Digitally Engineering the Future – Opportunities for VicRoads

Case Study Report

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Research Project 2.46 Whole-of-life Value of Constructed Assets through Digital Technologies

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1. Executive Summary

This case study explores opportunities for VicRoads to transition to digital engineering/building information modelling (DE/BIM). The case will examine VicRoads current DE status, state of play in the digital engineering field on international, national and state levels, explore potential DE pathways for VicRoads and speculate the presence of DE/BIM in two VicRoads traditional projects to explore potential cost savings if DE/BIM was to be used from the beginning of the projects.

2. Introduction

DE is a global phenomenon driving major change in the way public infrastructure is procured, delivered, operated and maintained. DE relies on collaboration, largely using existing information and communication technologies which unlock more efficient ways of working through the asset lifecycle. At its core, DE can provides better and more timely data and information management that can lead to better business outcomes such as improved safety, reduced risk, greater cost certainty and improved sustainability.

DE is simply a collaborative way of working, using digital processes to enable more productive methods of planning, designing, constructing, operating and maintaining constructed assets. This is achieved by aligning digital information systems including CAD, GIS, 3D BIM[1] models, electronic document management, project controls (time, cost, risk, etc.), facility asset data and other related systems, to create a Common Data Environment (CDE). Figure 1 is a representation of project and asset information management systems linked to enable DE [1].

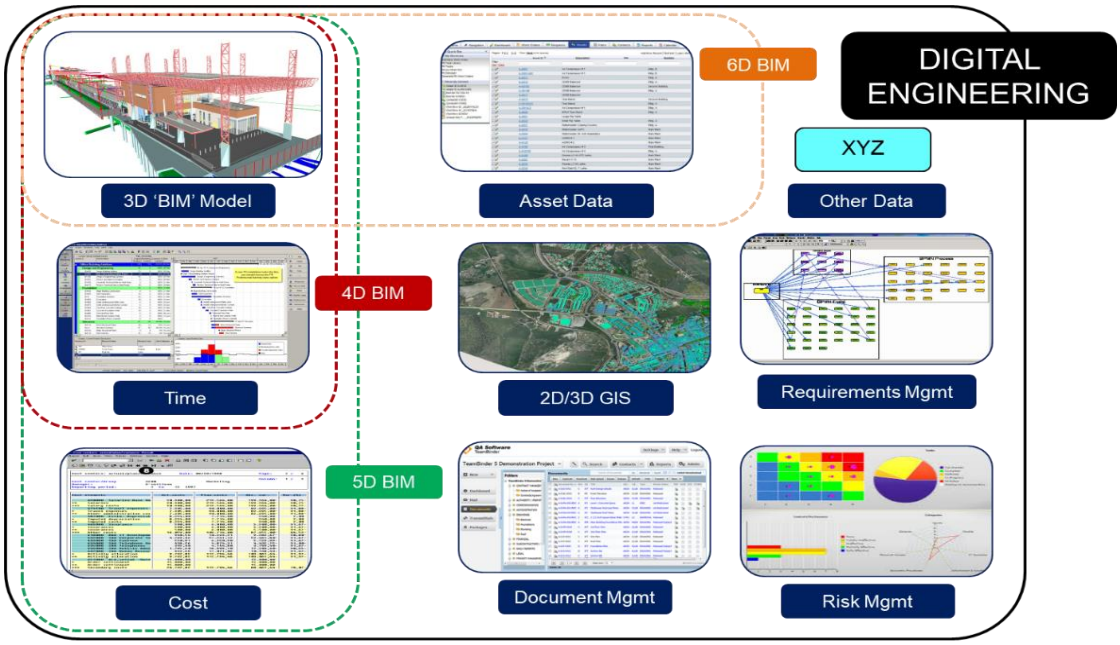

Figure 1. DE representation of project and asset information management [1]

Governments in Australia recognise the importance of DE (incorporating BIM) in the delivery and management of buildings and infrastructure assets and networks. Digital engineering offers many benefits throughout the asset lifecycle and has the potential to drive efficiency, value for money, productivity and innovation. However, the application of DE for infrastructure sectors presents a diverse set of challenges as assets can vary in nature from being discrete in stand-alone structures, to linear when forming part of a broader horizontal network.

[1] CAD: Computer Aided Design
GIS: Geographic Information System
3D BIM: 3 Dimension Building Information Modelling

3. VicRoads an Overview

VicRoads holds more than 100 years of history. However, VicRoads was formally formed in a step in 1989 when the Victorian Road Traffic Authority (RTA) and Road Construction Authority (RCA) were merged to become the Roads Corporation – better known by its trading name – VicRoads.

VicRoads plans, develops and manages the arterial road network and delivers road safety initiatives and customer-focused registration and licensing services in the State of Victoria, Australia. In 2015-16 VicRoads spent $1.9 billion on road asset management and improvements, including $0.6 billion in capital works to enhance the State's road network [13].

4. Digital Engineering in VicRoads - Current Status

The infrastructure sector is a huge sector that requires significant planning, execution and budgets from governments. For example, 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, contributing to 84% of the almost $7 billion invested by the State/Territory governments in the roads sector in 2012 and are currently responsible for almost 70% of the roads in the country in road length [4]. Figure 2 demonstrates the point above.

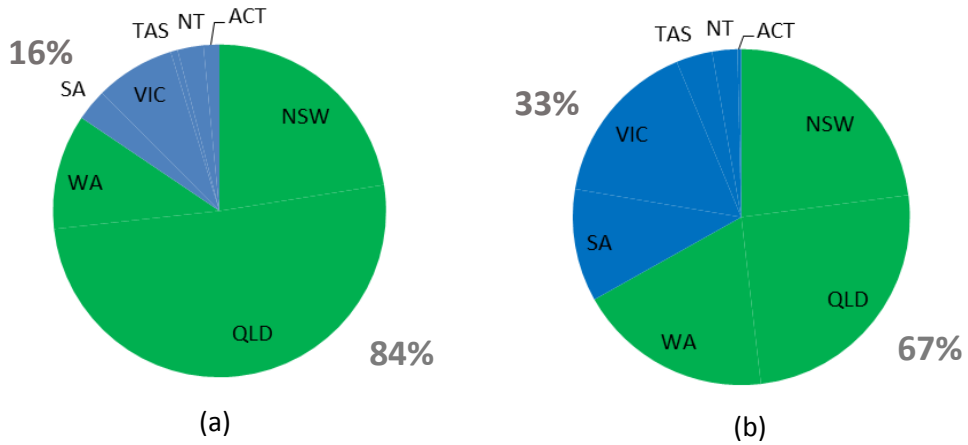

Figure 2. (a) Total road expenditure by state/territory, by level of government, 2011-12 prices — State/Territory; (b) total road length by state/territory (2011-12) [5]

The 2016-17 Victorian Auditor-General's Office Report highlighted that the road network in Victoria has deteriorated, maintenance is mainly reactive, VicRoads does not make full use of its maintenance data to inform the development of its road maintenance program and condition data collected has not been used in the past to drive state-wide decision making. The report adds that VicRoads uses disparate systems and data sets from different resources to monitor its road maintenance activities. To address this, VicRoads is developing a centralised data warehouse, the Transport Analytics Platform (TAP), which is yet to be fully implemented. The Report continues to elaborate, VicRoads is working on a number of asset maintenance reforms including the introduction of a pavement management system including pavement modelling. The latter system was used recently to forecast pavement condition based on various funding scenarios as part of preparing the 2017-18 state budget funding [3]. BIM with its unified approach to integrating project's lifecycle digitally, from design to renovation or disposal could function as a platform to solve these issues.

The DE/BIM adoption journey at VicRoads is at its infancy. There is currently no digital strategy in place. However, VicRoads are on a path to creating one. The first step was the formation of 'The Asset Management Transformation Team' in July 2017. The team will be responsible of creating a strategy towards VicRoads transition to the digital world.

5. Digital Engineering Opportunities for VicRoads

This section will scan international, national and State of Victoria's current practices in DE/BIM.

5.1. International Perspective

The UK Government, through their Government Construction Client Group Building Information Modelling (BIM) Working Party report 2012 (cited in [7]) identified construction as an enabling sector for its economic strategy and decided to seek world leader status in BIM by: (i) committing to the BIS BIM Program (developed by the Department of Business, Innovation and Skills); (ii) aim for growth; and (iii) help create the future by continually developing their capabilities. Melville, 2008 (cited in [6]) highlighted that this decision was followed by a concerted effort between government and industry peak bodies that: (i) led to a series of legal, economic and operational reforms and (ii) according to Strickland and Goodes, 2008 (cited in [6]), allowed these intermediaries to "directly participate in policy development through systemic approaches with the policy process". The government chose to have a national *push-pull* strategy with a number of reforms to be undertaken over the next few years to reach level 3 of their roadmap [7].

Björk, 2009 (cited in [6]) stated that Finland was one of the pioneers in this area and the RATAS Project (which stands for computer aided design and buildings) originated from discussions in 1982 about the need to integrate information technology (IT) applications in construction. This was part of a coordinated research, development and standardisation effort to bring computer integrated construction to Finland. This project, Björk continues, identified BIM as the central issue in using IT for a more efficient construction industry and brought together most of the Finnish industry key players to develop a roadmap. Mitchell et al, 2012 (cited in [6]) emphasised that Finland, nowadays, requires the use of BIM for government procurement and is seen as the BIM leader of Europe as stressed by Oy, 2014 (cited in [6]).

Trafikverket, 2013 (cited in [6]) stated that Sweden has paralleled the steps of Finland and also initiated concerted efforts to increase a nation-wide implementation of BIM. This led to the launch of the non-profit organisation OpenBIM (now BIM Alliance) in 2009 to establish BIM standards in Sweden. Public organisations such as the Swedish Transport Administration (Trafikverket) also mandated the use of BIM from 2015 as part of their nation-wide efficiency program as highlighted by Albertsson and Nordqvist, 2013 (cited in [6]).

International experience shows that: (i) industry takes action when the government demonstrates clear leadership; (ii) a national strategy facilitates the adoption of new information technologies such as BIM; and (iii) collaboration with industry is required to implement this strategy [6].

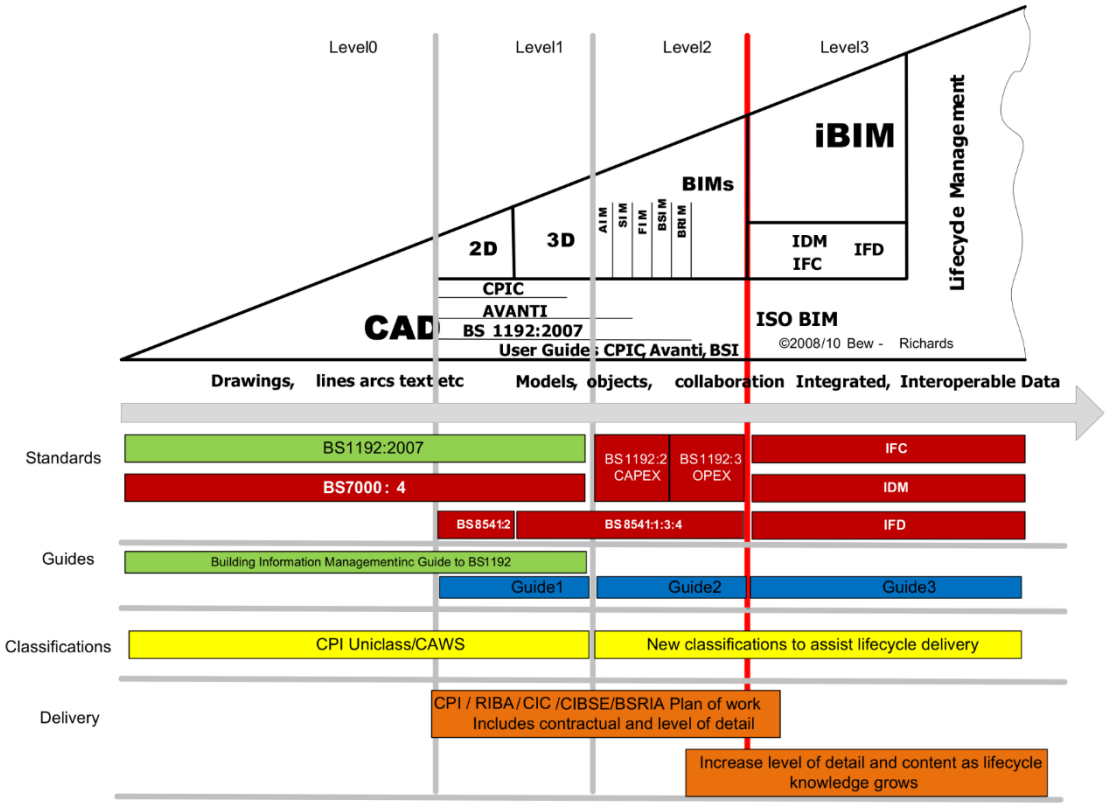

Figure 3. BIM roadmap for the UK [7]

5.2. National Perspective

Australia is experiencing an era of strong enquiry and activity around BIM and integrated project delivery throughout the construction industry. Initiatives include:

- Joint Australian Construction Industry Forum (ACIF) and Australasian Procurement and Construction Council (APCC) and Australasian BIM Advisory Group (ABAB) work including: *Creating Added Value from Construction: The Case for Project Team Integration* (2012); and the *Project Team Integration Workbook* (2014).
- ACIF's (2014) Policy Compendium publication in which they state: *ACIF believes that government, as a major client, has a responsibility to provide policy leadership in the adoption of new technologies and private sectors must coordinate the adoption of new technologies such as Building Information Modelling (BIM) in an orderly and consistent fashion*.
- Mitchell et al, 2012 (cited in [6]) highlighted that buildingSMART initiatives including the 2012 *National Building Information Modelling Initiative* and their reports to the Australian Department of Industry, Innovation, Science, Research and Tertiary Education on strategy.
- SBEnrc projects including Project 2.24 Integrated Project Environments – Leveraging Innovation for Productivity Gain through Industry Transformation; Project 2.34 - Driving Whole-of-life Efficiencies through BIM and Procurement; Project 2.46: Whole-of-life Value of Constructed Assets through Digital Technologies and National BIM Guidelines for Infrastructure delivered through SBEnrc Project 3.28 [17].
- Standards Australia activity including a review of *General Conditions of Contract* and considerations about a *BIM Addenda*. Published papers include: *The Economic Benefits of Standardisation* (2013); and *the Value in Governance of Information Technology* (2012).
- The Australian Department of Infrastructure and Regional Development (2014) report *Trends Infrastructure and Transport to 2030* (cited in [6]), in which they state that: *Smart*

infrastructure in the form of digital technologies will provide opportunities to improve productivity and contribute to sustainability (Department of Infrastructure and Regional Development, 2014).

- NATSPEC, 2013 (cited in [6]) has: (i) developed an on-line BIM Portal; (ii) the *National BIM Guide* (2011) to *assist clients, consultants and stakeholders to clarify their BIM requirements in a nationally consistent manner*; and (iii) NATSPEC, 2014 (cited in [6]) created, as well, a repository of Australian R&D projects currently being developed around BIM.
- The *Australian Government Productivity Commission* report, 2014a (cited in [6]) makes some specific recommendations in this area including:
  - *The 'early contractor involvement model' should be trialled to test the costs and benefits of applying past contract performance by tenderers as a means of constructor selection, consistent with the practices of some private sector clients.*
  - *For complex infrastructure projects, government clients should provide concept designs using Building Information Modelling (BIM) to help lower bid costs, and require tender designs to be submitted using BIM to reduce overall costs. Governments should give serious consideration to where in their best practice guides they may specify the use of BIM.*
- Austroads, ARRB and APCC co-sponsored the *Building and Construction Procurement Guide – Principles and Options* which highlights the use of BIM for high-performing teams and an increasing trend towards more collaborative models observed across Australia as highlighted by Casey and Bamford, 2013 (cited in [6]).
- The Sustainable Built Environment National Research Centre (SBEnrc) has developed a pilot on Interoperable Object Libraries that establishes a library of generic objects, accessible by the three major BIM tools in the Australian market intended to demonstrate a national solution for industry access to building product data [8].

In addition to the above, Trewin, 2002 (cited in [6]), states that the Australian Bureau of Statistics (ABS) has established information and communication technologies, such as BIM, as one of the three core dimensions of knowledge-based economies (Trewin, 2002). It has also been argued that the way in which countries *master and use these technologies "is the key to their future economic performance"* as highlighted by Ofori, 2002 (cited in [6]).

In early 2014, the Australian Government Productivity Commission, 2014a (cited in [6]) made a series of recommendations to the infrastructure industry where Building Information Modelling (BIM) and models with early contractor involvement were featured. Among other things, this report highlighted that: (i) there is a *widespread view that there was scope for more innovation and diffusion of new technologies in the industry;* (ii) *given the potential savings from BIM, government clients should consider* the use of BIM from early design stages; and (iii) *while it is in governments' best interests to pursue these reforms, it can hardly be said that reform has proceeded either apace or uniformly throughout Australia,* hinting to the need for a more efficient nation-wide strategy.

5.3. State of Victoria Perspective

The Victorian Government, in its 2015-16 Budget, provided for the development of a process of selecting key infrastructure projects to participate in a BIM pilot study. The Victorian Government will then use the results of the pilot study to inform a staged plan for BIM implementation across infrastructure projects in the state [9].

The Victorian Government is committed to advance the use of BIM which will position Victoria as a leading user of BIM to strengthen construction outcomes, improve asset management, stimulate innovation, and build competitiveness in domestic and overseas

markets. This will be achieved by developing a plan with industry to provide for the greater uptake of BIM through establishing an expert group comprising industry representatives, public and private sector procurers and key research organisations. The plan will establish a sensible but ambitious timetable for the greater uptake of BIM. It will also position Victorian industry to embed BIM in construction and asset management processes, and to realise benefits beyond government projects. The plan will also give specific attention to any potential impediments for progressing BIM, including in relation to the availability of comprehensive BIM protocols and standards, issues associated with legal and insurance matters and adoption costs for SMEs.

The Victorian Government is also keen on building expert skills in BIM. This will be founded on a collaborative approach to BIM education and training involving industry, the private section and the education sector.

Additionally, and as part of the plan, the Victorian Government will capitalise on digital technologies by attracting capability and promoting Victoria as the national hub for digital innovation for the construction industry by building and strengthening networks and incubators to support emerging Victorian digital technology firms with construction industry products. This will include sponsoring an annual flagship conference in Melbourne for digital technology companies and start-ups that produce apps, software, and digital solutions for the construction industry [10].

6. VicRoads DE Strategy – Potential Pathways

This chapter outlines SBEnrc's workshop, questionnaire and interview with VicRoads personnel as well as a parallel with TfNSW's strategy and approach to DE/BIM. The chapter then examines three VicRoads traditional projects and the financial savings if DE/BIM was to be used in these projects.

6.1. SBEnrc Workshop and Questionnaire

On 3 February 2017 a workshop titled "Digital Engineering for Linear Infrastructure", under the auspicious of SBEnrc, was run for VicRoads jointly with Transport for NSW (TfNSW). The presentation addressed the increasing use of Building Information Modelling (BIM) and Digital Engineering (DE) across the world and within Australia, and presented an overview of the TfNSW digital engineering strategy. Part of the workshop was a questionnaire survey for those who attended the workshop. This survey addressed the increasing use of Building Information Modelling (BIM) and Digital Engineering (DE) across the world and within Australia, and presented an overview of the emerging TfNSW digital engineering strategy. Additionally, the survey aimed to increase awareness of the benefits and outcomes of DE among VicRoads staff and generate discussion about the future use of DE within VicRoads. Full details of the questionnaire and its analysis can be found in Appendix 1.

6.2. Interview with VicRoads Senior Management

On 4 August 2017, two VicRoads Senior Managers were interviewed by a SBEnrc Researcher. The aim of the interview was to better understand VicRoads' plans for transforming to DE/BIM.

The interviews showed clear interest and commitment of VicRoads' senior management to developing a DE/BIM strategy and keenness to transfer the organisation to the digital world. The intention was to ideally have VicRoads' at the forefront of using technology in asset management in 5-10 years. It was stated that DE/BIM is one of the top five priorities among VicRoads leadership. There was no DE/BIM strategy in place yet.

As of now, VicRoads have not used DE/BIM in any of its completed projects. The first project to have DE/BIM requirements is the West Gate Tunnel Project commenced in 2017. VicRoads has started to use asset management standards such as ISO 55000 (2014) and is currently undergoing a self-assessment to understand what level of investment of time and money they need and ultimately put in place an action plan to close the gaps. This will be followed by a maturity assessment.

VicRoads uses numerous software packages throughout its operations, which are not consistent across the organisation/regions. The VicRoads IT Department is normally in charge of these systems. However, VicRoads are working on refining the system towards an enterprise asset management system (EAM), where governance around the system is being established. It will serve as a central platform for anyone who makes decisions.

In the interviews, a number of words emerged highlighting the translation of what DE/BIM means from VicRoads point of view. These words are:

- Value
- Investment
- Single platform
- Data for decision making
- Improve handing-over process
- Better value across project life-cycle

These words are consistent with benefits of DE/BIM.

6.3. Transport for NSW DE Strategy Approach

Transport for NSW (TfNSW) is currently embarking on a significant 'once-in-a-generation' program of infrastructure development and renewal throughout NSW. In addition, it is moving rapidly to be at the forefront of emerging transport technologies. There are currently a number of major business improvement initiatives underway to optimise how the NSW Transport Cluster will operate to meet the increasing expectations of their customers [1].

TfNSW are at the beginning of a long process using a two staged approach (TfNSW estimate that fully transitioning to DE will take around six years), to develop the Transport for NSW Digital Engineering Framework (DEF) Project as a step towards alignment and integration across the cluster.

Given that both organisations serve in the field of roads and infrastructure, VicRoads can benefit from TfNSW's approach to developing their DEF Project. The steps TfNSW have taken can serve as an initial roadmap for VicRoads towards defining their digital strategy. However, it is important to keep in mind that organisations have different cultures, systems and processes. So, what works in one organisation might not readily work in the other. Despite that, TfNSW's is a good example of a methodological approach to defining a strategy; in particular a digital change strategy.

Below, in brief, are the steps TfNSW's have undergone to develop their DEF Project:

a- Interviews with senior NSW Transport Cluster personnel over three days of interviews in March/April 2016.
b- Following these interviews, a survey was distributed to the supply chain.
c- A questionnaire was issued to staff on existing TfNSW projects that are using BIM and DE.

d- Numerous TfNSW documents were also provided for a desktop review, which included previous studies by TfNSW to define a strategy for the use of DE across the Transport Cluster.

TfNSW, and as part of their DE journey, have also listed a number of governmental best practices in asset management across the world to explore international approaches in DE/BIM. Appendix 2 lists these best practices. It shows governments are at different stages in BIM planning and implementation and highlights that it is a complicated journey.

Additionally, the report highlights a number of key elements of global best practice as follows:

1. Develop a structured, appropriate to agency maturity and project scale implementation plan with nominated people to support the transition and ongoing data management.
2. Communicate the change programme to industry, customers and staff with adequate time for them to up-skill.
3. Enable a benefits realisation tracking approach and return on investment to provide evidence of savings and benefits.
4. Create standardised information requirements based on business needs and include these as contractual requirements. This will ensure integration of CAPEX and OPEX[2].
5. Enable collaboration around a common data environment where up-to-date information is readily available for decision making.
6. Align approach to DE with developing national and international standards.
7. Focus on open data formats, classification systems and interoperability within and across agencies.
8. Develop a standardised object library to enable consistency and reduce the implementation costs for all tiers of the supply chain.
9. Provide staff with the ability to interact with DE information through model viewers. The more familiar they become, the more they will define the use cases of DE information.
10. Integrate DE with existing and future systems such as data analytics and mobile technologies. The technology should support the business need, not drive it.

6.4. Use of BIM in Completed VicRoads Projects

There are numerous benefits from implementing BIM for the whole life cycle of a project. The table below illustrates the benefits of DE/BIM throughout the project phases [12].

[2] CAPEX: Capital Expenditure
OPEX: Operational Expenditure

No.	Benefit	Project Phase				
		Planning & Strategy	Development	Design	Construction & Commissioning	O&M
	Productivity					
1	Reduction in time responding to RFI	X	X	X	X	X
2	Reduction in time spent searching and assessing information	X	X	X	X	X
3	Reduction in data verification	X	X	X	X	X
4	Reduction in variations		X	X	X	
5	Faster programming/Improved more effective scheduling		X	X	X	
6	Better scenario analysis and optimisation of construction sequence, enabling overall faster project delivery		X	X	X	
7	More efficient reporting on project progress and performance	X	X	X	X	
8	Minimise duplicative efforts	X	X	X		
9	Reduced tender and design review time	X	X	X		
	Capital Costs					
10	Reduction in rework		X	X	X	X
11	Reduction in in the quantum of contingency costs that D&C contractors build in to their price to cover risk due to error; DE allows Design and Construct of the project virtually, and to identify and eradicate errors before doing the physical work on site.		X	X	X	
12	Reduced waste due to reduction in errors	X	X	X	X	X
	O&M costs					
13	Better safety and crisis management through information accessibility and virtual scenario training.					X
14	More accurate planned maintenance through better analysis of network asset performance and being able to predict failures and take preventative actions that improve levels of service and lowers costs.					X
15	Lower operational costs through improved asset utilisation					X
16	Lower operational costs through more efficient asset management and improved identification and evidence based prioritisation of maintenance and renewal spend, with outcomes able to be quantitatively measured.					X
17	Reduction in time spent addressing asset failures					X
18	Seamless transfer of asset information, minimising manual processing					X
19	Better change control of asset configuration and greater traceability of asset history					X
20	Potential for 3D printing of replacement components, creating on-going savings and driving efficiencies.					X
	Societal Benefits					
22	Improved safety - automated exclusion zones, fatigue management, less reliance of manual labour				X	X
23	Increased productivity right through the asset life cycle will reduce Totex (total expenditure) which will allow the same dollar spend to go further and therefore achieve improved customer outcomes.					
	Intangible					
24	Enhanced reputation	X	X	X	X	X
25	Reduction in knowledge loss	X	X	X	X	X

6.4.1 BIM Value Benchmarking Tool

SBEnrc have developed the BIM Value Benchmarking Tool (BVB) which is freely available on their industry partner NATSPEC's website. BVB is a online tool for collecting project information and assessing the value of benefits delivered by BIM. By comparing a specific project performance with data collected from many BIM and non-BIM projects, project owners will be able to assess the relative value of using BIM. A number of metrics have been assigned to the tool for projects to benchmark against. These are contract sum variation, cost of project, number of RFIs, duration of project, number of clashes in construction, client satisfaction with project, safety incident rate and sustainability.

The intention was to insert data sets from completed VicRoads projects into the tool and benchmark it against other BIM and non-BIM projects. However, the tool was only recently launched and a sufficient number of organisations are yet to enter data points in the tool. Assessment using the SBEnrc BIM Value Benchmarking Tool can be done in the future when sufficient data sets are present in the tool.

6.4.2 VicRoads Projects

Three data sets relating to completed components of the Melbourne M80 Ring Road project were analysed. Those are Calder to Sydney, Western to Sunshine, and Edgars to Plenty.

In each of these three projects, and upon consulting with VicRoads, a number of variations were selected depending on the scope of works and its relevance to whether the existence of DE/BIM may have made a difference if it was used at the beginning of the project. Three metrics were extracted out of the nine BIM Value Benchmarking Tool metrics. These metrics were indicated depending on the significance highlighted through the interviews with VicRoads' Senior Management. The three metrics that were selected were "duration of project", "number of RFIs" and "number of clashes in construction". Various percentages were assigned for each metric and task/variance based on significance and importance to VicRoads. The highest percentage metric amongst the three was selected to come up with the estimated savings under this exercise.

It is worth mentioning that TfNSW Conceptual Business Case [12] concluded an estimated weighted average of annual cost savings at approximately 1.7%. Given the similar nature of business for both organisations, TfNSW and VicRoads, it is recommended that the estimated 1.7% factor be used to derive potential annual savings in VicRoads' future projects if DE/BIM was to be used.

It should be noted that there may have also been other additional costs incurred on the Calder to Sydney project for which DE/BIM may have made a difference, however due to the nature of the Alliance Contract Agreement these are not easily identified as they may have been shared by the Alliance partners within the Total Out-turn Cost (TOC).

Project # 1: Calder to Sydney

1- Project overview
   a. Project Scope
      Calder Freeway to Sydney Road (10.7 kilometres). Widening the central median and shoulders to provide at least three lanes in each direction, upgrade interchanges at Tullamarine Freeway and Sydney Road, upgrade the Jacana Underpass Tunnel, and widen the bridges at Tullamarine Freeway Interchange, Merlynston Creek and Sydney Road.

The Tullamarine interchange was redesigned to add new lanes and create grade-separated movements for the Pascoe Vale Road exit. This was done to ensure design volumes were catered for and to allow for weave movements in the area. More extensive traffic management and additional ITS infrastructure was required to cater for these changes.

The scope was also changed as a result of geotechnical investigations undertaken. Extra earthwork was required and additional bridgeworks was needed to provide structural safety.

Other changes included adjustments to the urban design to align with the M80 strategy, the use of barriers rather than parts of the planned earthworks, and additional work at Sydney and Camp Roads to cope with queuing issues at the Sydney Road on and off ramps.

b. Project commencement date
10/12/2009

c. Project completion date
28/05/2013

d. Type of Contracting
Alliance Agreement

e. Total contracting figure (Final)
$623,096,401

f. Project Duration (Final)
3 years and 6 months

2- Project Variances related to DE/BIM point of view

No.	Variation Brief Description	Amount
1	Asbestos and contaminated brick removal in Zone 40	$4,172,798
	Variations Total	**$4,172,798**
	% of total project value	**0.67%**

Potential savings if DE/BIM is used:

Calder to Sydney	
Asbestos and contaminated brick removal in Zone 40	$4,172,798
Percentage of "**Duration**" metric	60%
Percentage of "**RFI**" metric	20%
Percentage of "**No. of clashes**" metric	20%
Savings (4,172,798 x 60%)	$2,503,679
Total Savings in Variations	**$2,503,679**

Project # 2: Edgars to Plenty

1- Project overview

a. Project Scope

Edgars Road to Plenty Road (4.7 kilometres). The approved scope for the upgrade of the M80 Ring Road between the Edgars Road and Plenty Road included widening of the centre median and shoulders to achieve at least three lanes in both directions, with one or two auxiliary lanes between intersections for the 4.7km roadway.

The scope was changed to include upgrade works to spirally wound pipes in the M80/Hume Freeway interchange. This was required as investigations determined the three sets of pipes were reaching the end of their design life. To remediate this issue, the main contractor undertook work to install a new composite lining in the pipes.

Further minor adjustments included works initially overlooked in the contract or changes to VicRoads requirements post contact award. These changes include fall protection, additional resurfacing, strengthening works, yellow line marking, asbestos removal, changes to requirement for road safety features and pit covers, further traffic management and upgrade of existing public lighting infrastructure. An additional traffic control gantry was also required as the existing one was found not to be structurally sound for the new application.

b. Project commencement date
11/12/2011

c. Project completion date
03/04/2014

d. Type of Contracting
Lump Sum Design and Construct

e. Total contracting figure
$112,527,878

f. Project Duration
2 years and 3 months

2- Project Variances related to DE/BIM point of view

No.	Variation Brief Description	Amount
1	Pavement rehabilitation works	$3,877,950
2	Plenty Road bridge strengthening works	$618,100
3	Asbestos located at east of Tasman Drive Bridge	$132,000
4	Upgrade existing street lighting wiring	$211,633
	Variations Total	**$4,839,683**
	% of total project value	**4.3%**

Potential savings if DE/BIM is used:

Edgars to Plenty	
Pavement rehabilitation works	$3,877,950.41
Percentage of "**Duration**" metric	0%
Percentage of "**RFI**" metric	50%
Percentage of "**No. of clashes**" metric	50%
Savings (3,877,950 x 50%)	$1,938,975
Plenty Road bridge strengthening works	$618,100.00
Percentage of "**Duration**" metric	0%
Percentage of "**RFI**" metric	50%
Percentage of "**No. of clashes**" metric	50%
Savings (618,100 x 50%)	$309,050
Asbestos located at east of Tasman Drive Bridge	$132,000
Percentage of "**Duration**" metric	30%
Percentage of "**RFI**" metric	35%
Percentage of "**No. of clashes**" metric	35%
Savings (132,000 x 35%)	$46,200
Upgrade existing street lighting wiring	$211,633
Percentage of "**Duration**" metric	0%
Percentage of "**RFI**" metric	50%
Percentage of "**No. of clashes**" metric	50%
Savings (211,633 x 50%)	$105,816
Total Savings in Variations	**$2,399,241**

Project # 3: Western to Sunshine

1- Project overview

a. Project Scope

Western Highway to Sunshine Avenue (6.2 kilometres). Widening the central median and shoulders to provide at least three lanes in each direction and widen the bridges at the Western Highway Interchange, Jones Creek, St Albans Road and Furlong Road Interchange.

Changes were made to ITS, street lighting and signage to conform to VicRoads requirements, which were not confirmed at time of tender. This included changes to ramp meters and RC3 signs, as well as additional costs to design and install gantries as required. Structural changes were also made, with the originally designed bridge barriers not meeting VicRoads requirement. However these specifications were not made clear at time of tender so additional costs were added to the project. Drainage

design was also changed, with the contractor having to excavate additional pavement due to drawing errors.

This package of works will increase capacity, improve travel times and reliability for freight and passenger movement and address the safety issues identified.

b. Project commencement date
29/09/2010

c. Project completion date
19/08/2013

d. Type of Contracting
Lump Sum Design and Construct

e. Total contracting figure
$157,442,282

f. Project Duration
2 years and 11 months

2- Project Variances related to DE/BIM point of view

No.	Variation Brief Description	Amount
1	Asphalt patching on the existing pavement to a depth of 100mm	$359,242
2	Sunshine Tip claim	$4,250,000
3	Additional profiling and asphalt works between Tilburn Road and Western Highway	$1,869,958
4	Additional profiling and asphalt works between Western Highway and Furlong Road	$2,352,929
5	Additional works undertaken to complete sub soil drainage (SSD) works between Tilburn Road and Furlong Road	$1,057,760
	Variations Total	**$9,889,891**
	% of total project value	**6.28%**

Potential savings if DE/BIM is used:

Western to Sunshine	
Asphalt patching on the existing pavement to a depth of 100mm	$359,242.76
Percentage of "**Duration**" metric	0%
Percentage of "**RFI**" metric	40%
Percentage of "**No. of clashes**" metric	60%
Savings (359,242.76 x 60%)	$215,545
Sunshine Tip claim	$4,250,000
Percentage of "**Duration**" metric	0%
Percentage of "**RFI**" metric	40%

Percentage of "**No. of clashes**" metric	60%
Savings (4,250,000 x 60%)	$2,550,000
Additional profiling and asphalt works between Tilburn Road and Western Highway	$1,869,958.62
Percentage of "**Duration**" metric	0%
Percentage of "**RFI**" metric	20%
Percentage of "**No. of clashes**" metric	80%
Savings (1,869,958.62 x 80%)	$1,495,967
Additional profiling and asphalt works between Western Highway and Furlong Road	$2,352,929.02
Percentage of "**Duration**" metric	0%
Percentage of "**RFI**" metric	20%
Percentage of "**No. of clashes**" metric	80%
Savings (2,352,929.02 x 80%)	$1,882,343
Additional works undertaken to complete sub soil drainage (SSD) works between Tilburn Road and Furlong Road	$1,057,760.63
Percentage of "**Duration**" metric	30%
Percentage of "**RFI**" metric	30%
Percentage of "**No. of clashes**" metric	40%
Savings (1,057,760.63 x 40%)	$423,104
Total Savings in Variations	**$6,566,959**

7. Conclusions

The concept of the *digital twin* 'build virtually then build actually' has been a key driver in research and process innovation within the AECO[3] industry for the last 20 years. After many years of research, testing and incremental uptake, this concept is now being realised under the banner of virtual design and construction (VDC) [14]. The global financial recession has highlighted the importance of improving productivity and finding new ways to do business in the industry. BIM has contributed to that dialogue by supporting efforts to collaborate and use strategies like prefabrication, as well as to reduce inefficiencies that continue to plague the design and construction industries [15].

VicRoads is on the right track to transform its operations to the digital era. Although, this is a complex change management process in a long standing organisation with its own embedded culture, the steps that VicRoads have put in place can be seen as appropriate ones. Any change within an organisation, whether technical or strategic, cannot strive without the backup of the organisation's leadership team and this is a clear element in VicRoads' case. The leadership's buy-in has led to establishing the 'The Asset Management Transformation Team' that is responsible to put in place a digital strategy for VicRoads.

For VicRoads vision, transitioning to digital asset management (DE/BIM), to move ahead in the right direction a dissemination strategy needs to be in place. A research report by SBEnrc proposes a three-tiered dissemination strategy to build understanding of BIM and the requisite skills upgrade required within the industry. In the report "Reducing the Skills Gap" [16] laid down three main tiers (i) Tier 1 - Government Decision Makers, where its 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, (ii) Tier 2 - Mid-level Strategic Decision-makers, where its target audience is government program directors and industry leaders and (iii) Tier 3 - Project and Program Delivery, where its target audience is industry professionals and SMEs.

[3] AECO: Architecture, Engineering, Construction and Owner-operated

The case has discussed the presence of DE in three completed traditional VicRoads projects. It has speculated that if DE/BIM was used effectively from the beginning of the project, significant estimated savings in variations could be achieved by avoiding re-work and detecting problems from an early stage. Estimated prospective savings from all the three M80 projects, and from a DE/BIM point of view, is $11,469,878.

There is a positive level of awareness among VicRoads professional staff in regards to the importance of moving from where they are, doing things in a traditional way, to where they should be, integrating their processes and whole-of-life approach into digital. A long and inevitably complex journey is ahead for VicRoads to move to the next level. However, the right spirit, leadership commitment and planning are in place to achieve this outcome.

Appendix 1

VicRoads Digital Engineering Questionnaire Analysis

Case Study 1: Adopting digital engineering: Managing disruption to people, processes and procurement TfNSW and VicRoads developing digital engineering strategies

The research described in this report was carried out by Paul Akhurst, Jessica Brooks and Ross Smith

Project Leader: Keith Hampson (SBEnrc)

Team Members: Paul Akhurst (Curtin University)

Jessica Brooks (Griffith University)

Ross Smith (Curtin University)

Project Affiliates: Chris Coghlan (VicRoads)

Simon Vaux (TfNSW)

Research Project No.: 2.46

Project Name: Whole-of-life Value of Constructed Assets through Digital Technologies

Date: 24 April 2017

EXECUTIVE SUMMARY

The report analyses responses to a survey of 11 VicRoads staff who attended a workshop on digital engineering. Overall the responses to the concept of digital engineering were very positive and participants indicated a good understanding of the potential usefulness of digital engineering. However, the level of skills and knowledge was found to be very variable. There was a strong belief that successful implementation of digital engineering will depend on the leadership of senior management and creation of a dedicated implementation team. It was found that respondents are somewhat overwhelmed by the variety of software used by VicRoads for asset management and operations. There may be benefit in VicRoads establishing a small project to identify all the software that it uses, which could lead to consolidation through DE implementation or other changes. In summary, provided that the concerns for staff regarding leadership and resourcing are addressed there is good support for the implementation of digital engineering at VicRoads.

INTRODUCTION

On 3 February 2017 a workshop, “Digital Engineering for Linear Infrastructure”, under the auspices of SBEnrc Project 2.46, Case Study 1, was administered for VicRoads and presented by Keith Hampson, Paul Akhurst (both SBEnrc/Curtin University) and Simon Vaux (TfNSW). The presentation addressed the increasing use of Building Information Modelling (BIM) and Digital Engineering (DE) across the world and within Australia, and presented an overview of the TfNSW digital engineering strategy. The aim of the workshop was to increase awareness of the benefits and outcomes of DE among VicRoads staff and generate discussion about the future use of DE within VicRoads. Recognising the importance

of digital engineering to the future procurement of linear transport VicRoads had approached SBEnrc about conducting a workshop and study under the auspices of Project 2.46. This report details the findings from a questionnaire survey of those who attended the workshop.

QUESTIONNAIRE

Participants were asked to complete and return the questionnaire at the start of the workshop. This avoided any bias that might be caused by information provided during the workshop and subsequent discussions. In total, 11 participants completed the questionnaire. All participants were involved in roles within VicRoads where DE was relevant and potentially useful. The participant pool was specifically chosen by VicRoads to represent a diverse cross-section of employees who will be affected by DE in the future.

In order to provoke thoughtful responses and avoid automatic answers, the questions were designed to require either a positive or negative answer using a scale of 1-5 to indicate strength of feeling. The questions can be grouped into four categories for analysis; however they were presented randomly in the questionnaire given to the participants. The categorisation of the questions are summarised below in Table 1.

Category	**Questions**
Current Practices	Q15, Q22, Q23 and Q28
An Australian Perspective of DE	Q10, Q13, Q17, Q18 and Q21
Personal Experience of DE	Q1, Q2, Q5, Q16, and Q27
Personal Perceptions of DE	Q3, Q6, Q8, Q9, Q11, Q19 and Q25
Implementation Readiness for DE	Q4, Q7, Q12, Q14, Q17, Q20, Q24, Q26 and Q28

Table 1: Categorisation of questionnaire questions

The questions are typically qualitative by their nature and the data pool is small however the highly targeted nature adds to the relevance of the responses. Of the 28 questions, participants answered 27 by indicating their level of agreement on a scale of 1 – 5 (1 = strongly agree; 5 = strongly disagree). Question 29 required participants to indicate the number of software packages that VicRoads currently operates. A complete list of questions is included in the sample questionnaire found in the Appendix to this questionnaire report.

RESULTS and DISCUSSION

The data was processed by taking the scores on a scale of 1 (agree) to 5 (disagree) and correlating them to a new scale of 1 (a sub-optimal outcome) to 5 (an optimal outcome). This involved determining polarity; if agreeing to the question was a positive outcome its polarity was reversed and if agreeing to the question was a negative outcome the polarity was left unchanged. Questions with reversed polarity can be distinguished by an asterisk (*) in the graphs below. To execute this, the answer was subtracted from 6 to reverse its polarity (with a score of three taken as neutral). In the following graphs the outer axis represents each respondent with a number. The vertical axis records

each score in which 1 is a sub-optimal result and 5 is an optimal score. Thus the further a plot towards the outside of the graph the stronger the optimal outcome in response to the questions.

VicRoads Current Practices

Responses to questions about current practices were generally negative. These are summarised in Figure 1. Participants indicated that it is common for projects to be delayed because of design errors and to incur additional costs. With the exception of three participants, it was indicated that VicRoads has clearly established requirements for as-built information and structured asset data. Despite this, it was indicated that there are issues with the quality of as-built information that is received. This is significant in terms of adopting DE as the potential benefits include less rework due to design errors and more complete asset information.

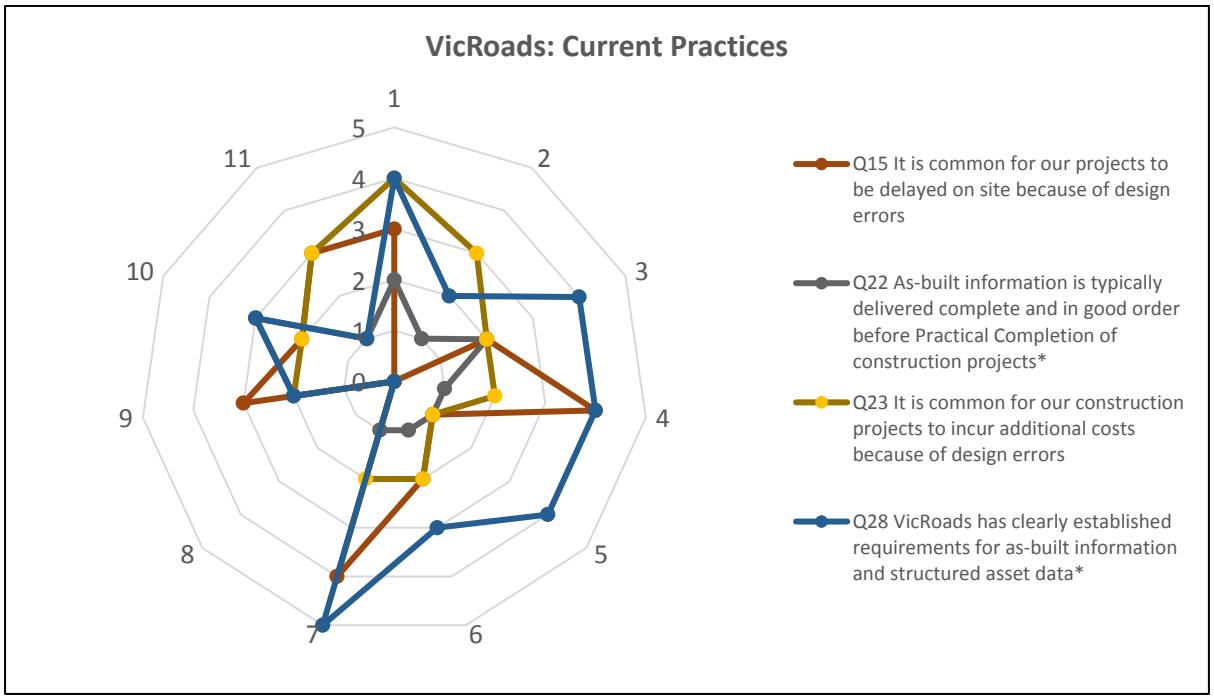

Figure 4. VicRoads: Current Practices

An Australian Perspective of Digital Engineering

There was a disparity between responses when participants were asked if DE is still in its infancy and VicRoads should wait to implement it; some participants felt that this is true and others indicated a strong belief that this is not true. There was a similar disparity about whether national guidelines are needed before VicRoads implements DE, with some participants agreeing and others disagreeing to this statement. The disparity in these results could be related to feelings of readiness to implement DE and lack of knowledge about DE.

It was generally agreed that VicRoads is not ahead of other states in terms of DE implementation. Participants gave neutral responses about whether wide-spread adoption of DE in Australia is many years away. There was also a strong to moderate belief that each state and territory should not develop their own approach to DE. This could indicate that participants would prefer national guidelines or to develop guidelines specific to their organisation. This information is summarised in Figure 2.

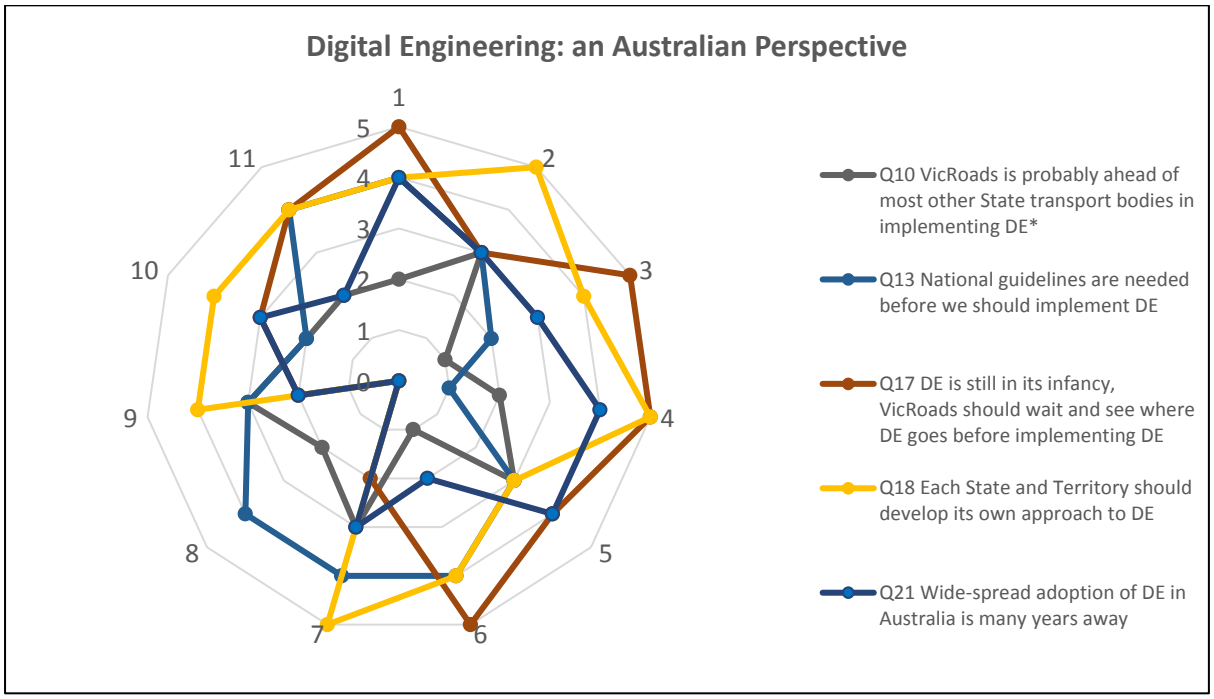

Figure 5. Digital Engineering - An Australian Perspective

Personal Experience of Digital Engineering

There was some disparity in responses to questions regarding personal experience with DE. These responses are summarised in Figure 3. With the exception of three participants, the responses indicated that the participants were excited about the challenge of implementing DE. This could be explained by some participants indicating experience and knowledge working with DE and therefore have already implemented it in their area. Other participants indicated an awareness of their lack of knowledge and experience working with DE. In this case, this enthusiasm could indicate a willingness to learn more about DE and to support the implementation of DE.

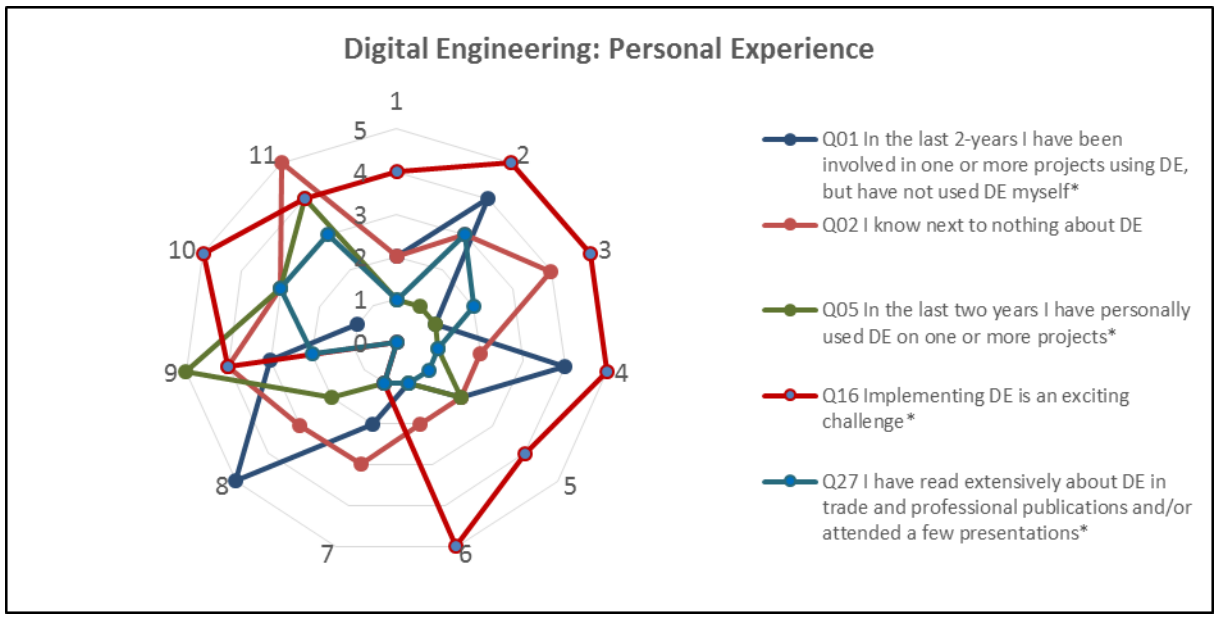

Figure 6. Personal Experience

Personal Perceptions of Digital Engineering

Responses in the Personal Perceptions section were varied. These are summarised in Figure 4. Some participants indicated a desire to learn more about DE before feeling ready to implement it in their area of responsibility. Others indicated the opposite, that they did not feel unprepared to implement DE. This suggests that there is an uneven spread of knowledge and experience of working with DE amongst the participants. Overall, participants indicated a good understanding of the potential usefulness of DE and its differences from Building Information Modelling (BIM).

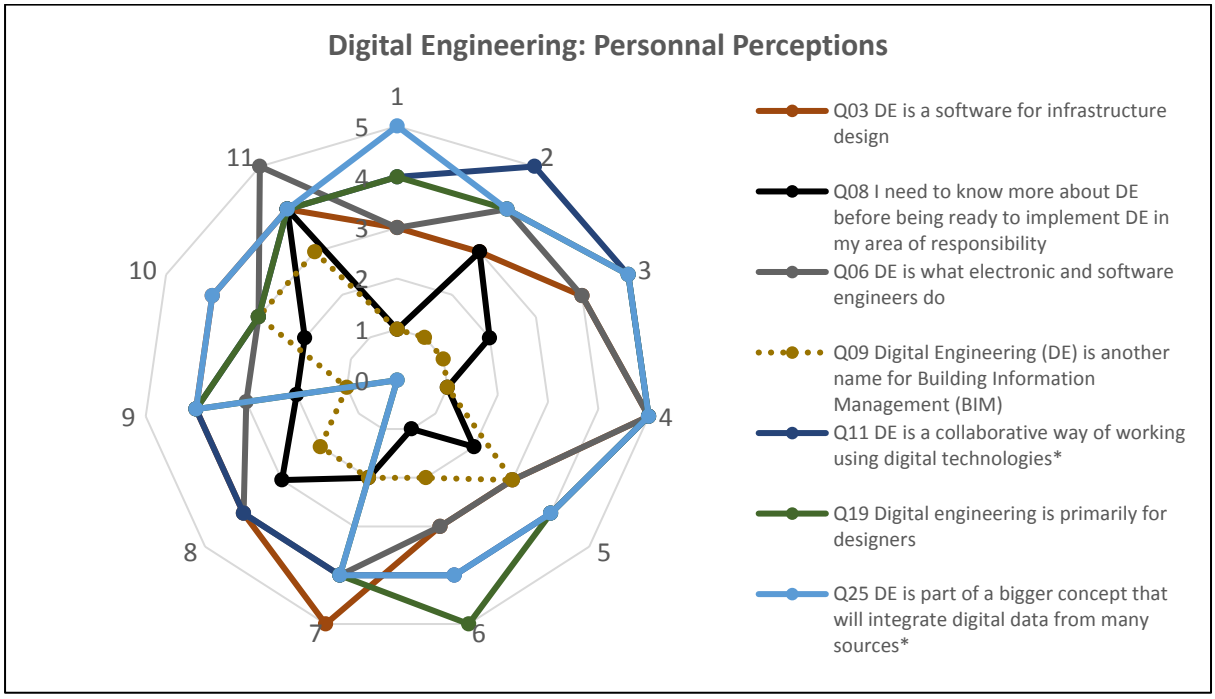

Figure 7. Personal Perceptions of Digital Engineering

Implementation Readiness for Digital Engineering

Overall, the responses indicated that the participants shared similar ideas on how DE could be successful implemented and issues that may arise. These responses are summarised below in Figure 5. This is a positive outcome as this suggests that any tactics to implement DE that appreciate these ideas are likely to be successful. Responses indicated a very strong belief that successful implementation of DE will depend on the leadership of senior management. Similarly, there was a strong to moderate belief expressed that a dedicated team is required to create and implement DE policies and procedures.

There is uncertainty that all VicRoads staff have the necessary skills and knowledge to implement DE; some participants indicated they that they were confident in their skills and knowledge while others indicated they were not. The responses also suggest that participants are not confident in the preparedness of consultants or the readiness of other staff for DE. There was also a strongly-belief held by several participants that the implementation of DE will be stymied by lack of resources. This obstacle is a very relevant concern of participants; however it is not insurmountable if it is taken into account when considering the implementation of DE.

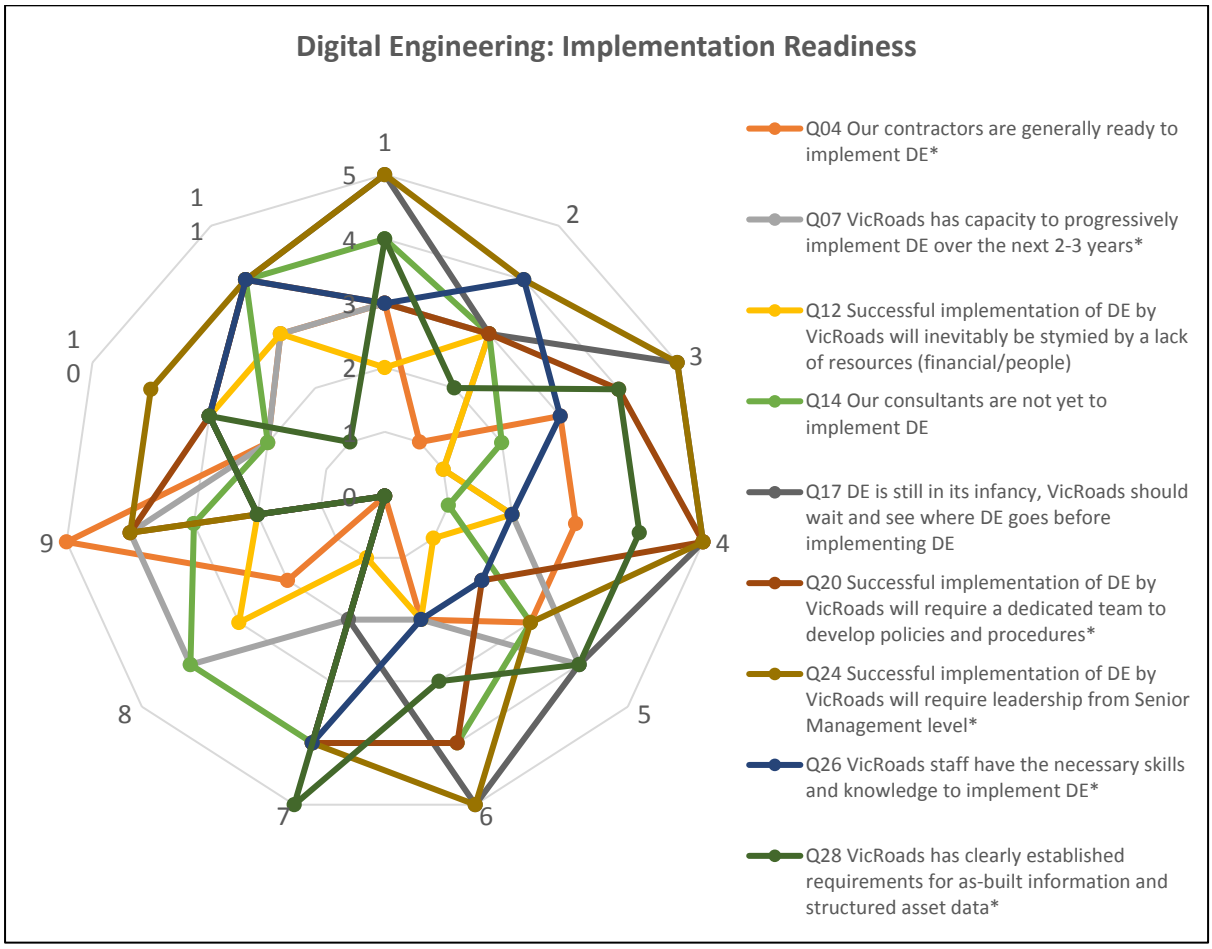

Figure 8. Digital Engineering - Implementation Readiness

Software Packages used by VicRoads

Respondents were asked to estimate the number of different software packages VicRoads uses to design and operate the road network. This may give an indication of the complexities involved in introducing a common, structured, approach to digital information management such as DE.

Not all participants responded to the final question (Q29) on the questionnaire. This was the only open question and asked participants how many software packages VicRoads currently uses. Only six participants responded with a number and these numbers varied from “3-5” to “25”, with the median number being 20 software packages. As this was the only question not regularly answered, this suggests that participants may not have felt confident or informed enough to even suggest a number. Other notable responses were “too many”, a question mark (?) and an infinity symbol (∞), suggesting that some participants felt confused or overwhelmed by the number of software packages being used.

Given the vagueness of the responses to this question there may be value in VicRoads conducting a small project to establish exactly how many different software packages it uses, how the data is structured in each and to what extent data can be easily integrated between software packages. This may allow some streamlining of data management practices and provide a foundation from which to consider the implementation of DE. SBEnrc Project 2.46 Case Study 3 and SBEnrc Project 2.51 may be relevant here as they are addressing a similar question applied data sets for digital asset information management.

CONCLUSIONS

It was anticipated that knowledge regarding DE would be limited as it is not widely used by all staff at VicRoads. While this was true of some participants, it is evident that other participants were confident and knowledgeable about DE. These staff could be very helpful to VicRoads in any attempts to implement further DE processes and software.

Overall some participants indicated that they were confident in their abilities to implement and use Digital Engineering while others indicated the opposite. This is also reflected in the less than optimal scores participants gave when asked about the readiness of other staff to implement digital engineering. This could indicate that some participants require support in developing their skills and knowledge. Despite the uncertainty in some areas, the responses to the concept of digital engineering were very positive. This suggests that most participants who do require greater support to develop their knowledge would be happy to embrace this opportunity.

Overall the responses are consistent with the adoption of DE in Australia generally, which has been uneven across the states and territories and lacked a national strategy. The recent endorsement by the Australian Transport and Infrastructure Council of “National Digital Engineering Policy Principles” [2] may address some of the concerns expressed and encourage VicRoads to prepare to adopt DE.

The varied responses to Question 29 suggest that most participants were unable to field a guess about the number of software packages operated by VicRoads. Other responses indicated that participants felt overwhelmed by the number of software packages. Although this research is based on a small sample, it does provide a case for further research into this question and the participants’ responses. It could also provide the beginnings of a business case for DE to help VicRoads staff manage the software packages currently in use.

APPENDIX - QUESTIONNAIRE

The purpose of this questionnaire is to gain an understanding of current knowledge and expectations of Digital Engineering (DE). Participants are requested to provide their name so that their responses can be referred to in any follow-up interviews. Individual responses will remain confidential and known only to the respondent and SBEnrc researchers.

Please print	Name	Position
Date	Department	Company

For each question tick a column to show your level of agreement	Agree				Disagree
	1	2	3	4	5
1. In the last 2-years I have been involved in one or more projects using DE, but have not used DE myself					
2. I know next to nothing about DE					
3. DE is a software for infrastructure design					
4. Our contractors are generally ready to implement DE					
5. In the last two years I have personally used DE on one or more projects.					
6. DE is what electronic and software engineers do					
7. VicRoads has capacity to progressively implement DE over the next 2-3 years					
8. I need to know more about DE before being ready to implement DE in my area of responsibility					
9. Digital Engineering (DE) is another name for Building Information Management (BIM)					
10. VicRoads is probably ahead of most other State transport bodies in implementing DE					
11. DE is a collaborative way of working using digital technologies					
12. Successful implementation of DE by VicRoads will inevitably be stymied by a lack of resources (financial/people)					
13. National guidelines are needed before we should implement DE					
14. Our consultants are not yet to implement DE					
15. It is common for our projects to be delayed on site because of design errors					

For each question tick a column to show your level of agreement	Agree				Disagree
	1	2	3	4	5
16. Implementing DE is an exciting challenge					
17. DE is still in its infancy, VicRoads should wait and see where DE goes before implementing DE					
18. Each State and Territory should develop its own approach to DE					
19. Digital engineering is primarily for designers					
20. Successful implementation of DE by VicRoads will require a dedicated team to develop policies and procedures					
21. Wide-spread adoption of DE in Australia is many years away					
22. As-built information is typically delivered complete and in good order before Practical Completion of construction projects					
23. It is common for our construction projects to incur additional costs because of design errors					
24. Successful implementation of DE by VicRoads will require leadership from Senior Management level					
25. DE is part of a bigger concept that will integrate digital data form many sources (e.g. Internet of Things, Smart Cities)					
26. VicRoads staff have the necessary skills and knowledge to implement DE					
27. I have read extensively about DE in trade and professional publications and/or attended a few presentations					
28. VicRoads has clearly established requirements for as-built information and structured asset data					

In your estimation how many different software packages does VicRoads use to design and operate the road network?

Appendix 2

Global Public Sector BIM Uptake Summary [11]

Country	Year	Gov. Initiatives and Mandates	Stated Objective/s
Australia	2010	Built Environment Industry and Innovation Council Economic Study	Impacts on national economic output is estimated over the period 2011 to 2025 is equivalent to a one off increase in GDP of $4.8B in 2010 and that this benefit could be as high as $7.6B.
	2016	State Government of Victoria Construction Technologies Sector Strategy	• Develop a Plan with industry to provide for the greater uptake of BIM • Build expert skills in BIM technologies
	2016	House of Representatives, Standing Committee on Infrastructure, Transport and Cities: Report on the inquiry into the role of smart ICT in the design and planning of infrastructure	Recommendation 7: Australian Government…require BIM to LOD500 on all major infrastructure projects exceeding $50m.
	2016	QLD State Infrastructure Plan. It represents a bold approach to addressing the state's future infrastructure needs, focused on using our resources wisely, partnering with the private sector, and implementing a program of reform initiatives.	Part B Action 15 Implement Building Information Management (BIM) The state will progressively implement the use of BIM into all major state infrastructure projects by 2023.
China		Ministry of Housing and Urban-Rural Development (MOHURD) and/or Ministry of Science and Technology (MOST) are sponsors of China's BIM Standard (CBIMS); intended for recommended use, not mandated use.	The Housing Authority (HA) has started piloting BIM since 2006. We have used BIM for design visualisation and progressively carried forward to subsequent stages to benefit the chain of stakeholders along the building life cycle, from design to documentation, construction and facility management. To facilitate the process, HK have prepared in-house BIM standards, user guide, library component design guide and references BIM Standards Manual BIM User Guide (Part I) BIM User Guide (Part II) BIM Library Components Design Guide BIM Library Components Reference Standard Approach of Modelling (SAM) for Creating Building Information Structural Mode
	2014	Hong Kong Housing Department (executive arm of the Hong Kong Housing Authority64) requires BIM for all new projects. HK MTR has used BIM technology for a variety of purposes, and has a 3+ year BIM roadmap established.	

Denmark	2013	Under a national mandate from the Ministry of Climate, Energy and Building, Danish state clients such as the Palaces and Properties Agency require their supply chain to use BIM for projects in excess of DKK5M.	– ICT coordination – Managing digital building objects – Digital communication and project web – The use of digital building models – Digital QTO and bid/tender – Digital delivery of building documentation – Digital inspection
Dubai	2014	Dubai Municipality (DM) mandated BIM65 for all buildings of 40 stories or higher (or 25,000sqm or more), all projects with an international client, all hospitals, universities and major public buildings.	DM said the decision was taken based on the ability of BIM tools and workflows in improving construction quality, enabling collaboration between project participants across phases, lowering costs, reducing time, unifying specifications and standards as well as cost planning.
European Union	2014	The European Union Public Procurement Directive[53] (EUPPD) means that all 28 European Member States may encourage, specify or mandate the use of BIM for publicly funded construction and building projects in the European Union by 2016.	Stated aim of enabling more efficient construction and building projects in Europe. 35% reduction in capital and operational costs.
Finland	2007	Finland's state property services agency, Senate Properties, has required the use of BIM for its projects since 2007.	To use IFC standards to understand relationships between project scope and cost as architectural design progresses.
	2012	The Common BIM Requirements are to be used for all state property and national public projects.	
France	2015	The then French Minister for Housing, Sylvia Pinel announced that France will implement a 'French digital strategy', mandating BIM for public procurement. A task group has been established to develop a BIM mandate first put forward by the Ministry of Dwellings (Ministère du Logement).	With a budget of €20M, the group is planning to build 500,000 BIM-developed houses by 2017. To take the housing ambition forward, Le Plan Transition Numérique dans le Bâtiment (the Digital Building Transition Plan) task group has been formed. Also the French National Research Project MINnD has been set up with a consortium that joins together contractors, engineers, software vendors, academia and professional institutes. The 'Interoperable Information Model for Sustainable Infrastructures' project has started to develop and explore open BIM standards for infrastructure projects.
Germany	2015	The Federal Ministry of Transport and Infrastructure (BMVI) have led the creation of an industry 'Digital Building Platform', in coordination with industry organisations.	Key areas of focus are standardisation, digital data exchange, and new BIM-ready legal contracts. The strategy is part of a reform commission for construction that looks to understand why a number of large German public sector projects had significant time and cost problems.

Japan	2010	Ministry of Land Infrastructure (MLIT) adopted BIM63 on a trial basis for a government building project.	The use of BIM data for facility management of government buildings.
	2012	MLIT Government Buildings Department began to study the development of BIM modelling rules.	Combine the use of BIM together with 'green' approaches and product use.
Norway	2010	Statsbygg (Norway's Directorate of Public Construction and Property) established a requirement for BIM58 on new and renovation projects. Frameworks date back as far as 2005.	To reduce errors, improve coordination, increase energy efficiency of its buildings and in general gain efficiencies. This Joint Statement defines requirements for all parties involved in their projects to use software based on open standards by 1 July 2016. This will put pressure on architects, consultants, software vendors and contractors in terms of how they work and what programs they can use. Attention now focuses on lifecycle costs and environmental impact of infrastructure.
	2013	Four large Norwegian public building clients and owners; Norwegian Defence Estates Agency (NDEA); Helse Midt-Norge RHF (Central Norway Regional Health Authority); Helse Sør-Øst RHF (South-Eastern Norway Regional Health Authority); and Statsbygg (Directorate of Public Construction and Property), have established and signed a Joint Statement.	
Qatar	2014	Qatar Rail66 has adopted a BIM standard $50B worth of rail expansion projects 'BIM-enabled' throughout Middle East.	BIM will enable project teams of architects, engineers, building and infrastructure owners and construction firms to use 3D digital models to collaborate and support building projects throughout their lifecycle - from design and documentation to building and field support - ensuring that projects are delivered to the required specifications on schedule and within budget.
Russia	2015	BIM development is a fairly recent focus outside the academic institutions. The Expert Council59, under the government of the Russian Federation, selected some pilot projects to explore the potential of BIM implementation.	Ex-1138GS, paragraph 2 b) b) Develop and approve an action plan for the implementation of BIM in the construction industry. Ex-1138GS, paragraph 2 c) c) with the involvement of national associations of
Singapore	2010	In 2010 the BCA implemented the BIM Roadmap with the aim that 80% of the construction industry will use BIM by 2015. A key part of the roadmap is the implementation of the world's first BIM electronic submission system.	To improve the construction industry's productivity by up to 25% over the next decade.

South Korea	2012	The Public Procurement Service made BIM compulsory for all projects over S$50M from 2012 and for all public sector projects by 2016.	Initial targets to improve document quality and shorten decision making. Longer term aims to develop accurate and automated cost plans and sustainability.
The Netherlands	2012	In 2012, a Building Information Council57 was set up as part of the Rijkswaterstaat highways and waterways BIM Program. There are many aspects to the project, including a standard format for data exchange and cross-discipline translation.	The most important reason for building a BIM Gateway, for its users as well as its financiers, is to reduce maintenance costs by bringing together the open BIM standards into one coherent system. This will ensure that the standards can be used more effectively and with greater efficiency as well as promoting their widespread use
	2016	Statsbygg requires BIM for all national public projects.	
United Kingdom	2011	In response to its 2011 Construction Strategy50, the UK Government has mandated 'Fully Collaborative 3D BIM' as a minimum by 2016 on all publicly procured projects. In July 2013, the UK Government released its updated Construction	To reduce the whole of life cost of infrastructure by 33% To reduce the delivery time by 50% To lower emissions by 50%
United States of America	2006	In 2006, the General Services Administration (GSA) mandated that BIM be the minimum requirement for submission for Final Concept approvals. Projects are encouraged to go beyond the minimum BIM requirement to deploy mature 3D, 4D and 5D BIM technologies.	Promote value-added digital visualisation, simulation and optimisation technologies to increase quality and efficiency throughput project lifecycles

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