



Reducing the Skills Gap

Research Report 3

SBEnrc - Integrated Project Environments

Leveraging Innovation for Productivity Gain Through Industry Transformation (Project 2.24)

This document is the last of three primary deliverables from this project to address the objectives: (i) inform a national strategy for the adoption of BIM/VDC, (ii) develop guidelines for new contractual frameworks and (iii) provide a strategy to reduce skill gaps especially for SMEs, within the context of Integrated Project Delivery in Australia

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Executive Summary

Education and training costs for companies looking to adopt BIM technology will be, to a degree eliminated when universities and other educational providers incorporate BIM training into degrees and coursework. (Allen Consulting, 2010)

This project aims to deliver on three important areas:

1. recommendations for ministers and policy makers for a nationally consistent strategy
2. recommendations for modifications of current procurement and contractual framework 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 our work with organisations such as CCF and EA, as well as through our partner organisations and our media resources (youtube channel, industry publications, etc).

To inform each of these aims, this current research report aims to inform this discussion through providing information on three key areas being: (i) a current insight into relevant BIM/IPD skills more broadly; (ii) knowledge dissemination and uptake; and (iii) the role of knowledge intermediaries.

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 roadmap 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.

1. Introduction

BEIIC's Early 21st Century Vision for the Construction Industry in Australia (2012) identified that this industry will become one that:

- *Is organised around the logic of Integrated Project Delivery (IPD), as enabled by integrating technologies.*
- *Has collaborative contracting as the norm.*
- *Respects the skills and experience of all industry participants.*
- *Attracts and retains people who collaborate.*
- *Maximises the time, cost and quality efficiencies of off-site fabrication and assembly and minimises exposure to on-site variables.*
- *Works to improve quality while reducing costs across the supply chain.*
- *Serves both the domestic and export markets through high end products, materials and skills (Fien and Winfree 2012a)*

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, 2012; Australian Institute of Architects, 2010).

BEIIC (2012) further highlighted the fact that clients, contractors, sub-contractors, architects and consultants are all struggling to come to terms with BIM. This situation creates the need to promote:

- (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).

Peansupap & Walker (2005) also identified training as a key barrier to adoption and implementation of information technologies and suggest that learning should also be part of any intra-organisational IT implementation diffusion strategy. This is traditionally provided through formal or informal training, short courses, or university courses. For intra-organisational learning, it is paramount to continually assess the requirements to reduce the knowledge gap by tailoring the training programs to the trainees' technical skill level (Peansupap & Walker, 2005). Results from the McGraw Hill Construction (2008) survey also highlight the relevance of the choice of method depending on experience level and audience for intra-organisational training.

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

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.

This report summarises the findings from research carried out under SBEnrc project 2.24 *Integrated Project Environments: Leveraging Innovation for Productivity Gain through Industry Transformation*. The report focuses on those research results that pertain to the reduction of the skill gap related to

IPD and BIM. It also provides recommendations for a way forward as well as a dissemination strategy to increase the understanding of IPD and BIM in the transport infrastructure industry.

1.1. Coordination to Provide Leadership and Address Complexity

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

Giangregoria and Goss (2008) identified the need to provide 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. 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.

Fien and Winfree (2012b) identify 7 key stakeholder groups in industry innovation 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.

Further to this Fien and Winfree (2012a) highlight the differences between the various players in the education and training sectors in Australia (Figure 1). This analysis does not include training provided through alternate mechanisms such as *in-house* training. This is normally done by employers with a vested interest in addressing skills gaps which may include mentoring, or buying-in those with knowledge. For example the Centre for Integrated Facility Engineering (CIFE) provides company-funded courses delivered in Sweden and/or Australia.

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.

Figure 2 illustrates the peak body maps for both Australia and Sweden prepared as part of this research. These maps highlight the complexity evident in Australian relations in comparison to that in Sweden.

	Vocational Education and Training	University	Industry Professional Development
Funding	Industry and Government	Government	Full fee from student or reduced member fees, grants
Regulation	Australian Skills Quality Authority and state regulators	Tertiary Education Quality Standards Agency	Self-regulated
Australian Qualifications Framework Levels	AQF levels 1 to 6 and non-AQF courses	AQF levels 5 to 10 and non-AQF courses	Non-standardised or AQF courses
Market	Demand driven funding in Victoria only, under review in NSW, Qld, SA, WA	Fully demand driven funding	Competitive free market
Accreditation of courses	Competency based training (national/state standards and accreditation)	Self-accredited by the universities	Accredited and non-accredited training often to support professional recognition
Focus	Industry led training	Academic research and education reflective of industry and market demands based on professional standards	Based on professional standards or specific client based needs

Figure 1. Key differences between education and training sectors (Fien and Winfree, 2012a).

Fien and Winfree (2012b) 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.

In the United Kingdom (UK), NBS (2014) reported that in small firms of one to 5 people only 35% were confident in their skills and knowledge in relation to BIM, and 62% of the firm considered a lack of in-house expertise a barrier to adoption. Whilst in firms that are six or more, 50% were confident in their skills and knowledge, and 77% considered a lack of in-house expertise a barrier.

We're partnering with universities to gain content and the response has been 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

1.2. From Diffusion to Uptake

In technology diffusion theory,¹ it is generally recognised that the process of diffusion realises the productive potential and competitiveness achievable from new technology (Stoneman & Diederer, 1994). Fichman (1992) divides the implementation phase into six stages: initiation, adoption, adaptation, acceptance, routinisation and infusion. Of particular interest to the present research are the latter three stages. Acceptance can be most successfully encouraged through the documentation of well-selected events. Together these legitimise the new work reality as an effective solution to a class of important organisational challenges and opportunities (Zmud & Apple, 1992). Routinisation is defined as the permanent adjustment of an organization's governance system (e.g., its administrative infrastructure) to account for the incorporation of these technological innovations. And infusion is defined as the final stage of IT implementation and is highly influenced by interpersonal communication and innovation maturity (Peansupap & Walker, 2005).

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.

¹ The acceptance and spread of new technology in a market or user community (Loch & Huberman, 1999).

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.

According to McGraw Hill (2008), college and on-the-job training can help users unlock the potential of BIM, since research shows that users gain more positive results from BIM as they develop higher levels of expertise. This survey showed that training programs on BIM basics is the most important training need across all surveyed experience levels and company sizes. However, there is no agreement on the best delivery method and the industry still splits between: external trainers, train at off-site locations, use internal trainers, or self-training (McGraw Hill Construction, 2008).

It is also important to note that meta-governors² 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 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).

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

² 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, et al., 2011).

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

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

1.3. The Case of SMEs

In Australia, interviewees indicated that for SMEs to embrace technology then the investment decision needs to be there. They need not necessarily the support it, but they need 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 no 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 bigger and bigger. They explained that this happens because of the large 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 represents 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.

Another interviewee expressed the view that every design company has a CAD system today and therefore there is no handicap specific to smaller companies. From a contractor’s perspective, a one-man company who has a truck, or bigger machinery would already have GPS systems and computers, otherwise they would not be able to operate as sub-contractors. Bigger contractors do not want to employ them if they do not have this modern equipment. For example, NCC, one of

Sweden's largest contractors, has always had local truck drivers that were hired only if they had the right equipment. Small companies must have the right quality equipment in order to survive. In some instances, larger contractors have bought equipment that they place in machines owned by level 2 contractors (i.e. large contractors *kit-out* smaller contractors for specific projects). One interviewee also noted that, the smallest of the SME is another element which needs to be lifted up in terms of knowledge and training and competencies in working with BIM.

1.4. The Role of 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)

Although standards are being developed to expand the use of BIM in the construction industry, only a fraction of the users are aware of these efforts (McGraw Hill, 2008). 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 intermediary knowledge transfer 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). The roles of these intermediaries include: (i) coordinator: mediating technological knowledge flows when technologies belong to the same industry; (ii) gatekeeper, absorbing technological knowledge from *outer-industry* technologies and transfer it to *within-industry* technologies; (iii) representative, diffusing *within-industry* technological knowledge to external industries; (iv) consultant, mediating technological knowledge between different technologies in another industry; and (v) liaison or arbitrator to enhance technological knowledge interactions between other industries when the technologies belong to different industries (Lim & Park, 2010).

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).

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 mediator 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).

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

Swedish Contractor

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. SMEs stand to benefit from both technological and professional development activities which are strongly related to the adoption of new technologies (Swan & Newell, 1995). Therefore, when trying to increase the rate of diffusion of a particular technology to benefit SMEs throughout the infrastructure construction industry, it is paramount to include professional association such as the Civil Contractor Federation (CCF) and Engineers Australia (AE) in the strategic planning.

As mentioned in an earlier section, the Australian construction industry is dominated by SMEs. Therefore, the role of knowledge intermediaries will be particularly important in the context of transport infrastructure delivery. 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 and 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.

1. Skills – A Current Insight

Internationally, the UK is considered to be one of the world's leaders in BIM adoption and implementation. This is an outcome of the UK government's industry leadership in meeting the 2016 mandate to level to them for all publicly funded work (NBS 2014). The National Building Specification (NBS) Committee acknowledge *there is a real need in training and professional development* and that will *increase as BIM becomes a reality and more practices moved toward level 2 and 3 BIM*.

There is much activity in Australia in this arena, including:

Public Policy Advice:

- APCC's report *Investing in Better Outcomes through Professional Procurement Development* concludes that *maintaining excellence in procurement is a continuous process*. Thus, public clients must *support skills development through training and education to continually keep pace with advances in procurement*. This report highlights the links between investing in the development of the right skills and achieving long-term savings and efficiency gains (APCC, 2013).

- Australian Institute of Architects (2010) proposes that training programs have to be tailored to provide communication and *thinking* skills to suit collaborative work. This report also highlights the importance of having a coordinated approach to developing training programs to reduce adoption cost.
- The Australian Workforce and Productivity Agency (formerly Skills Australia) explains the need for a national approach to developing specialised skills and talents. They argue that this will help Australia face global trends created by ICT driven productivity growth and innovation in the 21st century. This report reinforces the need for a lifelong learning culture supported by structural organisational and policy changes and highlights that *'human capital is the key to realising the innovative potential of ICT'*. (AWPA, 2013).
- CRC for Construction Innovation book *Building information modelling: Future roadmap* explains that current education systems and structures are based on *traditional document-based processes*. This creates an urgent need to update the curricula which should be supported on a collaborative effort across education institutions (Kiviniemi, 2009).
- The Built Environment Industry Innovation Council (BEIIC) *Final Report to Government* stressed the fact that clients, contractors, sub-contractors, designers and consultants are all struggling to come to terms with the concept of BIM. Therefore, there is a need for *investment in knowledge transfers and curriculum change policies across VET, higher education and the industry to support the widespread adoption of 21st century technologies such as BIM* (BEIIC, 2012). Technical Report A focuses on the development of basic skills across the workforce to capitalise on future opportunities and achieve a more productive industry (Fien & Winfree, 2012). This report offers a suite of areas where skill development should be focused.
- buildingSMART Australasia suggests that the industry and government should work together to address six key targets including education based on a new multi-disciplinary approach (Mitchell, et al., 2012).

Coordination:

- ACIF and APCC commenced three new projects in 2014 including development of: (i) an adoption roadmap for Project Team Integration (PTI) and BIM; (ii) a *Procurement Models and Application of PTI and BIM Options Guide (BIM Procurement Guide)* detailing how to integrate BIM into each procurement model including roles and responsibilities; and (iii) a draft strategy for *Education and Skills Program for PTI and BIM* for industry and clients (ACIF, 2013).
- The Australian Mechanical Contractors Association (AMCA) launched BIM-MEP^{AUS}. This initiative has a working group focused on training and education who prepared an 18 month plan. 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, 2012).

Training and Awareness:

- AIA has offered BIM Workshops (Australian Institute of Architects, 2013a) and hosts the BIM/IPD^[AUS] portal which provides access to standards, documentation, reports, libraries, presentations and AIA-Consult Australia Education Working Group Publications. (Australian Institute of Architects, 2013b). This working group reported barriers to introducing BIM in

formal education and identified 20 education principles (Succar, et al., 2012a; 2012b; 2012c).

- Centre for Interdisciplinary Built Environment Research (CIBER) provides a list of courses available in 2012 across some Australia's tertiary education system and highlights the shortage of skills as a key barrier to BIM adoption (Brewer, et al., 2012).
- In 2013, buildingSMART Australasia planned to start an Education Working Group that focused on: (i) developing and delivering BIM awareness programs for government and industry; (ii) developing and delivering BIM training packages; and (iii) encouraging the inclusion of BIM in VET and professional education. However, this effort was cancelled due to lack of resources (buildingSMART Australasia, 2013). This group has also organised conferences and workshops co-sponsored with other organisations such as Virtual Australia and New Zealand Initiative (VANZI) and Minter Ellison.
- NATSPEC report on BIM Education provides a brief introduction to the state of BIM education in different countries including Australia. This report found that although Australian universities and TAFE institutes are starting to include BIM related courses, these are very basic and associated to particular software platforms (Rooney, 2014). NATSPEC also produced a 7 minute tutorial to introduce their BIM guidelines (NATSPEC, 2013) and NATSPEC is heading the *Certification and Accreditation Work Group for the Air Conditioning and Mechanical Contractors' Association (AMCA) BIM MEP^{AUS} project* (NATSPEC, 2014).
- The AMCA also collaborated with A2K to develop an online course that serves as a *beginner's guide to the business of BIM and BIM-MEP^{AUS}* (AMCA, 2012).
- CODEBIM provides information on BIM-related courses provided by UNISA and UTS, as well as a library of support material such as books and other texts for specific disciplines (i.e. architects, owners, engineers, construction managers, etc) (CODEBIM, 2014).
- Engineers Australia has offered BIM related webinars and seminars through Engineers Education Australia (James, 2013; Engineers Australia, 2013; Kulatunge, 2013; Chater, 2013).
- At the more local level, BrisBIM was formed as a non-for profit group that organises regular meetings in Brisbane, Queensland that provide information about a range of BIM-related topics (BrisBIM, 2014).
- Construction and Property Services Industry Skills Council (CPSISC) has endorsed BIM-MEP^{AUS} forums and their recent Environmental Scan identified BIM as a current emerging issue. This organisation is investigating e-learning opportunities to address this trend in the future (CPSISC, 2014).

Although this list is not at all exhaustive it does show that there has been a significant level of activity and interest in BIM and IPD education and training in Australia. It also shows that there are many organisations currently developing their own curricula and others trying to coordinate these efforts. However, the sheer number of organisations in this space is an indication of the fact that the approach is still disjointed and uncoordinated.

1.1. A 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 forming professionals as well as to *re-skill* the current workforce (BEIC 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. At an organisational level, particularly for architecture and engineering SMEs, staff training cost can also represent a significant challenge. Thus, firms might find that encouraging universities and TAFE institutions to train students in basic BIM skills might be an important strategic step towards lowering organisational training costs (Hollenstein, 2004).

Fien and Winfree (2012b) 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*³ 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 and Yolles, 2002). Thus, knowledge intermediaries might have key roles in the reduction of the skill gap in SMEs.

Additionally, it has also been proposed that, for meta-governance frameworks to be successful there is an urgent need for further and better training of public managers at the lower administrative levels. These public managers should have a background and temperament that enables them to mobilise and connect a plurality of actors (Sørensen and Torfing, 2008).

Views expressed from interviews

In Australia, there are a number of universities and TAFE institutes currently developing and implementing BIM training programs in Australia (Brewer et al., 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 et al., 2012).

In Sweden, the BIMAlliance 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. Andersson (2013) undertook a survey of BIM related teaching in construction courses in Sweden-based on BIM objectives set by industry. The distribution of BIM courses across discipline was significantly different between architectural and engineering courses. In architecture

³ These are skills needed 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 (Li, et al., 2008).

courses this accounted for only 13% of the total number of BIM credits, whereas in bachelor of engineering program this figure was 70%. Within the Master of Architecture courses, BIM related ECTS credit account of 3% of the total credits whilst in Masters of Civil Engineering courses this accounted for 9%. Further to this, Andersson notes that 86% of these credits concern construction of buildings whilst only 14% relate to the issue of urban planning and landscape design. Importantly, only 1% of ECTS case credits consider matters of business strategy in relation to implementation of BIM.

1.2. 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.

The use of IPD with BIM/VDC requires an array of changes including: (i) using 3D visualisation capabilities to communicate with all stakeholders; (ii) using BIM/VDC on the jobsite to guide construction activities; (iii) investing more time in the design phase and less time documenting, among others (McGraw Hill, 2008); and (iv) highly involved teams with high level communication and technical skills (AIA, 2010).

Views expressed from interviews

In Australia, eleven interviews undertaken in 2013 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 Australia⁴ (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 webinar 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.

⁴ <http://www.eeaust.com.au/>

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.

APCC (2013) 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 will be 2,500%.

In Sweden, Vinnova⁵ 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 OpenBIM⁶ (now the BIM Alliance) program was a valuable external entry point for linkages between industry and educational institutions.

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.

Companies can provide internal (or external) training in BIM, whereas other skills such as the right attitude, an ability to liaise with clients, and training in problem solving and creativity is not considered something that companies are *good at teaching*. For example one contractor interviewed has links to several universities, SBUF, Stanford via CIFE, and recently arranged a Virtual Design and Construction (VDC) certificate course for 29 people. This included a special one-week session in Helsinki with Martin Fischer and John Kunes (CIFE) (four day start up course) which is now being followed by up to 12 months of reporting to CIFE, with a two day completion session, from which participants will receive a VDC certificate.

Overall the industry is being well served by universities, for example Lund, Chalmers, Lulea, and KTH provide courses in this area (see Appendix C for more information). It does however take time to change courses in our universities. But now, for instance BIM and VDC are being integrated into Masters level courses at Swedish universities. The aim is to organise this education through a collaborative network of Swedish Built Environment universities as each university is too small actually to start developing new courses.

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

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

⁵ VINNOVA – Sweden’s Governmental Agency for Innovation Systems - <http://www.vinnova.se/en/>

⁶ http://www.bimalliance.se/about_bim_alliance

R&D Organisation (SBUF)⁷ started. There are also adjunct professors that work in both academia and industry.

Contractors such as NCC are involved in many different ways in the work of the universities. This contractor has industrial PhD students, adjunct professors and members of education boards working on BIM. NCC also provides working positions to Master students to do their thesis or diploma work. This activity at Master and PhD level however reflects the fact that this is still an area of improvement.

2. Knowledge Dissemination and Uptake

Views expressed from interviews

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 managerial 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 a significantly larger cohort 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 a more widespread uptake, with significantly more technology being embraced than ever before (i.e. continuous business improvement model). Future investments and whether new technology will be integrated is a business decision considered on a regular basis. 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.

As an emerging technology, organisations such as CSQ would need a trigger to embrace BIM training more fully, such as industry saying “we are being asked to embrace this new technology and there is very little skills base here to be able to support it”. Similarly 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 collective focus. Their role being more one of support or endorsement once an agreement is reached. They would also provide technical capability for development of skills and training, and how to effectively manage both the technology and documentation side of BIM uptake. More initiatives such as Collaborate ANZ⁸ are therefore needed. This organisation has served as forum for some of the largest industry participants to discuss the state of the industry and share their experiences.

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 the extent they are on the same page in terms of what they want BIM to look like (such as a road map) and with the potential is to reach significantly more people. Coupled with this then is the need for organisations such as Standards Australia to develop standard forms of contract and the like.

⁷ 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>

⁸ <http://collaborate-anz.com/main/>

Professional associations such as CCF and EA could influence the uptake of more collaborative models and new technologies.

Examples of industry association activities are: (i) to assist members with information on contracts, now that contracts will be impacted by the use of BIM; (ii) Engineers Australia is working to review and start writing the practice notes to inform their members.

We normally go after people that have some experience. And then if they don't have much we send them off to external training that gives them the basics and then we do some in house on the job training as they go. We found that the external training is good to get started but after someone has been to the external training you can't let them loose on the project, they need a lot more than that

Australian Consultant

In Sweden, the coordination and uptake of BIM in the construction sector in Sweden is, in a broad sense led by the client, but in a specific sense leading consultants and their sub-consultants also have a role. Many companies stated they are using BIM but they use it only in limited aspects of particular elements. But now slowly we can see that there is an uptake and that people are getting more interested in “how do we train our employees? How do we look into procurement aspects as well which is an important element?” There are a lot of initiatives, different initiatives as well. And they are working very hard, but it's a bit slower in Sweden because they have to get a clear understanding of all the different elements. There are a number of policies coming in 2014, and several groups are coming up with guidelines and a possible set of standardised ways of dealing with BIM.

Trafikverket have set up a good program, dealing with good projects which are now integrating BIM, but development is slow. They also distribute outcomes for industry learning, including BIM requirements and information quality. Findings are disseminated through seminars, publications, and the internet. Small web-based questionnaires are being undertaken with Trafikverket asking them “did you use 3D modelling in the presentation”, “did you get any increased understanding of the project and greater value than you might normally get”. They have deduced that there's a huge intangible, and soft, value to the use of BIM. This does not include monetary values against objective process improvement measurements however. One example is the Stockholm Bypass project, where the client and industry are working together implementing BIM.

There are also national and European programs, with many companies engaged with OpenBIM. The extent of industry adoption however is not clear. For example: SBUF have been successful in beginning to support industry uptake; in the recent years, Vinnova has been more dedicated to seeing the uptake of BIM and the innovations aspect also in the construction industry; SWECO has a team of seven people dedicated to spread knowledge and to pick up knowledge; Skanska run seminars, workshops, make formal publications and make it available on the website for industry learning to the industry beyond their organisation (whilst not revealing too much of their commercial confidentialities in these case studies); and in Poland, Germany and the Czech Republic public talks are run to talk about different projects from different countries.

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

3. Recommendations

Thus, it is necessary that senior decision makers in the built environment industry and associated higher education sectors develop the capacities to:

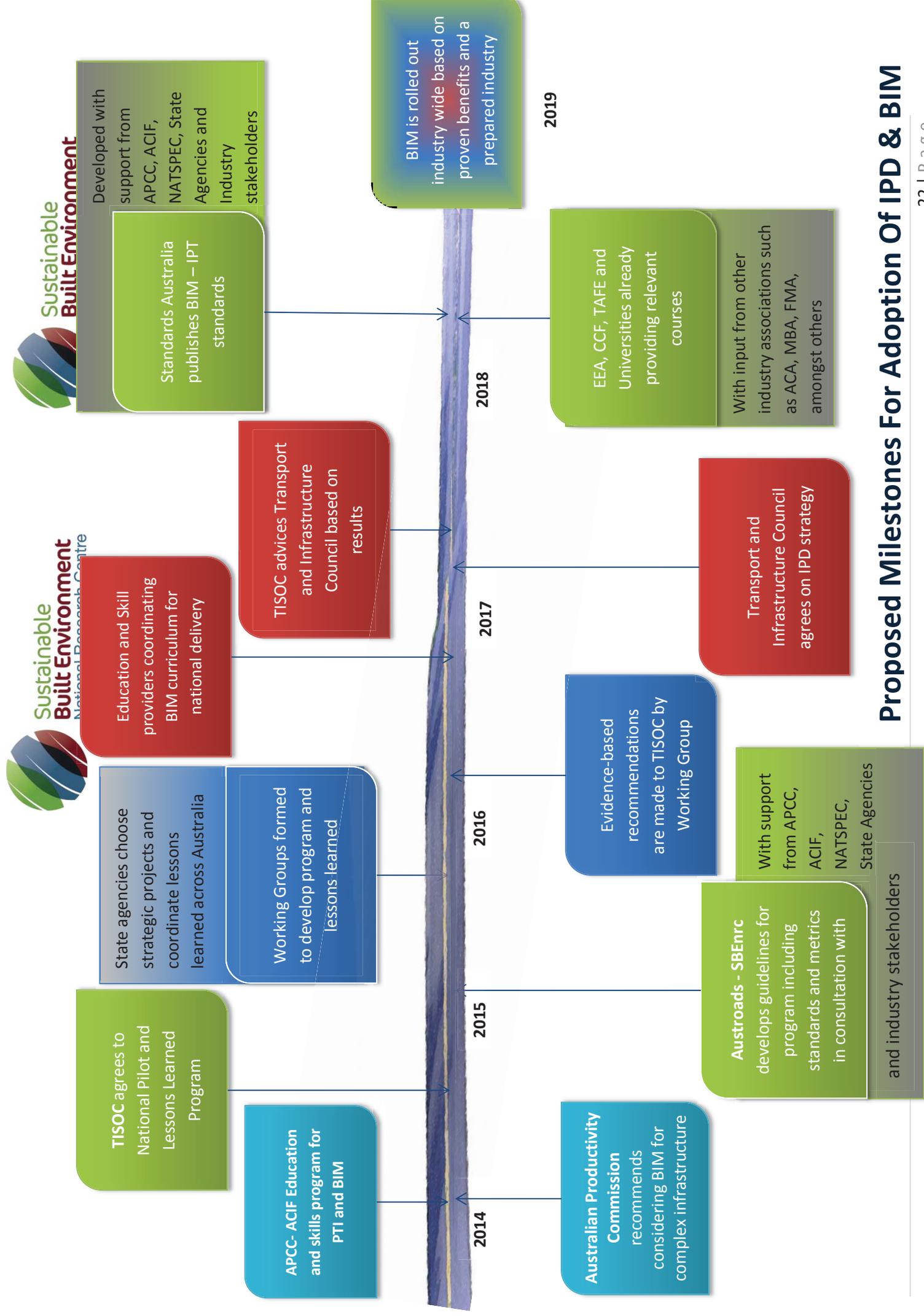
- *Attract and train people skilled in collaborating across trades and professions.*
- *Re-engineer traditional industry roles to enable Integrated Project Delivery with seamless iteration between innovation, design, fabrication, delivery and assembly.*
- *Readjust accreditation to be in line with re-engineered industry roles and skills*
- *Equip clients, designers, contractors, trades and manufacturers with access to, and a high level of skills in the using, integrating technologies.*
- *Support small to medium businesses to re-skill around new industry practices, so they can embrace change and prosper from it.*
- *Identify career paths and vehicles for stability of employment.*
- *Apply energy efficiency and related skills. (Fien and Winfree, 2010b)*

This approach has been reinforced by the findings of this current research. Based on the review of literature and industry documentation, and analysis of interviewee findings, issues for consideration in developing a strategic approach to skilling (whether national, state or organisation-based) that addresses the three tiers and the three types of skills needed (i.e. technical, human and conceptual) including:

- 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 roadmap proposed in the accompanying document *Towards a National Strategy*. Educational and training providers need to engage with such an ongoing collaborative effort 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.

These recommendations need to be integrated as a part of a series of proposed milestones proposed in the accompanying document ***Towards a National Strategy*** (Figure 3). 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.



Proposed Milestones For Adoption Of IPD & BIM

Figure 3. BIM/IPD Implementation Milestones

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 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.

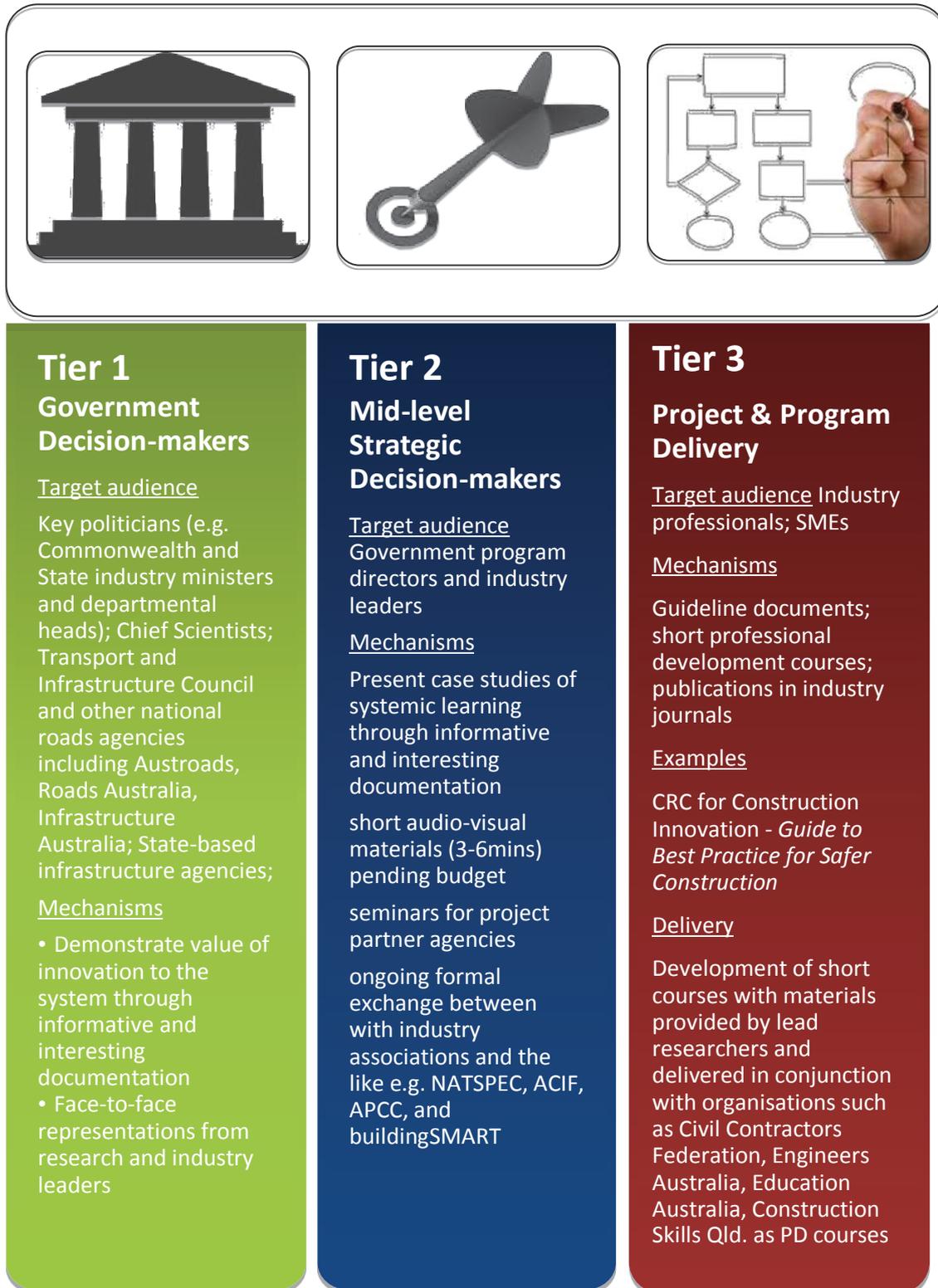


Figure 4. SBEnc research outcomes dissemination strategy

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5. Appendix A – Interview Responses

In some cases these have been paraphrased to assist with clarity.

5.1. Skills

5.1.1. Australia

Demand:

- *There needs to be some acknowledgement of the requirement of the skill [for] the workforce to embrace it.*
- *There'll definitely be a skill set change - you need to get information flowing through properly and that will require some sort of mind change in the way they operate.*
- *Change (required)... it's more of a mindset and the skills and the knowledge of the operators which is the issue...*
- *it's just a matter of getting the industry trained up for that new technology...*

- *If Consult Australia felt that it was appropriate to shout about it, train people, (and) guide the nation then we (contractors) would fall in line with those...*
- *Professional associations are being a slightly more active recently due to pressure from their membership*

TAFE and University Approaches:

- *I think there's a responsibility to let the education systems know what it is that they require. So we (contractors) should be telling the education institutions more vocally about what we think the skills of the future that we need are...*
- *Think new university courses that force collaboration between engineers, architects and other careers could help in creating a more skilled or creating that capability*
- *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 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.*
- *TAFE has been very active in this space recently providing courses in digital building.*
- *Maybe it would also make more sense for universities to "up" their requirements, so if you want to apply for a Masters in Arts for example, you need to prove you have the skills needed to use digital modelling and have carried out maybe a TAFE course on this.*

Industry-lead Approach:

- *Associations should be formulating plans to up skill their members, it's a great opportunity for them to engage with their members and make money.*
- *Engineering Education Australia⁹ (EEA) has been in existence for 23 years providing professional development for the whole range of engineering sectors and construction. EEA is launching a major online initiative. We're trying to bring together all of the professional development opportunities that are available through us and through Engineers Australia into one portal. EEA run a graduate program for engineers and they value the communications, collaboration, team work... The Victoria division [of EEA] are doing a series of little webinars sessions on BIM ... and having some international guest speakers.*

Mixed-mode Approaches:

- *We just have to provide lots of options and that's really what we're working through at the moment. So it's finding out what the skills gaps are, providing different options to address them because you know it's just a very fickle situation.*
- *We are up-skilling 340 engineers across the globe - they've all been given a modular training course.*

⁹ <http://www.eeaust.com.au/>

- *We normally go after people that have some experience. And then if they don't have much we send them off to external training that gives them the basics and then we do some in house on the job training as they go. We found that the external training is good to get started but after someone has been to the external training you can't let them loose on the project, they need a lot more than that.*
- *I work on the 10/20/70 per cent framing of this: 10 per cent of what we get in terms of capability in the training courses and education and workshops that's sort of 10 per cent of what we gain. Quickly lose it. 20 per cent would come from mentoring, coaching, sharing ideas with people but the big 70 per cent of capability comes from actually doing it, experiencing it.*
- *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.*

5.1.2. Sweden

- *Vinnova financing a group at a national level from the Swedish construction industry (i.e.) the clients, the contractors, it's the universities and so on got together around BIM competencies required for the next 5, 7, 10, 15 years.*
- *The openBIM program is a very useful external entry point for linkages between industry and educational institutions*

Industry Related:

- *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.*
- *They (employees) have to start to learn CADD as a platform to be able to go to the next level to use BIM... so are you training them on the job. We send them to classes external to some companies, and pay their classes.*
- *We want someone with construction knowledge first and foremost because we believe we can teach them the VDC tools or BIM tools. But of course it's great if someone comes with some knowledge of BIM before entering our company.*
- *There's more or less enough coming out of the universities, it's really about getting the right people and the right attitudes, particularly as they try to make an impact on clients.*
- *[I] think it's better to have a sound theoretical background, with training in problem solving, than knowing how to use the latest computer program. Companies can do internal training for that, but problem solving and thinking and creativeness is not something that companies are good at teaching.*

University Related:

- *Overall the industry is being well served by universities, for example Lund, Chalmers, Lulea, or in KTH*
- *We (contractor) linked to several universities, SBUF, Stanford via CIFE... a couple of weeks ago we arranged an 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.

- *It takes some time to change courses in our Universities. But we are seeing that, for instance BIM and VDC is getting implanted in university courses for our Masters students now.*
- *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... This is 4 universities that have these kinds of Masters students and Civil engineering...*
- *It's a longer term tradition [PhDs going into senior levels of technology development in Industry]. It started in the 1980s, when SBUF started. And also, we've started to try the other way, actually to adjunct people from university into industry. We have some PhD people working at university Lulea and they work at NCC.*
- *There's a lot of communication between, for example, NCC is involved in many different ways in the work of the Universities. We have industrial PhD students, adjunct professors, members in these educations boards working on this, and also having a lot of students working for NCC doing their Masters Theses, or diploma work.*
- *I think the level for this is probably Master and PhD pretty much because there's so much development still to be done. But of course you have to have some designers in lower levels as well and they can maybe be lower than Masters or even High school.*

5.2. Knowledge Dissemination and Uptake

5.2.1. Australia

- *A very powerful push for endorsement from CSQ, Engineers Australia, CCF and major contractors... they're all in the business of productivity so if that's the end game then certainly they would support... It's the higher level skills that governments are saying will be the key to productivity enhancement. That it's not about the labour market programs and apprenticeship traineeship programs, it's more about providing the upper levels of the workforce, the skills to improve productivity which creates the pull as opposed to trying to push by bringing in significantly larger cohort in at a much lower skill level...*

Uptake

- *Inevitably there will be a trickledown effect from major to mid-size projects once the technology becomes more main stream, then we will need to embrace it.*
- *This organisation embraces significantly more technology now than it ever did before (i.e. continuous business improvement model). We decide on future investments and whether new technology will be integrated as a business decision on a regular basis. It's important ... to have a 'schedule' for adoption so contractors can put it in their investment pipeline.*
- *If it could tick the R&D box or if it could tick the business support box for medium sized enterprises such as mine it would probably embrace it.*

Knowledge Dissemination

- *Construction Skills Queensland (CSQ) could support the concept that this is an emerging technology that the industry would do very well to embrace but it would need a trigger. It*

would need the industry to say to the CSQ “we are being asked to embrace this new technology and there is very little skills base here to be able to support it”

- *You’ve got to take and learn from the US experience with this, I think there’s then probably a flow on effect.... Some of the UK guys are probably a bit more progressive like Lang O’Rourkes .*
- *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.*
- *Role of these organisations (...) could be on how you effectively manage technology side of it and the document side of it.*
- *We are doing presentations within the organisation to promote BIM as being one of the key enablers for business.*

Skills Delivery

- A co-contribution/co-investment model tends to work more in that project management engineering/senior site-supervisor type space, where this new technology would more likely reside... One has to justify your training investment as being relevant to the enterprise and what the enterprise does, so you need a bit of flexibility around it.

Role of Industry Organisations in Knowledge Dissemination

- *The problem is that not everyone that you want to get this to, is a member of those organisations (i.e. EA and APESMA). Several different media that they could use; you could capitalise on in Engineers Australia and other industry bodies (including APESMA). Professional organisations could have a role [in skilling the labour force]; or in a rollout of the benefits that would be in the very first instance. [Having professional organisations endorse the movement] means more exposure and to the extent they’re both on the same page in terms of what they want BIM to look like as a road map, then you know you’re reaching double the number of people ... Roads Australia or whoever it might be Australian standards actually have standard form contracts...*
- *Professional associations can push the idea through. Saying “this is coming or this is what we should be pushing for”. Because it’s obviously a lot of benefits and... I’m sure they’d realise that but it’s more like guidance in that sense.*
- *Collaborate ANZ¹⁰ which has got some of the big players that come together to talk about what is going on out there on the streets, to share stories about what’s going on.*
- *Professional associations such as CCF and EA could influence the uptake of more collaborative models and new technologies.*
- *There would be a big benefit if they [professional associations] assisted their members with information on contracts, now that contracts will be impacted by the use of BIM and BIM systems.*

¹⁰ <http://collaborate-anz.com/main/>

- *Engineers Australia is working with its other subsidiary Engineer media or one of the ex-editor to review and start writing the practice notes that used to be very popular...*
- *Maybe their role is in dissemination and bringing that information down to a more practical sense of the benefits and uses of BIM for their membership. So not so much in the skilling but in informing their members and education at that level.*

5.2.2. Sweden

Coordination and Uptake

- *In the Stockholm bypass where I work mostly with the construction industry and they're very fond of looking into BIM. In other parts of industry, in the electronic, mechanical industry they've come a lot further*
- *So the coordination and uptake of BIM in the construction sector is, in a broad sense, led by the client but in a specific sense, led by leading consultants, like his firm. Sub-consultants also have a role, but the primary consultant takes the lead.*
- *You can say that SBUF is the contractors and construction industry on front, and they have been very successful in the beginning to support industry uptake.*
- *SBUF and Vinnova - you need a 50% industry company - this sort of mechanism has made these kinds of implementation projects are what you can say more industry related projects, because we have SBUF, we do that.*
- *There's a lot of different initiatives. And they are working very hard, but it's a bit slower in Sweden because they have to get a clear understanding of all the different elements. There are a number of policies coming in 2014, that is, a number of groups are coming up with a set of guidelines and a set of possibly standardised ways of dealing with BIM.*
- *Many companies stated they are using BIM but they use it only in limited aspects of particular elements. But now slowly we can see that there is an uptake and that people are getting more interested in "how do we train our employees? How do we look into procurement aspects as well which is an important element?" But it takes a little bit more time than the other countries... it's a bit of a slower process.*
- *Results that are needed for their business, and so the rest is changing currently I think, but we see, especially larger consultancy firms and contractors, have developed a real set of BIM related activities that fit with their company's activities (building sector example).*
- *We have a lot to do before we have a complete system that includes not only 3D models. ... And why? Because I can see how we can use them, what the benefits are...it's going too slow really. I work a lot with Trafikverket for the road and railroad and they set up a good program ... (and) they are dealing with some good sharp projects now that they try to put in BIM, but it goes very slowly.*

Dissemination

- *Trafikverket distributes learnings to industry ... in order to learn how to (do it) next time (for example we might) say we have a bridge here and you have to fulfil BIM requirements and also the quality of the information and so on and so it's a learning. Distributed through seminars, publications, and on the internet.... It can be extra work for us but it's also*

competitive. We talk to them, we help them and define (outputs) so they can next time they know that we are good to work with.

- *(We participate in meetings with colleagues in) Poland, Germany and the Czech Republic... and talk with others all over the world. They invite some people to talk about different projects, to get a taste of what we do in different countries.*
- *(Contractor) runs seminars, workshops, makes formal publications and make it available on the website for industry learning to the industry beyond (our company), while not revealing too much of their commercial confidentialities in these case studies.*
- *(Consultancy firm) has set up are some small web-based questionnaires with Trafikverket people as they go from meeting to meeting with them. Asking, for example: “did you use 3d modeling in the presentation”; “did you get any increased understanding of the project and greater value than you might normally get”. They’ve deduced that there’s a huge intangible, and soft, value to the use of BIM. But they don’t have clear dollar values against objective process improvement measurements.*
- *There’s a lot of companies from the industry engaged with OpenBIM, but unsure of how much of the output is actually adopted by the industry.*
- *What we are doing internally is that we’re looking we are actually doing a big massive push on education for all our sales managers are going to be receiving education and I think that’s an important thing to illustrate what BIM is all about.*
- *There are national programs, then we have the European programs as well... the Framework program that many of the Swedish Universities have been a part of. They have also had construction-related research, big framework programs.*
- *It’s not so far away that it (TV) was two authorities that have been put together into one. One for rail, and one for road, and now there’s actually one... still these are two very different organizations that have been put together so they’re still sort of different traditions and cultures that need to be sort of unified. That takes time. (Now internalising the mandate from the government to have greater efficiency and delivering more road or rail for the dollars).*
- *(Contractor) has a team of seven people who are dedicated to spread knowledge and to pick up knowledge.*
- *I’ve (contractor) done some research projects with the open BIM, and we work with the Swedish Transport Administration [Trafikverket] actually driving this development*

5.3.SMEs

5.3.1. Australia

Incentives that would work for SMEs: a level of inclusiveness that’s beyond the perceived tokenism of the process... there needs to be again some confidence that we [the client] are really committed to the process as opposed to “we are obliged to run through these steps”... in at least one instance... If small to medium enterprises want to embrace that technology then the investment decision needs to be there... they need not necessarily the support, they just need the opportunity for inclusiveness.

If client groups were looking for that system or that 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...

While small contractors don't have enough people for an innovation information technology type department.

Some of the smaller companies may not be able to afford some of this high tech equipment... So somehow we need to have... more filtered down versions for them to access as well.

Large contractors tend to do internal up-skilling of their workforce through courses. He doesn't think this is a limitation for SMEs because in an SME all you would need is a single person who knows about BIM and the major software tools used that could do the training for that company. Because the only way you learn how to use BIM is by doing it.

EEA is looking to target smaller organisations for our Engineering online. We have a special strategy for the small organisations for accessing CPD through Engineering online in a good, at a good rate. They can't afford often the money and especially at the moment things are very tight... Australian Human Resources Institute AHRI about two months ago and they were having a national wide campaign for small business on human resource issues which obviously are really huge for small business people as well. We're hoping with Engineering online to make a bit of a, to provide some extra support. One of the other things is the regional, regional companies. But there is nothing [no business support programs for SMEs] specific to Engineers Australia

5.3.2. Sweden

SMEs could be consultants or software developers... they can benefit from it.

SMEs and smaller sub-consultants can clearly be part of the process provided they've got the open formats for ease of exchange, of data transfer, and file formats. So small innovative SMEs can be an important part of the industry up skilling.

There is definitely still room for innovative, small, expert firms that work to global standards and open BIM, but be aware of the information overload across the lifecycle of facilities

The vast proportion of consultants are becoming bigger and bigger, so they're buying all the small guy. This becoming a trend, and I think it's because it's very expensive to be in front and to have all this expertise and skill. There are some special kinds of consultants in Sweden that are actually trying to introduce BIM in smaller companies, that is, specialists coming out from research

Every design company has a CAD system today, so there's no differences specified for the small companies or big companies at all. And we see at the contractor side, normally they can, a one man company who has a truck, or bigger machine, they have all GPS and computers today, otherwise they can't operate as sub-contractors. The big contractors don't want to employ them if they don't have this modern equipment. For example, the big contractor NCC always had local truck drivers from the local towns, and they took them on board only if they had the right equipment. So I think to survive for the small companies, they must have the right quality equipment.

What we're doing in Sweden is that the NCC and Skanska bought equipment that they put onto the machines on the level 2 contractors (i.e. large contractors "kit out" smaller contractors for specific projects).

Especially the medium sized and smaller sized companies have much more difficulty with adapting to the changes of particular clients. They have different clients and have to use different types of

software and different types of processes. For small and medium sized companies it's a big challenge [this is mostly based on the building sector].

The other aspect is the very small or companies the SME companies I think there would also be another element which also needs to be lifted up in terms of knowledge and training and competencies in working with BIM.

The Swedish Construction Federation¹¹ (BI) is an alliance between the clients and the union. BI helps members to have a system for quality, and mainly it's for the smaller companies.

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[http://translate.google.com.au/translate?hl=en&sl=sv&u=http://www.sverigesbyggindustrier.se/&prev=/search%3Fq%3DBI%2B\(Sveriges%2Bbyggindustrier%26biw%3D1680%26bih%3D955](http://translate.google.com.au/translate?hl=en&sl=sv&u=http://www.sverigesbyggindustrier.se/&prev=/search%3Fq%3DBI%2B(Sveriges%2Bbyggindustrier%26biw%3D1680%26bih%3D955)

6. Appendix B – Some Training/Education Options

This is not a comprehensive list. Sources include Brewer et al. (2012), and a recent desk-top search.

Australia-wide: NATSPEC Professional Development and Continuing Education Seminars¹² – Getting Started with BIM, The NATSPEC BIM Protocol.

New South Wales:

UNSW: Computer Aided Design - BENV1242; Building Information Modelling - BENV2425; Advanced Techniques using BIM - BENV2421 & BENV7148

UTS: Digital Design and Construction 1 (introduction to BIM) – UG16212; Digital Design and Construction – UG216470; Digital Built Environment - UG16137; Digital Design and Construction 2 - UG16470; Design Team Management – UG16263; Procurement and Contract Management – UG16423; Time and Quality Management – UG16913; Cost Management 1: Measurement (also CM2 & CM3) – 16105; Architectural Design: Computational Environments – PG11516; Architectural Communications: Advanced Modelling Software - PG11316; and Human Resources and Communications Management - UG16914).

Queensland:

QUT: Introduction to Collaboration - BEB210; Advanced Collaboration - BEB212; BEN 910: Integrated Project for MSc Project Management; and I think they were talking about having some more courses under the creative industries banner/

South Australia

UniSA: Architectural Practice Management (ARCH 5034); Managing Resources BIM (INFS 5076); Civil Engineering Practice (CIVE 2009 & ENR203); Masters by Research Geoinformatics (Dr Nicholas Chileshe).

CITB: [Building Information Modelling](#)

TAFESA: Introduction to Revit Architecture - Produce and Present 3D Models of Small-Scale Building Designs

Western Australia

Curtin University: Building Information Modelling (CME205) – and We should ask Xiangyu what other courses there are.

UWA: Integrated Design Bachelor in Science Major

Central Institute of Technology: Revit 2014 Essentials for Architecture (V0816)

Masters by Research in BIM are also offered including those by: Xiangyu Wang at Curtin University; Nicholas Chileshe at UniSA; Robin Drogemuller at QUT; Julie Jupp at UTS ; and Jim Steel at UQ . There is also a proposed Masters through Curtin in partnership with Industry, with the first two master students to commence in Semester 2, 2014.

Private sector:

¹² www.natspec.com.au

IMAGINIT¹³: Revit and BIM for Facilities Management; Autodesk Revit Collaboration Tools; BIM Workflow for Roads and Highways Using the Autodesk Portfolio; Autodesk Infrastructure Design Suite BIM Workflow for Roads and Highways; Autodesk Revit Architecture Fundamentals; Autodesk Revit Architecture Conceptual Design & Visualization; Revit Overview for High School Teachers; Autodesk Revit MEP Fundamentals; Autodesk Revit Structure Advanced; Autodesk Revit Structure Fundamentals; PITStop: Revit - Working with Topography in Revit; PITStop: Revit MEP: Creating MEP Families; Autodesk Revit for Project Managers; Autodesk Revit BIM Management: Template and Family Creation; Autodesk Revit Architecture Site and Structural Design.

A2K: Revit Fundamentals, Revit Intermediate and Advanced Series.

International:

UK: <http://www.findamasters.com/search/courses.aspx?Keywords=building+information+modelling>

Sweden:

- Chalmers University courses include:
 - Masters in conjunction with NCC - students work at the designing firm but get support from academic experts until they submit a thesis and are co-funded by the State and the organisation
 - BIM for Clients
 - MSc Design Management including BIM and IPD
 - Swedish vocational course, primarily for clients and property managers since they lack in Sweden the knowledge concerning BIM. This course is presented from construction master's perspective to provide knowledge on how to plan, design and procure long-term management using BIM. The course includes discussions, exercises and examples to provide knowledge of BIM as a step towards introducing the tool in the long term development and management of the properties. The aim is that for three days, two modules introduce how to control, standardize and develop the necessary information to make the right decisions concerning the design, energy solutions and maintenance of property. Emphasis is placed on the work situation, but the program also aims to link the program phase and management phase to give the opportunity to get a complete picture of a property's life cycle. Through project work and presentation of its own case, you are given the opportunity to take the step to develop your own and your company's way of working with the support of teachers, guest speakers and other participants. The program provides theoretical and practical knowledge of how BIM tool can be used in the development and management of properties.

7. Appendix C - Acronyms

ABCB Australian Building Codes Board

ABSDO Accreditation Board for Standards Development Organisations

¹³ <http://www.imaginit.com/training/in-person-classes/course-descriptions>

ACA	Australian Constructors Association
ACIF	Australia Construction Industry Forum
AIA	Australian Institute Of Architects
AIB	Australian Institute of Building
APCC	Australia Procurement and Construction Council
ASBEC	Australian Sustainable Built Environment Council
AUD	Australian Dollar
CCF	Civil Contractors Federation
CoE	Centres of Excellence
CRC	Cooperative Research Centre
CUT	Curtin University of Technology
DIRD	Commonwealth Department of Infrastructure and Regional Development
FM	Facility Management
OECD	Organisation for Economic Cooperation and Development
QTMR	Queensland Transport and Main Roads
RA	Roads Australia
	Standing Council on Transport and Infrastructure (Transport and Infrastructure Council since May 2014)
SCOTI	
TIC	Transport and Infrastructure Council (Previously SCOTI)
TISOC	Transport and Infrastructure Senior Officials' Committee