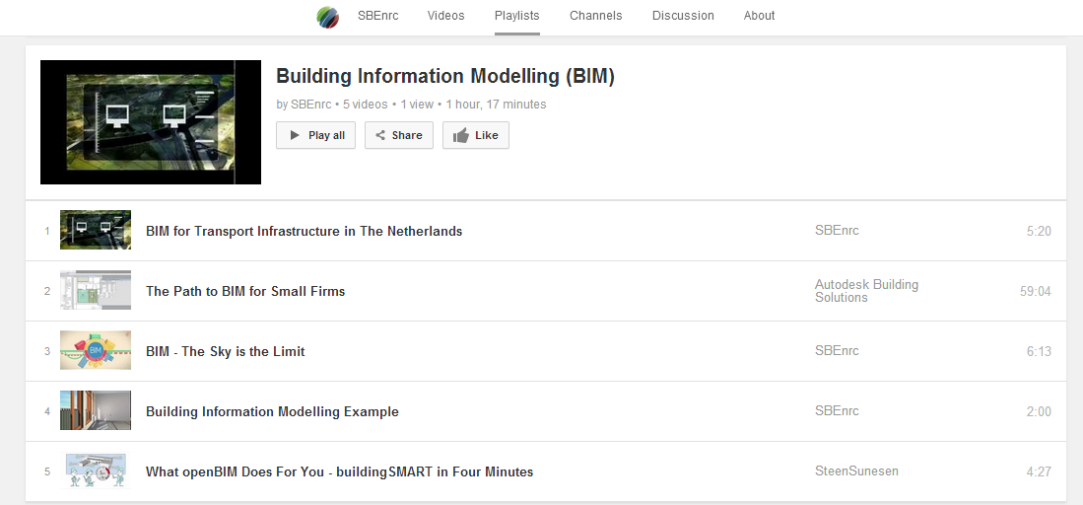
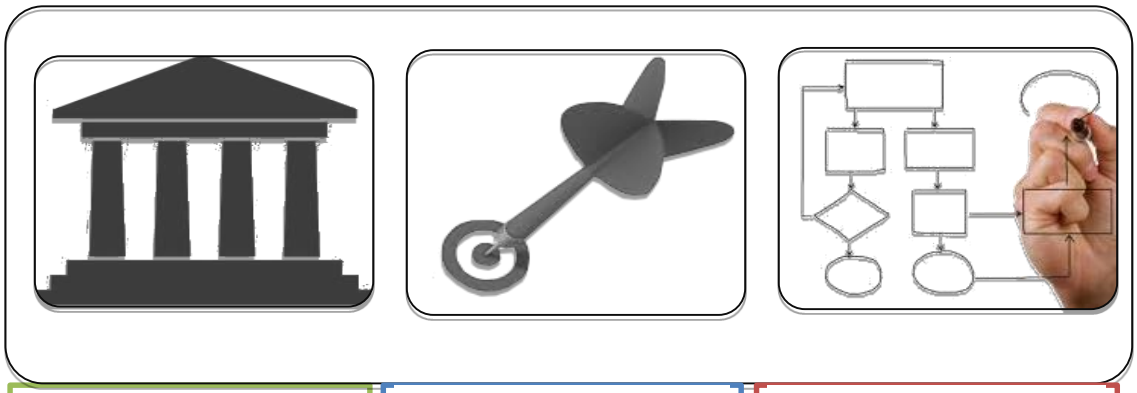


Figure 3. BIM information playlist on SBEnrc YouTube Channel

[9] SBUF was instituted in 1983, and is the construction industry's own organization for research and development of almost 5,000 member companies in Sweden - http://www.sbuf.se/sa/node.asp?node=3



Tier 1
Government Decision-makers

Target audience

Key politicians (e.g. Commonwealth and State industry ministers and departmental heads); Chief Scientists; Transport and Infrastructure Council and other national roads agencies including Austroads, Roads Australia, Infrastructure Australia; State-based infrastructure agencies;

Mechanisms

• Demonstrate value of innovation to the system through informative and interesting documentation
• Face-to-face representations from research and industry leaders

Tier 2
Mid-level Strategic Decision-makers

Target audience
Government program directors and industry leaders

Mechanisms

Present case studies of systemic learning through informative and interesting documentation

short audio-visual materials (3-6mins) pending budget

seminars for project partner agencies

ongoing formal exchange between with industry associations and the like e.g. NATSPEC, ACIF, APCC, and buildingSMART

Tier 3
Project & Program Delivery

Target audience Industry professionals; SMEs

Mechanisms

Guideline documents; short professional development courses; publications in industry journals

Examples

CRC for Construction Innovation - *Guide to Best Practice for Safer Construction*

Delivery

Development of short courses with materials provided by lead researchers and delivered in conjunction with organisations such as Civil Contractors Federation, Engineers Australia, Education Australia, Construction Skills Qld. as PD courses

Figure 4. SBEnrc three-tiered dissemination strategy

Key Recommendations for Reducing the Skills Gap

Recommendations from the analysis of a review of academic literature and industry document, and an analysis of interview findings have highlighted the need for a more strategic approach to skills development in this country (whether national, state or organisation-based) that addresses the three tiers and the three types of skills needed (i.e. technical, human and conceptual). This includes:

- A need for *better coordination* across knowledge providers, and industry support for initiatives such as the APCC-ACIF education and skills project. The team recognised that this approach is problematic due to the current market driven approach to education and training at both tertiary and professional levels.
- Recognising the significant benefits of *stronger links between industry and academia* (for example Swedish students often served placements in industry and industry staff were often involved in education).
- *Developing support systems for capability development by SMEs* such as that employed by some state agencies where contractors receive training when new processes are being adopted for project delivery.
- These recommendations then need to be integrated as a part of the milestones proposed in the accompanying document *Towards a National Strategy*. Educational and training providers need to engage with such an ongoing collaborative effort in order to continue to fine-tune and focus training and courses which are available at undergraduate, post-graduate and professional levels.
- A strategy is also proposed for *disseminating research findings to upgrade skills* across a three tier hierarchy of decision-makers, that is, government decision-makers, mid-level strategic decision-makers, and those involved in project and program delivery.

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