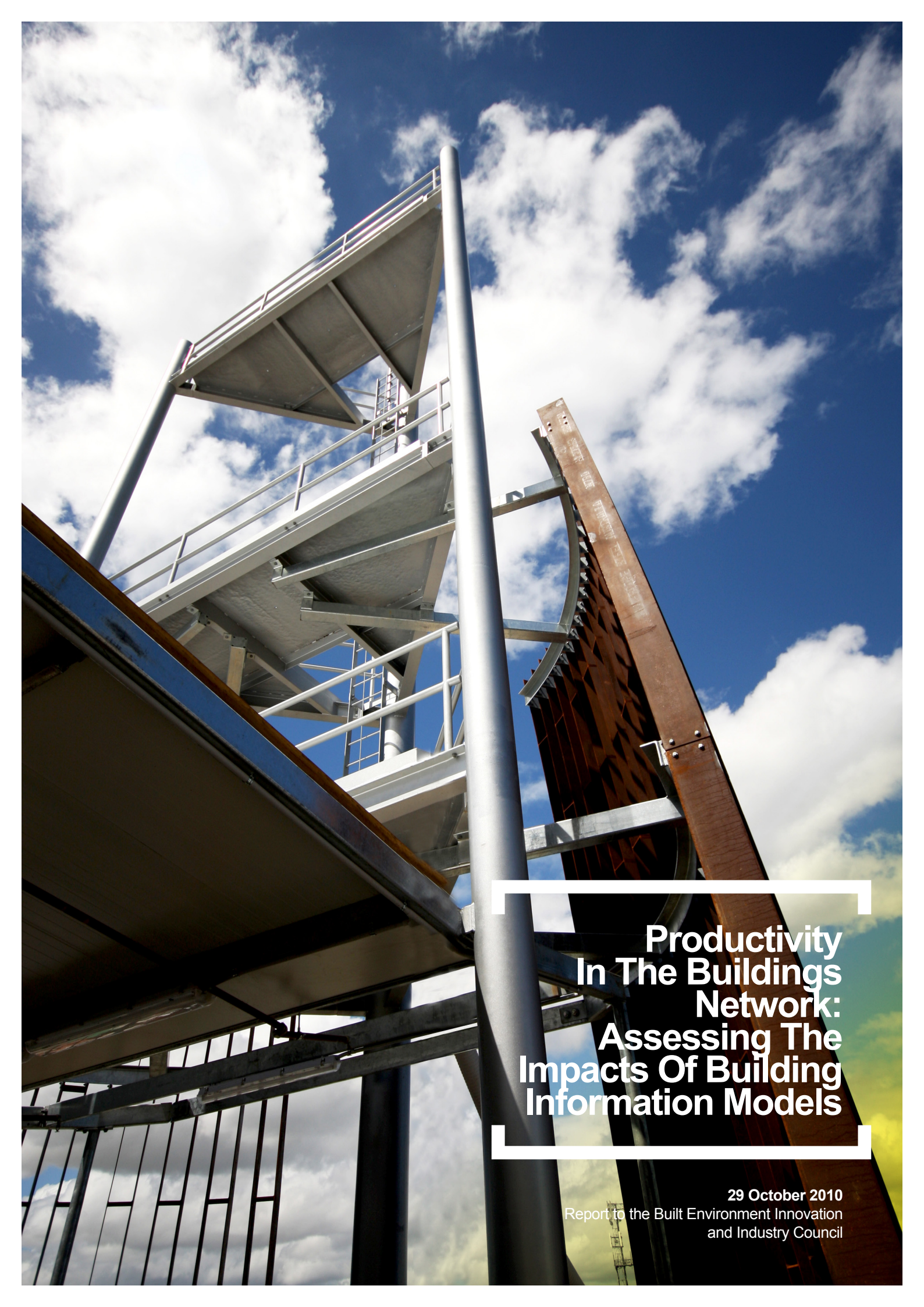




Productivity In The Buildings Network: Assessing The Impacts Of Building Information Models

29 October 2010
Report to the Built Environment Innovation
and Industry Council

The Allen Consulting Group

Allen Consulting Group Pty Ltd
ACN 007 061 930, ABN 52 007 061 930

Melbourne

Level 9, 60 Collins St
Melbourne VIC 3000
Telephone: (61-3) 8650 6000
Facsimile: (61-3) 9654 6363

Sydney

Level 1, 50 Pitt St
Sydney NSW 2000
Telephone: (61-2) 8272 5100
Facsimile: (61-2) 9247 2455

Canberra

Empire Chambers, Level 2, 1-13 University Ave
Canberra ACT 2600
GPO Box 418, Canberra ACT 2601
Telephone: (61-2) 6204 6500
Facsimile: (61-2) 6230 0149

Online

Email: info@allenconsult.com.au
Website: www.allenconsult.com.au

Cover image: Joint Contact Centre (JCC), Zillmere, Brisbane.

Suggested citation for this report:

Allen Consulting Group 2010, *Productivity in the buildings network: assessing the impacts of Building Information Models*, report to the Built Environment Innovation and Industry Council, Sydney, October.

Disclaimer:

While the Allen Consulting Group endeavours to provide reliable analysis and believes the material it presents is accurate, it will not be liable for any claim by any party acting on such information.

© Allen Consulting Group 2010

Acknowledgments

We thank the following sponsors who made this report possible through their financial support:

- Department of Innovation, Industry, Science and Research (Michael Green, Elisabeth Egle);
- buildingSMART Australasia (John Mitchell);
- Australian Institute of Architects (Ross Clark);
- ARUP (Peter Bowtell);
- Atlas Industries (Joshua Ridley);
- NATSPEC (Richard Choy);
- Built Environment Design Professions (Warren Kerr);
- BlueScope Steel (Manu Siitonen); and
- Polyflor (Kevin Doidge).

The authors wish to thank the Reference Group Members for their input and comments on this report:

- John Mitchell, buildingSMART Australasia;
- Ross Clark, Australian Institute of Architects;
- Peter Scuderi, buildingSMART Australasia;
- Neil Greenstreet, NATSPEC;
- John Hainsworth, ARUP; and
- Steve Fiorio, Grocon.

We also thank the following reviewers for providing comments:

- Matthew Inman, CSIRO;
- John Hainsworth, ARUP;
- Tom Fussell, Project Services, Queensland Department of Public Works;
- Richard Choy, NATSPEC;
- Jennifer MacDonald, School of Natural and Built Environment, University of South Australia;
- Michel Hedley, Australian Information Industry Association; and
- Jim Plume, Faculty of the Built Environment, University of New South Wales.

The following people contributed to the 2010 BIM Industry Survey:

- Neil Greenstreet, Richard Choy, NATSPEC;
- Jennifer MacDonald, School of Natural and Built Environment, University of South Australia; and
- John Mitchell, buildingSMART Australasia.

Allen Consulting Group staff that contributed to this report:

- Kerry Barwise, Director;
- Mayela Garcia, Senior Manager;
- Astrid Edwards, Manager; and
- Angela Phang, Senior Analyst.

Contents

<i>Acronyms</i>	<i>vi</i>
<i>Executive summary</i>	<i>vii</i>
BIM: an industry perspective	viii
Accelerated BIM adoption, large gains for the Australian economy	ix
Conclusion	xi
Chapter 1	1
<i>Assessing the impacts of BIM</i>	<i>1</i>
1.1 This study	1
1.2 Introducing the buildings network	2
Chapter 2	4
<i>BIM: Scaffolding the buildings network</i>	<i>4</i>
2.1 Current state of play in the buildings network	4
2.2 What is BIM and how can it support the buildings network?	8
Chapter 3	13
<i>Benefits of BIM adoption</i>	<i>13</i>
3.1 Improved information sharing	15
3.2 Enhanced productivity	18
3.3 Improved quality	18
3.4 Increased sustainability	19
3.5 Labour market improvements	20
3.6 Wider benefits of digital modelling	21
3.7 The Australian experience	21
3.8 Lessons from the United States	23
Chapter 4	25
<i>Costs of BIM adoption</i>	<i>25</i>
4.1 Education and training costs	25
4.2 Administration and start up costs	25
4.3 Transition and behavioural costs	26
Chapter 5	27
<i>BIM in Australia: State of Play in 2010</i>	<i>27</i>
5.1 BIM survey 2010	27
5.2 Who answered the survey?	28
5.3 BIM adoption and usage	28

5.4 Impacts of BIM	31
Chapter 6	40
<i>Challenges and the means to overcome them</i>	40
6.1 New technologies and barriers	40
6.2 Market failures	41
6.3 Government and Industry intervention and coordinated action	42
6.4 Summing up	44
Chapter 7	45
<i>Exploring the opportunity: approach to measuring the impacts of BIM</i>	45
7.1 Modelling framework	45
7.2 Modelling scenarios	46
7.3 Estimating the direct impact of widespread BIM adoption	49
7.4 Estimating the economy-wide impact of higher BIM adoption	51
Chapter 8	57
<i>Benefits of change: impacts of widespread use of BIM</i>	57
8.1 Economy-wide results	57
8.2 Industry results	62
8.3 Sensitivity analysis	64
Chapter 9	66
<i>Conclusion</i>	66
9.1 Key findings	66
9.2 Limitations	69
9.3 Areas for further investigation	71
Appendix A	72
<i>The MMRF Model</i>	72
A.1 The MMRF model	72
A.2 Introduction to the MMRF model	72
A.3 The database	72
A.4 Structure of the model	75
A.5 Government finances	78
A.6 MMRF dynamics	78
A.7 Closure assumptions of MMRF	80
A.8 Interpretation of MMRF simulations	81
<i>References</i>	82

Acronyms

3D	Three-dimensional graphic data
4D	Three-dimensional graphic data, including scheduling and project timeline capability
5D	Three-dimensional graphic data, including cost data capability
AIA	Australian Institute of Architects
APCC	Australian Procurement and Construction Council
ASBEC	Australian Sustainable Built Environment Council
BAU	Business as usual
BCR	Benefit Cost Ratio
BEDP	Australian Council of Built Environment Design Professions
BEIIC	Built Environment Innovation and Industry Council
BIM	Building Information Model/Modelling
CAD	Computer Aided Design
CGE	Computable General Equilibrium
CIFE	Centre for Integrated Facility Engineering
CRC	Cooperative Research Centre
CURT	Construction Users Roundtable
CWIC	Collaborative Working in Construction
eDA	Electronic Development Assessment
GDP	Gross Domestic Product
HEFCE	Higher Education Funding Council for England
IPD	Integrated Project Delivery
IPT	Integrated Project Team
IT	Information technology
MMRF	Monash Multi-Regional Forecasting
NIST	National Institute of Standards and Technology
ROI	Return on Investment

Executive summary

The buildings network¹ is a vital part of the Australian economy. Indeed, the industries within the buildings network are significant contributors to the national economy in terms of output and employment. Furthermore, through its activities, the buildings network also has a significant impact on the efficiency and productivity of other sectors of the economy. Yet, on some indicators, it is lagging behind in terms of productivity growth when compared to the national average and other industry sectors.

To increase its contribution to Australia's wellbeing and capture new opportunities, the buildings network industries must respond positively to new and significant challenges, including finding ways to become more productive. In this context, innovation is a critical tool to increase the buildings network productivity, drive its future profitability, improve its competitiveness and build a sustainable environment for Australia's future.

Government and industry are aware of the importance of innovation in the buildings network and are working together to help transform and improve the competitiveness of these industries. It is in this context that the Built Environment Industry Innovation Council (BEIIC) was created with the aim of facilitating dialogue across many of the diverse stakeholders that comprise the buildings network and promoting whole of industry responses to government priorities. Since its creation in 2008, BEIIC has been considering industry innovation challenges and ways of raising industry competitiveness in diverse areas, including climate change, sustainability, regulatory reforms and productivity.

It is against this background that Building Information Models (BIM) are emerging as a transformative, enabling technology that has the potential to improve the buildings network productivity and raise the economic wellbeing and competitiveness of the Australian economy as a whole.

BIM is a 3D modelling technology and design process that has already begun to change the way buildings are designed, built, operated and decommissioned. While there is no single accepted definition of BIM it is generally described as a database that provides digital information about the design, fabrication, construction, project management, logistics, materials and energy consumption of a building.

The use of BIM has the potential to streamline processes throughout a building's lifecycle through the integration of design, engineering, construction, maintenance and decommissioning information about a built asset project into a single rich model. Further, the use of digital modelling tools can have wider benefits for the Australian community when the use of this technology is extended to, for instance, urban planning, infrastructure development and the designing and understanding of city environments.

¹ In this study, the buildings network involves all those players and activities that relate to the whole life of a building and who can generate large amounts of data that need to be shared during a building's lifecycle, including architects, engineers, builders and contractors and owners and facility managers. For more information about this definition see Section 1.2 in the main body of the report.

The accelerated widespread adoption of BIM by the buildings network presents both issues and opportunities. This study explores the ways in which BIM can change the current state of play in the industry and the perceived costs and benefits of this technology. Also, a key contribution of this study is that it pulls together and reports the results of the first nationwide survey about the adoption, usage, costs and benefits of BIM in Australia. The study then provides a brief overview of the factors that are limiting the broader adoption of BIM and identifies a range of actions that could help address these challenges. There is little point in discussing how things could be different unless it is also shown that the change is worth pursuing. Hence, the study reports on detailed economy-wide analysis of the impacts that the accelerated widespread use of BIM by the buildings network could have on the Australian economy.

BIM: an industry perspective

BIM technology offers the potential for many direct and indirect benefits to the buildings network industry, including:

- improved information sharing;
- time and costs savings that can be directly translated into productivity gains;
- improved quality;
- greater transparency and accountability in decision making;
- increased sustainability; and
- labour market improvements.

While BIM is expected to deliver important benefits to the buildings network, it is clear that its adoption would also have costs. The perceived costs of adopting BIM technology identified in the literature (e.g. McGraw Hill, 2008, 2009) include:

- education and training costs;
- administration and start up costs; and
- transition and behavioural costs.

These costs are common to the adoption of many new technologies. Further, some of the literature in the topic suggests that users of BIM technology perceive the benefits to outweigh the costs involved (McGraw Hill 2007, buildingSMART Australasia et al. 2010). Industry stakeholders consulted for this study also indicated that the marginal cost of BIM software compared to current 3D CAD is not significant.

While BIM is expected to deliver many benefits and the costs are not materially higher than traditional or alternative management approaches, there are many factors that currently impede its widespread adoption. Consultations held with key industry stakeholders familiar with BIM point to the following factors playing a role in impeding adoption of BIM:

- lack of BIM object libraries;
- lack of model building protocols;

- legal and insurance impediments;
- lack of standards for information exchange and management and inconsistencies in information handover protocols;
- skills gaps;
- lack of strategic research focus; and
- industry resistance to process change.

Experience with other enabling technologies suggest that while technological and organisational barriers may appear daunting and even insurmountable at first, they have been overcome in time where the benefits from innovation exceed the costs.

However, market failures may present a more formidable set of barriers to the adoption of BIM. The common theme with market failures in the adoption of BIM is that because of market failure associated with research, development and commercialisation of new technologies, private innovators and adopters of innovative technologies are not able to capture for themselves the full social value of their innovations.

If in fact market failures are imposing structural and substantial barriers to the accelerated widespread adoption of BIM, then these barriers cannot be overcome without government intervention and industry-wide changes. Encouraging these changes would be of little value unless it is shown that the changes are worth pursuing. To measure the magnitude of these changes and illustrate the significance of BIM to the Australian community, a detailed economy-wide analysis of the impacts of accelerated widespread BIM adoption has been conducted. To our knowledge, this is the first time that the impact of BIM use would have on the Australian economy has been measured.

Accelerated BIM adoption, large gains for the Australian economy

The impact that accelerated widespread BIM adoption would have on the Australian economy was estimated using a model of the Australian economy (the Monash Multi Regional Forecasting model, MMRF). This model is a high-level representation of the Australian economy that enables measurement of the wider effects of changes in economic activity in key industries and regions. The MMRF model is widely known and has been used by the Productivity Commission, the Commonwealth Treasury and other government agencies to evaluate economy-wide impacts of industry and policy changes.

When assessing the impacts of an industry or policy change on the Australian economy, there are a range of key macroeconomic variables that are commonly evaluated, these include:

- *Gross Domestic Product (GDP)* — GDP is a measure of Australia's economic activity. GDP is the sum of consumption, government spending, investment and net exports. Therefore, changes in GDP largely reflect changes in these economic variables, particularly those of investment and consumption.

- *Consumption* — consumption is generally the largest component of GDP and measures private consumption expenditure. This variable is an indicator of living standards. An increase in private consumption indicates an increase in welfare of Australians.
- *Investment* — investment is another component of GDP that measures demand by private firms and individuals for capital, including factories, machinery, computer software, etc. This variable is an indicator of the future productive capacity of the Australian economy.

The impacts of accelerated widespread BIM adoption on these key macroeconomic variables are summarised in the points below.²

- Accelerated widespread adoption of BIM technology would enhance the productivity of different players in the buildings network and have a significant expansionary effect on the Australian economy. Indeed, accelerated widespread adoption of BIM could boost Australia's economic output (GDP) by 0.2 basis points in 2011. As the difference in adoption of BIM increases over time, impacts on productivity also become larger. This flows on to higher GDP over time. In 2025 GDP is estimated to be 5 basis points higher, when compared with a 'Business as Usual' (BAU) scenario.³
- While the impacts on national economic output may look small in percentage terms, it is estimated that this benefit over the period 2011 to 2025 is equivalent to a one off increase in GDP of \$4.8 billion in 2010 and that this benefit could be as high as \$7.6 billion.
- One way of putting this impact into context is to look at the Benefit Cost Ratio (BCR) of this change. Industry experts have advised that the incremental costs of adopting BIM are not materially higher than the costs of alternative technological approaches being used by the buildings network. However, even if for illustrative purposes it is assumed that the incremental costs of adopting BIM are, say \$500 million, the BCR of this change would be almost ten. A BCR of ten implies that this change would provide a benefit that is ten times higher than the alternative investment (say, repaying government bonds). Another way of putting this into context is to consider the fact that government applies a BCR threshold of two for road infrastructure projects (such as the black spot sites) to qualify for federal funding.
- The best single measure of the impact of accelerated widespread BIM adoption on the Australian community is consumption. Consumption, the best indicator of wellbeing, is also expected to rise as a result of higher BIM adoption. The estimated cumulative boost in real consumption over the period 2011-25 is equivalent to a one off increase in private consumption of \$1.4 billion in 2010.

² All the results of the economic analysis are in 2008-09 dollars and all net present valuations of the impacts of BIM refer to Net Present Values (NPVs) in the year 2010. More details about the methodology used to estimate these economic impacts are provided in Chapter 7.

³ The 'business as usual' (BAU) scenario refers to a situation where the adoption rate of BIM in the buildings network industry is based on current BIM market settings, without additional support from government or major changes in the industry. The analysis is comparing a scenario where there is accelerated adoption of BIM against a BAU that has a background level of adoption. This is a conservative, but realistic approach.

- Investment, an indicator of the future productive capacity of the Australian economy, would also be boosted by accelerated widespread BIM adoption. The increase in investment Australia-wide is equivalent to a one off increase of \$3 billion in 2010.
- Another way in which the community would benefit from higher BIM adoption is via wages. Compared with a BAU scenario, productivity improvements stemming from higher BIM adoption would lead to an increase in real wages of 3 basis points in 2025.
- Although higher BIM adoption *directly* raises productivity only in the buildings network industry, it also *indirectly* benefits all other Australian industries as the effect of higher productivity in the buildings network is passed on to other industries in the form of lower prices for inputs. Indeed, production increases across all industries, with the biggest gains concentrated in the business services and construction sectors.
- A sensitivity analysis of these results using lower and higher estimates of productivity gains stemming from BIM was undertaken. This analysis shows that, while the economy-wide impacts vary in magnitude depending on the productivity estimates being used, the accelerated widespread use of BIM consistently translates into higher output (GDP), higher wages and higher living standards (household consumption).

Conclusion

The results described above may seem small when the size of the buildings network, which was estimated to be around \$350 billion in 2005-06, is considered. However, it is important to keep in mind that, while BIM is a transformative, enabling technology that is very beneficial relative to its costs, it will only change a portion of a segment of a wider economy which has a value today of more than a trillion dollars. Still, achieving accelerated widespread adoption of BIM would be an important stepping-stone towards raising the overall productivity of the Australian economy.

In our experience, there are very few options available for enhancing productivity that can be achieved on such favourable terms and without difficult to achieve structural reforms.

The approach that we have taken in the economic analysis in this study is conservative, but is also realistic. The key factors that drive this conservative analysis are that it takes into account that there is a background level of BIM adoption; that widespread adoption, even though accelerated, still takes time to occur; and that it takes into account conservative independent experts' views about the magnitude of the productivity gains delivered by BIM. The analysis has sought to avoid excess hyperbola and raising expectations that cannot be fulfilled.

Clear messages stemming from this analysis are that BIM has macroeconomic significance, that its accelerated widespread adoption would make a significant difference to national economic performance and that there is a compelling economic case for encouraging greater use of BIM in Australia.

Some pressure is needed to pull BIM technology from the promising early start to widespread adoption by the majority of professionals in the buildings network. A range of actions has been identified by industry that could help the realisation of the potential gains from greater use of BIM in the buildings network. These are outlined in the points below.

- The development of a national strategy for BIM implementation that sets out national priorities, a plan of adoption and provides guidance across the whole industry.
- Actions to support and promote the development of industry standards of practice and information management guidelines.
- Actions to develop and implement new contractual frameworks, such as Integrated Project Delivery (IPD), that address issues of risk, fees, responsibilities, intellectual property, legal liability and insurance when using BIM.
- Actions to enable the creation and maintenance of open object libraries with defined product parameters and properties that comply with accepted national classification systems and support for analysis, sustainability, energy efficiency and regulatory compliance.
- Actions to close or reduce the skills gaps. These could include actions to incorporate BIM in the curricula of educational institutions and to promote and deliver training for businesses' existing staff.

While these actions suggested by industry provide a good illustration about the means to overcome the identified barriers to adoption, more research beyond the scope of this study is necessary to identify specific policy interventions and industry actions and convert these general directions into recommendations and actual actions.

BIM is expected to deliver many benefits to industry at costs that are not materially higher than traditional or alternative management approaches. Accelerated widespread BIM adoption can also make a significant difference to national economic performance and raise the economic wellbeing of the Australian community. However, there are many factors that currently impede BIM accelerated widespread adoption. If these barriers are overcome, the buildings network industry and the Australian community will be better off.

Chapter 1

Assessing the impacts of BIM

1.1 This study

The Allen Consulting Group was engaged by the Built Environment Innovation and Industry Council (BEIIC) Digital Modelling Working Group and a group of industry sponsors to undertake a study assessing the economic impacts of widespread adoption of Building Information Models (BIM) in Australia.

The industry sponsors that contributed to this study were the Department of Innovation, Industry, Science and Research, buildingSMART Australasia, the Australian Institute of Architects, ARUP, Atlas Industries, NATSPEC, Built Environment Design Professions, BlueScope Steel and Polyflor.

The terms of reference for the study are to provide:

- a brief review of the current state of play in the construction process to identify the extent to which poor information management, incomplete data and the lack of effective communication are affecting the property industry (addressed in Chapter 2);
- a broad assessment of how the adoption of BIM may improve construction processes and drive greater understanding of a building's environmental performance prior to construction (addressed in Chapter 2 and Chapter 3);
- a review of existing national and international literature on the economic benefits of BIM adoption (addressed in Chapter 2 and Chapter 5);
- a broad, qualitative analysis of non-quantifiable costs and benefits associated with increased uptake of BIM, including transition and behavioural costs and cultural change issues (addressed in Chapter 3 and Chapter 4); and
- an analysis of the impacts that widespread adoption of BIM would have on the Australian economy and particular industries (addressed in Chapter 7, Chapter 8 and Chapter 9).

In addition to addressing these terms of reference, this study:

- pulls together and reports the results of the first nationwide survey about the adoption, usage, costs and benefits of BIM in Australia. This survey was conducted by buildingSMART Australasia, the School of Natural and Built Environment (University of South Australia) and NATSPEC. The results of this survey have not been published but are reported here to provide the reader with a picture about the current state of play of BIM in Australia;
- explores some of the factors limiting BIM adoption in Australia; and
- identifies a range of broad directions that can be taken by industry and government to stimulate greater use of BIM in Australia.

This report is structured as follows:

Chapter 2 provides an introduction to BIM technology, an overview of the current state of play in the buildings network industry in Australia and outlines how BIM can support the buildings network.

Chapter 3 analyses the benefits of BIM technology for the buildings network industry found in the literature in terms of improved information sharing, enhanced productivity, improved quality, increased sustainability, and labour market improvements.

Chapter 4 examines the costs involved in the implementation of BIM technology. These costs include start up and administration, education and training, and transition and behavioural costs.

Chapter 5 summarises the key findings of the 2010 BIM Survey.

Chapter 6 briefly outlines the key factors limiting BIM adoption in Australia and a range of actions that can be taken by industry and government to stimulate greater use of BIM in Australia.

Chapter 7 explains the methodology used in this report to estimate the economic impacts of widespread adoption of BIM in Australia.

Chapter 8 presents the modelling results examining the impacts of widespread BIM adoption on the Australian economy.

Chapter 9 outlines the key findings of this report, its limitations and topics for further study in this area.

1.2 Introducing the buildings network

Building information models can play a key role in the built environment. The term ‘built environment’ and the disciplines that define it are broad and defined in several ways. For instance, Griffiths argues that the built environment field includes ‘a range of practice-oriented subjects concerned with the design, development and management of buildings, spaces and places’ (Griffiths, 2004). A panel from the Higher Education Funding Council for England (HEFCE) defines the field as including ‘architecture, building science and engineering, construction, landscape and urbanism’ (HEFCE, 2005).

In general, literature on the subject describes the built environment as referring to the man-made surroundings that provide the setting for human activity, ranging in scale from buildings to neighbourhoods to cities, and often including supporting infrastructure, such as transport, water supply and energy networks.

In practice, the term is typically used to describe the interdisciplinary fields which address the design, construction, management and use of these man-made surroundings as an interrelated whole, as well as their relationship to human activities over time.

While this report acknowledges the extensive implications that BIM may have on the built environment as a whole, the focus of the analysis is on the economic impacts that widespread adoption of this technology by a narrow section of the built environment would have Australia-wide. We define this narrow part of the built environment that is the focus of this report as the *buildings network*.

In this study, the *buildings network* involves those players and activities that relate to the whole life of a building and that generate large amounts of data that needs to be shared throughout a building's life, including architects, engineers, builders and contractors, as well as owners and facility managers.

These players are not traditionally regarded as part of a traditional industry, instead cutting across many industries (for example, construction, business services, and manufacturing).

Chapter 2

BIM: Scaffolding the buildings network

Chapter 2 provides an overview of the current state of play in the buildings network industry in Australia, an introduction to BIM technology and a discussion about how BIM can support the buildings network.

2.1 Current state of play in the buildings network

The buildings network includes a wide range of sectors — from construction services to product manufacturing, property management services and professional services. While it is difficult to accurately measure the size and economic contribution of the buildings network, drawing on the limited information available, a rough estimate has been made about its size. As outlined in Table 2.1, it is estimated that in 2005-06, the buildings network industry accounted for around 12 per cent of Australia's total production (equivalent to around \$355 billion).

Table 2.1

OUTPUT OF SELECTED SECTORS WITHIN THE BUILDINGS NETWORK, 2005-06, \$M

Sector	Total production
Building construction services	\$125,179
Property services	\$172,764
Scientific research, technical and computer services	\$52,301
Structural metal product manufacturing	\$4,816
Total	\$355,060
Australia	\$3,046,267

Source: ABS 2009a. Note: This table provides a rough indication of the size of the buildings network. This estimate has been calculated using available information from the ABS. Finer disaggregation of sectors such as facility management and architectural services is not available. Further, this table does not take into account the public sector contribution to the buildings network as a facility owner.

An accurate estimate about employment in the buildings network industry is also difficult to produce. This is because employment statistics distinguish between occupations and industries. If employment in the buildings network industry is measured using the occupations that work in buildings network related sectors (e.g. architects, designers, planners, etc), many support people that are needed by firms to deliver buildings will be excluded. Similarly, if employment in the buildings network is measured using the number of people employed in the industries that shape the buildings network, then people in related occupations hired by other industries will be excluded (for instance, architects employed in the public sector).

In light of this, we have used both approaches to provide a range estimate of the buildings network employment. Table 2.2 shows that the total employment in the buildings network measured using the industry classification approach was around 916,969 persons in 2005-06. Using the occupation classification approach, it is estimated that employment in the buildings network in 2005-06 was around 1,061,576 persons. Using these two approaches it is estimated that the buildings network accounts for around 10 per cent to 13 per cent of total employment in Australia.

Table 2.2

ESTIMATED EMPLOYMENT OF THE BUILDINGS NETWORK, 2005-06 (PERSONS)

	Employment	Share of total
By industry		
Property Operators and Real Estate Services	111,853	1.2%
Construction services	656,473	7.2%
Architectural, Engineering and Technical Services	125,828	1.4%
Structural Metal Product Manufacturing	22,815	0.3%
Total	916,969	10.1%
By occupation		
Construction, Distribution and Production Managers	179,551	2.0%
Architects, Designers, Planners and Surveyors	78,334	0.9%
Engineering Professionals	81,346	0.9%
Building and Engineering Technicians	86,591	1.0%
Fabrication Engineering Trades Workers	70,936	0.8%
Construction Trades Workers (includes bricklayers, electricians, plumbers, etc)	364,343	4.0%
Construction Labourers	115,923	1.3%
Others	171,143	1.9%
Total	1,061,576	12.6%
Australia	9,104,181	100.0%

Source: ABS 2008. Note: This table provides a rough indication about employment in the buildings network. This estimate has been calculated using available information from the ABS. Finer disaggregation of sectors such as facility management and architectural services is not available.

Given the noted difficulties in measuring output and employment of the buildings network, it is even more challenging to attempt to estimate productivity measures for this sector, especially when several measures of productivity exist (See Box 2.1). A good proxy of the productivity of the buildings network is that of the construction sector. Figure 2.1 shows the labour productivity of the construction sector as compared with the aggregate productivity in Australia from 1974-75 to 2007-08 as measured by the Productivity Commission.

Box 2.1

WHAT IS PRODUCTIVITY?

The Productivity Commission (PC) defines productivity as:

a measure of the rate at which outputs of goods and services are produced per unit of input (labour, capital, raw materials, etc). It is calculated as the ratio of the quantity of outputs produced to some measure of the quantity of inputs used.

At a very broad level, productivity measures are often used to indicate the capacity of a nation to harness its human and physical resources to generate economic growth. There are two ways of thinking about productivity:

- *minimising* the use of inputs - for example, reflecting efficient production processes that minimise waste; and
- *maximising* output - reflecting the use of resources in the production of goods and services that add the most value.

Measures of productivity

Productivity can be expressed as a physical measure (for example, number of cars produced per employee), a monetary measure (for example, thousands of dollars of output per hour worked), or an index (for example, output per unit of labour = 100 in 1997-98).

In principle, inputs can be broadly defined to cover people's time, their skills, land, raw materials, machinery and equipment, energy (for example, electricity) and so on. But, most commonly, inputs are defined in terms of labour (number of employees or hours of work) and capital (buildings, machinery and equipment, etc).

There are a number of approaches to measuring productivity.

- *Labour productivity* — is the ratio of (the real value of) output to the input of labour. Where possible, hours worked, rather than the numbers of employees, is used as the measure of labour input. With an increase in part-time employment, hours worked provides the more accurate measure of labour input. Changes in labour productivity can be attributed to labour where they reflect improvements in education levels, labour efficiency or technology that makes labour more productive.
- *Capital productivity* — is the ratio of (the real value of) output to the input of capital. Changes in capital productivity reflect the joint influence of capital, labour, intermediate inputs, technological change, efficiency change, economies of scale and capacity utilisation.
- *Multifactor productivity* — is the ratio of (the real value of) output to the combined input of labour and capital. This is a more comprehensive productivity measure how efficiently and effectively the main factors of production - labour and capital - combine to generate output. Sometimes this measure is referred to as total factor productivity (PC 2010). However, in some circumstances, robust measures of capital input can be hard to find.

Source: Productivity Commission 2010.

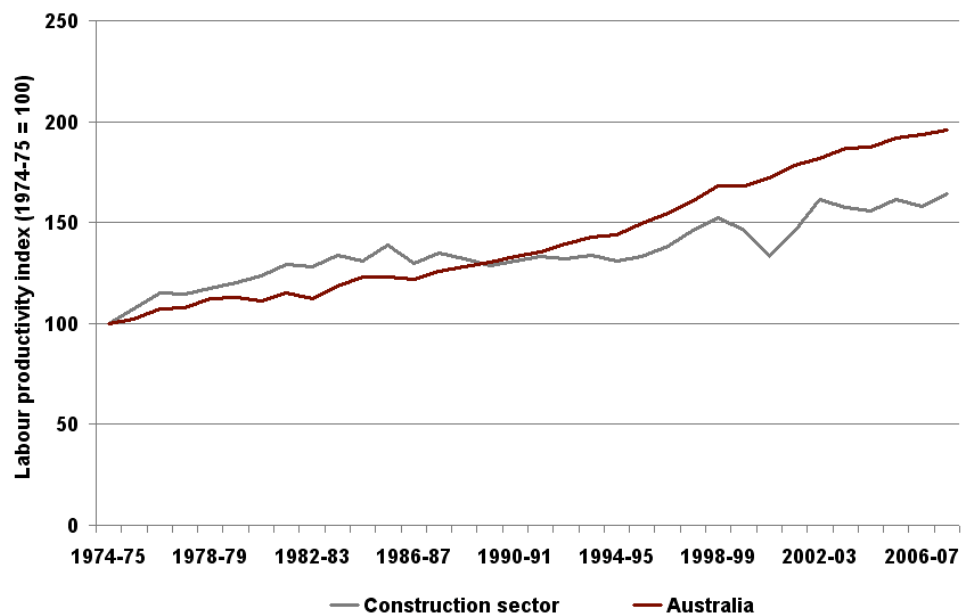
As shown in Figure 2.1, labour productivity in the construction sector has been growing, albeit at a slower rate than the aggregate productivity in Australia. While there are several explanations of the lower labour productivity in the construction sector, it is possible that the divergence can be explained as partly due to the lack of interoperability in the sector. Indeed, improvements in information sharing and interoperability have been suggested as fundamental to improving the productivity of the construction sector (McGraw Hill, 2007, p. 6).

The Productivity Commission does not provide productivity measures for other sectors that are part of the buildings network. However, estimates about labour productivity of some of these sectors (the rental, hiring and real estate services and professional, scientific and technical services sectors⁴) have been produced using published data from the ABS (see Figure 2.2). As shown in this figure, productivity in these other two sectors of the buildings network has actually declined since early 2000, while overall productivity in Australia is growing.

⁴ The rental, hiring and real estate services sector includes residential and non-residential property owners, while the professional, scientific and technical services sector includes architectural and engineering services.

Figure 2.1

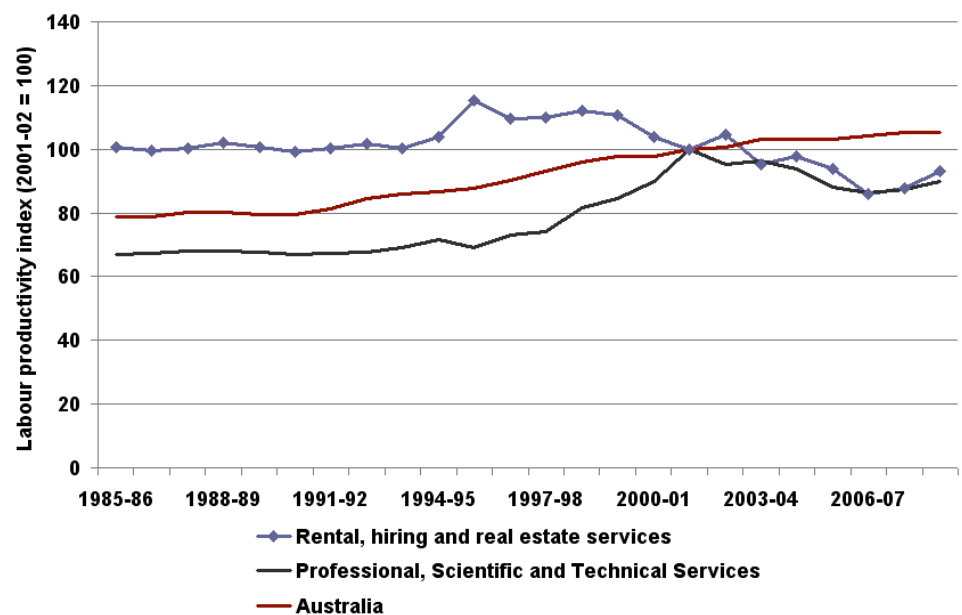
**CONSTRUCTION SECTOR LABOUR PRODUCTIVITY, 1974-75 TO 2007-08
(1974-75 = 100)**



Source: Allen Consulting Group analysis based on Productivity Commission 2010.

Figure 2.2

**LABOUR PRODUCTIVITY OF SELECTED SECTORS IN THE BUILDINGS NETWORK,
1985-86 TO 2008-09 (2001-02 = 100)**



Source: Allen Consulting Group analysis based on ABS 2009b and 2009c. Note: Figure shows labour productivity at the 1-digit level. Finer disaggregation of industries such as facility management and architectural services is not available.

In a period where other industries are experiencing productivity growth, the slower productivity growth in the construction sector and the falling productivity in some other sectors of the buildings network is a concern.

The buildings network industry is a fragmented and highly competitive industry, with extensive and complex contracting arrangements between principal and supporting agents. At present, communications between parties involved in the different stages of a building's life cycle are largely conducted by traditional means that are increasingly becoming inefficient as the volume of information exchanged and the number of parties involved in the supply chain increase. Further, while the parties involved in these stages produce information supported by information technologies, most of these systems are far from being fully integrated. These factors result in increased costs to the industry and the economy as a whole due to inefficient and fragmented communications, bottlenecks, redundant work, information gaps and repetition.

Additionally, analysts report that the buildings network industry is plagued with miscommunication, including slow documentation processing, inaccurate facility and maintenance planning, and scheduling conflicts (Hedges, n.d), as well as information loss throughout the supply chain (CWIC, 2005). The causes of such miscommunication are related to poor information management systems, incompatibility between different data management software and low levels of cooperation, coordination and collaboration.

The resultant double and triple checking of information, the manual re-entry of data into multiple systems and the duplication of business functions reduce the effectiveness of the supply chain, particularly at the design, construction and operational phases. Such inadequate 'interoperability' broadens the gap between all elements of the buildings network, and increases the cost of construction and maintenance (Chapman, 2005).

The application of innovative IT solutions in the Australian buildings network sector lags behind other sectors of the economy (ABS, 2004; Dubois and Gadde, 2002, cited in CWIC, 2005). Indeed, poor documentation and subsequent rework is estimated to contribute an additional 10-15 per cent to project costs in Australia (Engineers Australia, 2005). This is because inadequate information and data management, and the lack of standardisation of communication protocols, are likely to lead to increased costs and delays during the construction process. Such delays reduce the efficiency and competitiveness of the sector and increase the life-cycle costs of buildings.

2.2 What is BIM and how can it support the buildings network?

By implementing BIM risk is reduced, design intent is maintained, quality control is streamlined, communication is clearer, and higher analytic tools are more accessible

CRC for Construction Innovation, 2007a, p. 9.

A Building Information Model (BIM) (also referred to as building information modelling) is a database that provides digital information about the design, fabrication, construction, project management, logistics, materials and energy consumption of a building.

BIM is a 3D modelling technology and design process that has begun to change the way buildings are designed, built and operated. There is no single accepted definition of BIM, however, following the national *Digital Modelling Guidelines* produced by the CRC for Construction Innovation (2009), this report defines BIM as a model that has two essential characteristics:

The first is that it must be a three-dimensional representation of a building (or other facility) based on objects, and second, it must include some information in the model or the properties about the objects beyond the graphical representation.

CRC for Construction Innovation 2009, p. 1.

Other available definitions are available. For example, Eastman defines BIM as:

[...] a modeling technology and associated set of processes to produce, communicate and analyse building models.

Eastman et al., 2008, p. 13.

In the United States, McGraw Hill defines BIM as:

The process of creating and using digital models for design, construction and/or operations of projects.

McGraw Hill, 2008, p. 2.

Finally, Erabuild defines BIM as:

[...] an object-oriented model — a digital representation of a building to facilitate exchange and interoperability of information in digital format.

Erabuild, 2008, p. 12.

The use of BIM has the potential to streamline processes throughout a building's lifecycle through the integration of design, engineering, construction, maintenance and decommissioning information about a built asset project into a single rich model. Table 2.3 provides an overview of the possible application of BIM to various stages of a building's lifecycle.

Table 2.3

APPLICATION OF BIM TO VARIOUS STAGES OF A BUILDING'S LIFECYCLE

Design	Construction/ Procurement	Operations / Facilities Management	Decommissioning
- Ensure the right facility is designed. - Evaluate the design from many perspectives. - Evaluate the design against building codes and sustainability before construction.	- Develop better cost estimates. - Ability to track work in real time. - Ability to manage site and flow of resources. - Demonstration of the construction process, including access and egress, traffic flows, site materials, machinery, etc.	- Keep track of built asset - Manage the facility proactively. - Capability to schedule maintenance and review maintenance history.	- Identify elements that can be recycled or those that require particular care (eg. Hazardous materials). - Know the composition of structures prior to demolition.

Source: Adapted from CRC for Construction Innovation, 2008.

An important aspect of BIM technology is its dynamic ability to explore the structure of objects and their relationship to each other (for example, doors are a type of opening that permit access to different areas of a building). Furthermore, both 4D (scheduling) and 5D (cost data) functions may also be able to be integrated with BIM, further boosting its application potential (McGraw Hill, 2008).

It is essential to remember that BIM is process-driven, and does not rely on a single piece of software. BIM may be a series of interconnected models and databases. BIM establishes a high level of interoperability between software packages, as it is capable of integrating information from disparate software systems. This enables participants to use, reuse and exchange information for decision-making or design purposes in a coordinated and efficient manner. Box 2.2 outlines the concept of interoperability and Figure 2.3 illustrates the potential of BIM technology to coordinate all aspects of the information exchange.

Box 2.2**INTEROPERABILITY AND BIM**

The *BIM Journal* defines interoperability as:

[...] the ability to communicate and manage electronic data effectively, without the need for human input in terms of manipulation or translation of data [...] from a business perspective, interoperability is a cultural rather than a technological requirement. In this sense a more meaningful definition for interoperability is the ability to implement and manage collaboration between project team members. Viewed from a combination of these perspectives, the overriding benefit of interoperability is that team members can easily exchange information across the numerous platforms and applications used in a typical project, thereby increasing efficiency and reducing errors.

An effective interoperable environment ensures one-time data entry and the seamless flow of information to all stakeholders throughout the project life cycle. Because multiple stakeholders share the same information, improvements in interoperability lead to improvements in the efficiency and competitiveness of each stakeholder.

A global standard on interoperability, the Industry Foundation Classes, is published by the International Alliance for Interoperability. The standard was set in order to address the waste of resources, money and time that occurred due to the historic inefficiencies of the built asset process. Open international standards are imperative for an efficient information exchange.

Source: BIM Journal, 2009; Brown, 2008.

The purpose of promoting widespread adoption of BIM technology in Australia is to move towards integration of members of the buildings network to advance information dissemination and data management and reduce transaction costs, which will improve decision-making and enhance collaboration along the supply chain. BIM technology addresses interoperability issues by:

- providing the infrastructure to reduce delays due to inefficient design and operational processes; and
- engaging stakeholders through a single database.

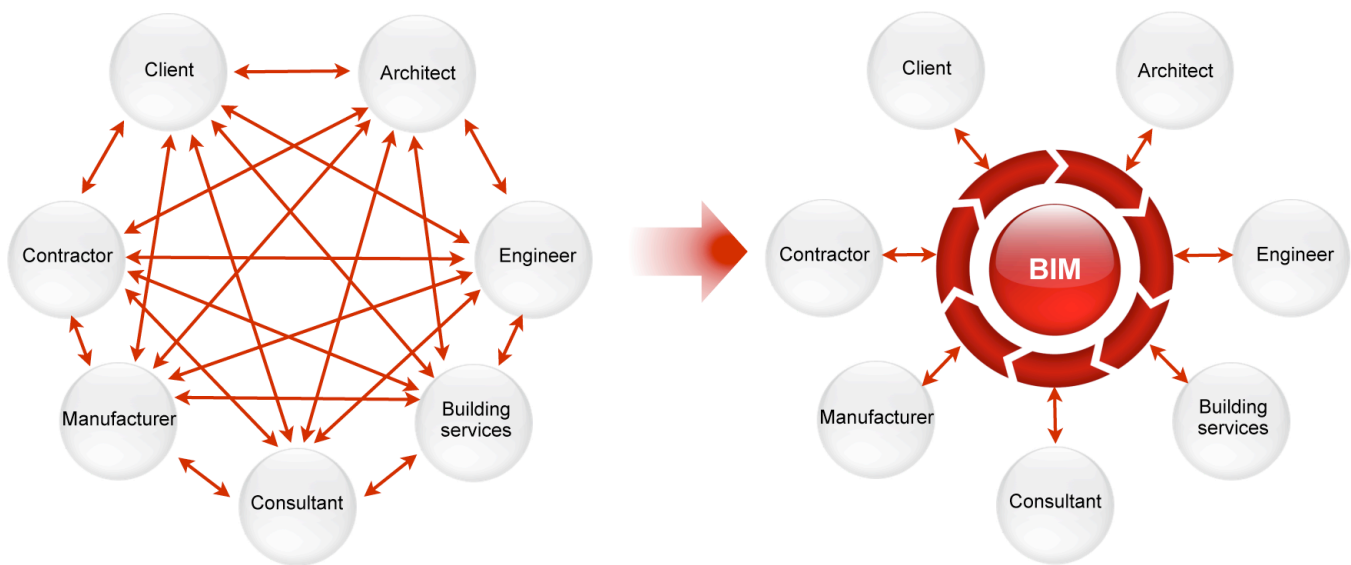
The time saved through enhanced information management is likely to generate productivity and efficiency gains, and also improve design outcomes through better understanding of design alternatives by clients and designers (CRC for Construction Innovation, 2007a).

Key areas of improvement for the industry may be assisted by the use of BIM technology. These include (NAS, 2009):

- improving on-site efficiency through more effective interfacing of people, processes, materials, equipment, and information;
- utilising prefabrication, pre-assembly and off-site fabrication techniques and processes; and
- measuring performance more accurately to increase efficiency.

Figure 2.3

BIM: INFORMATION EXCHANGE



Source: Adapted from Dinesan, B., 2008.

BIM can be adopted for projects in differing ways. The Australian Institute of Architects (AIA) diagram, 'Towards Integration', which has been developed jointly by the AIA's Integrated Practice Taskforce and the CRC for Construction Innovation, seeks to describe these possibilities graphically in defined stages (see Figure 2.4). This diagram is an intentional simplification of what is a complex and evolving process to assist in developing awareness of BIM implementation (CRC for Construction Innovation 2009, p.11). The diagram is arranged in four major stages, each with two subdivisions.

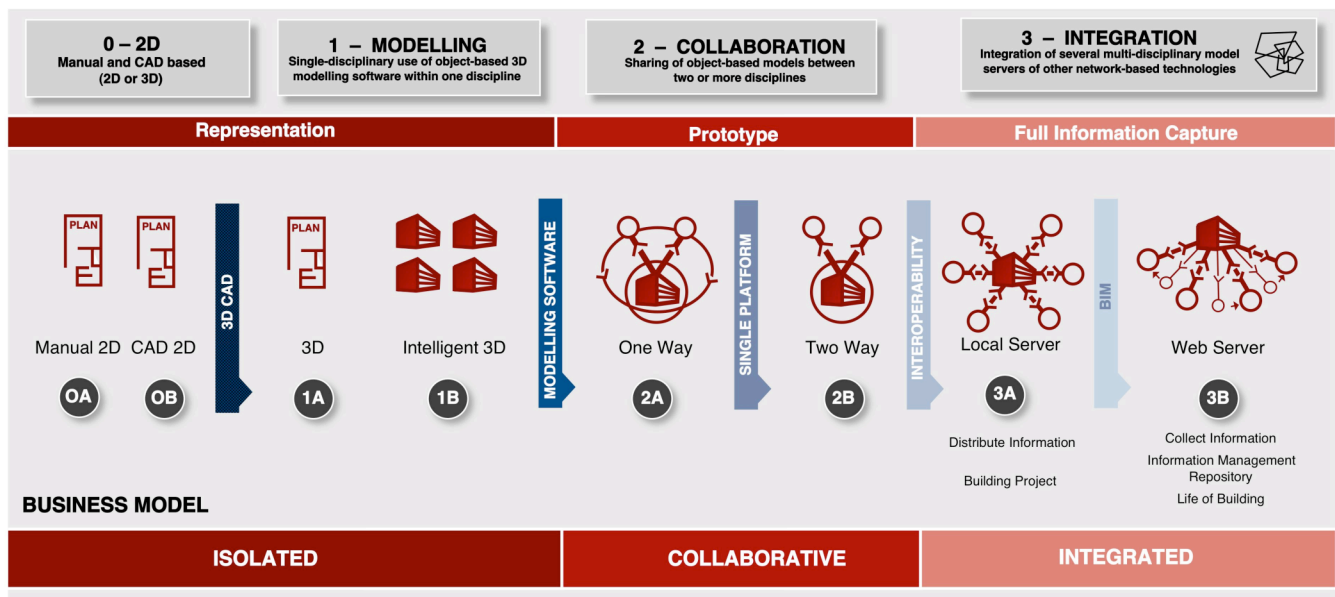
- Stage 0: 2D documents — based on manual and CAD 2D drafting.
- Stage 1: Modelling — moving from visualisation to intelligent 3D modelling.
- Stage 2: Collaboration — starting with one-way exchange and expanding to two-way collaboration.
- Stage 3: Integration — exploiting server technologies, initially locally and extending to web-based systems.

Stages 0A, 0B and 1A represent pre-BIM technology. A large part of industry practice is still operating at this stage. Stages 1B, 2A and 2B describe the first stages in the adoption and use of BIM. They also represent that part of the industry that is implementing BIM. The evidence is that most practitioners are currently at stage 1B (CRC for Construction Innovation 2009, p.11).

3A and 3B describe technologies and processes hosted on model servers. These model servers are yet to be implemented in the Australian buildings network industry, but are currently being used for research at the University of New South Wales and Queensland University of Technology.

Figure 2.4

TOWARDS INTEGRATION



Source: Adapted from CRC for Construction Innovation 2009, p. 13.

Chapter 3

Benefits of BIM adoption

In Chapter 3, the benefits of BIM technology for the buildings network industry are analysed in terms of improved information sharing, enhanced productivity, improved quality, increased sustainability and labour market improvements.

The adoption of BIM technology offers direct and indirect benefits to all parts of the buildings network. Nevertheless, BIM technology requires a shift in not only the technology used, but also in the way design and construction teams work.

As BIM technology becomes more widespread, the benefits are likely to spur changes throughout the buildings network — through the design, construction, operation and decommissioning stages, potentially leading to the development of new business models.

The key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment (CRC for Construction Innovation, 2007c, p. 3-4). Related benefits are:

- automated assembly — digital product data can be exploited in downstream processes and manufacturing;
- better design — building proposals can be rigorously analysed, simulations can be performed quickly and performance benchmarked, enabling improved and innovative solutions;
- controlled whole-life costs and environmental data — environmental performance is more predictable, lifecycle costs are understood;
- enhanced processes — information is more easily shared, can be value-added and reused, which enables government, industry and manufacturers to have a common data protocol and operate more effectively;
- higher production quality — documentation is improved as objects are only modelled once in BIM, meaning that drawings automatically derived from that model are more consistent and accurate, and avoid clashes that may otherwise occur;
- improved customer service — proposals are understood through accurate visualisation; and
- lifecycle data — requirements, design, construction and operational information can be used in facility management integration of planning and implementation.

Figure 3.1 illustrates the generic value added benefits of the BIM system across the sector supply chain. For example, BIM technology improves the approval, design, specification and documentation, as well as the tendering, appointment and contract management stages of a project by increasing data integration and information sharing, as well as reducing design and documentation shortcomings.

Figure 3.1

THE VALUE ADDED BENEFITS OF BIM TECHNOLOGY

VALUE CHAIN ELEMENT	TYPICAL ACTIVITIES	BIM VALUE ADD
MAINTENANCE OR CAPITAL INVESTMENT NEED IDENTIFIED	Asset Management Project Identification and Assessment	Increased data integration and information sharing. Reduced design and documentation short comings
FUNDS ALLOCATED	Investment Analysis and sourcing	
APPROVAL	Concept, Business Approval, Planning Approval	
DESIGN, SPECIFICATION AND DOCUMENTATION	Design, Estimate, Specification, Contract Documentation	
TENDERING, APPOINTMENT AND CONTRACT MANAGEMENT	Procurement Models Contract and Project Management Models	Reduced dependability between project stages Improved coordination between steps will reduce network costs
SET-OUT AND SITE CONTROL AND WORKS	Survey, Site Safety, Earth Works	
CIVIL AND STRUCTUAL	Pavement, Drainage, Concrete, Steelwork, Framing, Brickwork, Roofing	
SERVICES	Utilities, Communications, Lighting, Control Systems	
FIT-OUT AND FINISHING	Painting, Rendering, Plastering, Tiling, Floor Covering, Kitchens, Bathrooms, Joinery, Street Signs and Furniture	Clear and complete (digital) information will ensure diligence in documentation
TAKE-OVER AND MAINTENANCE PERIOD	Inspection, Remediation	
DOCUMENTATION AND INSPECTION	Documentation, Asset Management	
BUILDING AND CONSTRUCTION VALUE CHAIN		

Source: Adapted from Farley, 2007, pp. 27-60.

The literature on the benefits of BIM technology in Australia is limited. However, it has been estimated that 60 to 90 per cent of all project variations are the result of poor project design documentation — a failing that BIM technology can address (CRC for Construction Innovation, 2007a).

Significantly, BIM technology reduces three types of costs (Hedges, n.d):

- avoidance costs — by reducing interoperability problems such as maintaining paper exchange systems due to improved information and communication processes;
- mitigation costs — by reducing the need to perform redundant activities such as manually re-entering data as professionals are able to work simultaneously within the same 3D model; and

- delay costs — for instance, by reducing the waiting times for informational exchange.

It is generally accepted that as much as 30 per cent of the cost of construction is wasted due to coordination errors, incorrect materials, and labour inefficiencies (CURT, 2004; Brown, 2008, p. 16).

The 2009 McGraw Hill survey found similar benefits to the use of BIM technology. These benefits are outlined below (McGraw Hill, 2009, pp. 4-5).

- Better than expected value — 70 per cent of users who measure return on investment (ROI) saw a positive return on the use of BIM, and 20 per cent of those recorded ROI of more than 50 per cent.
- Competitive advantage — BIM is seen as a way of entering new markets, and an additional way of marketing a firm. For example, half of BIM users reported that offering new BIM services is a significant benefit to their business.
- Improved productivity — BIM technology reduces rework and duplication, with 80 per cent of experts saying that BIM brings high to very high value to a firm. BIM also has the potential to improve productivity and reduce conflicts and changes during the construction stage of a project.
- Investing in the team — The use of BIM technology facilitates better multi-party communication and 3D visualisation, which 80 per cent of users consider to be of high importance. It also improves project process outcomes (such as fewer field coordination problems), which was rated by users as the second-most important way of improving value.
- Rapid adoption — Half of the US construction industry is using BIM and BIM-related tools, more than four times the number in 2007. Significantly, two-thirds of experts use it on more than 60 per cent of their projects.
- Owner demand — Half of owners report better construction outcomes as a result of the use of BIM technology.

3.1 Improved information sharing

The potential to use BIM for operations and maintenance of the building through its life cycle, even to the point of telling the demolition contractor what materials are in the building at the end of its life, is a plus [...] The Army hasn't gone that far yet, and I don't think many private owners have gone that far [...] But I believe in five to 10 years it will be the norm throughout the industry to use BIM for operation and maintenance.

United States Army Corps of Engineers, 2009, p. 8.

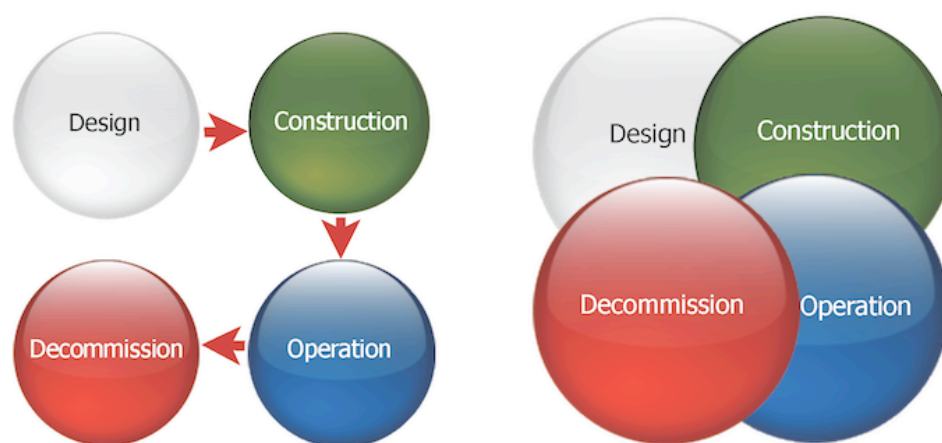
Before the development of BIM technology, each stage of the building supply chain — design, construction, operation and decommission — was obliged to source the required information from prior stages, as illustrated on the left hand side of Figure 3.2. Differences in terminology and software compatibility usually increased the time needed to finish the project (CRC for Construction Innovation, 2007a).

However, it is estimated that BIM technology can reduce the time to complete a project by 7 per cent, as all stakeholders have access to critical information, including schedule and budget information, materials quality and costing information, performance, utilisation, and financial information (Brown, 2008, p. 10; CRC for Construction Innovation, 2007a).

BIM technology has the potential to facilitate information sharing in real time between all stages of the building's life. For example, the information required at the end of a building's life (such as information about the materials within the building, hazardous substances, and potential materials to be recycled) will be available to decommissioning or demolition teams without having to liaise with the original designers or plans. In addition, all stakeholders will have immediate access to critical information such as schedule and budget information, and materials quality. This is illustrated on the right hand side of Figure 3.2.

Figure 3.2

INFORMATION SHARING IN THE BUILDINGS NETWORK: BEFORE AND AFTER BIM

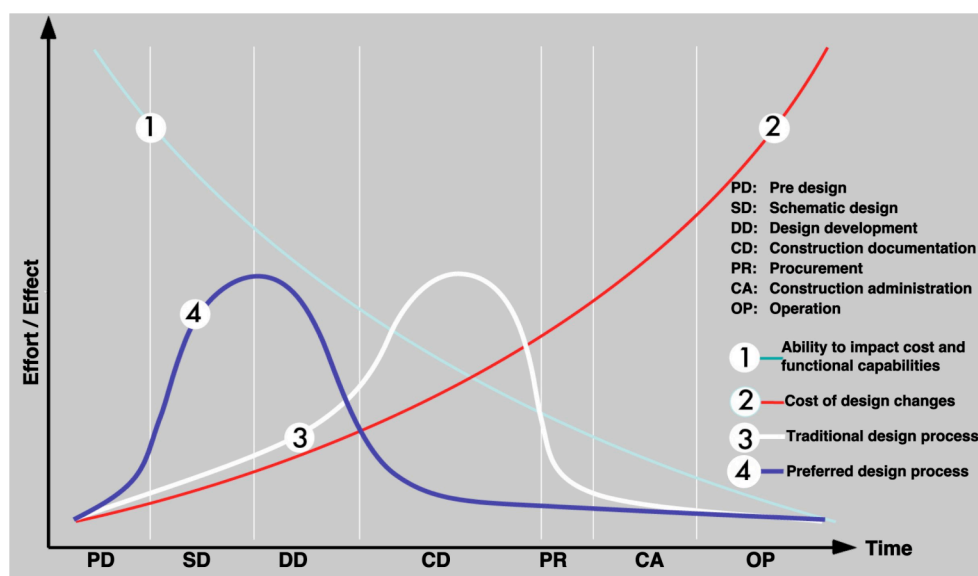


Source: The Allen Consulting Group, 2010.

The benefits of improved information sharing include the avoided costs of miscommunications. In 2007, McGraw Hill estimated that inadequate or failed software directly resulted in an increase in costs of around 3.1 per cent. Improved interoperability and information sharing reduces costs associated with manual re-entry of data between different systems, time spent duplicating software, time lost to document version checking, increased time required for information processing, and money for data transactions (McGraw Hill, 2007, p. 5).

Figure 3.3 highlights the benefits to be gained from earlier information sharing, when there is greater opportunity to detect potential problems and influence positive outcomes, both at minimal costs. Earlier decision-making will also lead to a shorter documentation phase and accelerated building construction.

Figure 3.3

BIM TECHNOLOGY: THE BENEFITS OF EARLY INFORMATION SHARING

Source: Adapted from buildingSMART UK, 2010.

The potential benefits of streamlined processes, better data quality, visualisation of data, enhanced fault finding and increased communication through the supply chain ensure productivity and efficiency gains across the sector. For example, in Figure 3.3, the preferred design process (line 4) achieved through the use of BIM technology allows most of the work to occur while there is still the opportunity to impact cost and functional capabilities of the building being constructed. This compares with the traditional design process (line 3), in which most of the work is done after opportunities to impact the cost and functional capabilities of the building are diminished.

Another key benefit of BIM is that, through improved information sharing, it facilitates the implementation of Integrated Project Delivery (IPD) approaches (see Box 3.1). An integrated design and delivery team having aligned objectives with high-level transparency is seen as the optimal solution to enhance both design value and overall project value. Indeed, IPD is seen as an effective process that results in better, faster, less costly and less adversarial construction projects that can drive significant and rapid change in the construction industry (AIA 2007).

Box 3.1

INTEGRATED PROJECT DELIVERY

Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimise project results, increase value to the owner, reduce waste, and maximise efficiency through all phases of design, fabrication, and construction.

IPD principles can be applied to a variety of contractual arrangements and IPD teams can include members well beyond the basic triad of owner, architect, and contractor. In all cases, integrated projects are uniquely distinguished by highly effective collaboration among the owner, the prime designer, and the prime constructor, commencing at early design and continuing through to project handover.

Source: AIA, 2007.

3.2 Enhanced productivity

BIM technology is likely to enhance productivity throughout the building supply chain. The ability to design complex buildings virtually, working closely with all engaged stakeholders in real time, ensures feature optimisation and high quality physical construction and production efficiency. Enhanced productivity is common to all sectors that have adopted similar modelling technologies in their supply chain activities (McGraw Hill, 2008, p. 21).

In the United States, the National Institute of Standards and Technology considers the widespread deployment and adoption of BIM technology to be a breakthrough opportunity. Other benefits of BIM that may improve productivity include greater use of pre-fabrication and pre-assembly, widespread use of demonstration projects, and effective performance measurement (McGraw Hill, 2009, p. 12). Furthermore, the 2009 McGraw Hill survey found that two-thirds of BIM users report a positive ROI on their overall investment in BIM, and 87 per cent of expert users are experiencing positive ROI with BIM (McGraw Hill, 2009, p. 4). This is in keeping with the results of the 2007 McGraw Hill survey on interoperability, which found that the industry perceives interoperability to be a major determinant of productivity growth.

In Australia, Engineers Australia estimated that a 10 per cent improvement in efficiency in the construction industry would increase GDP by 2.5 per cent over five years (Engineers Australia, 2005).

3.3 Improved quality

Trade-offs of quality against time and cost have often been a feature within the buildings network. Competitive tendering processes and sub-contractor arrangements, in conjunction with uncontrollable variables such as adverse weather conditions, result in cost and time pressures, and hence negatively impact on quality (CWIC, 2005).

BIM provides object-oriented models with rich semantics and relationships encoded, supporting the automated analysis of the performance of building products and designs. This basically leads to improved design, implementation and management at all stages of the building's life cycle.

A major opportunity arising from the use of BIM technology is the ability to improve quality by raising on-site efficiency through the utilisation of prefabrication, pre-assembly and off-site fabrication techniques and processes. Indeed, BIM technology provides a means to encourage more industrialisation of building components, meaning the building site will become a place of assembly rather than manufacture.

In addition, BIM has been proven to improve data quality, enhance visualisation of data, and improve fault identification at all stages of the construction supply chain (Brown, 2008). Apart from facilitating information exchange and reducing coordination problems, BIM may also dramatically decrease errors. Virtual design and construction with BIM creates the potential to identify problems earlier in the building process.

3.4 Increased sustainability

BIM [...] has the potential to be aligned with the recent movement towards a language and practice of sustainability, which relies heavily on an integrated systems approach to drive energy and resource efficiencies.

Lesniewski et al., n.d. pp. 7-8.

Sustainability, and particularly emissions mitigation and abatement, is an integral consideration for all new developments. BIM technology provides the tool with which to incorporate sustainable design and implementation at all stages of the building sector supply chain. Indeed, many of the analysis and design opportunities to make buildings more sustainable throughout their lifecycle would be unaffordable without the use of BIM technology, which facilitates performance measurement. Box 3.2 highlights the relationship between the built environment and emissions.

Box 3.2

THE BUILDING SECTOR AND GREENHOUSE GAS EMISSIONS

According to the Australian Sustainable Built Environment Council's *Second Plank* report, 23 per cent of Australia's emissions are attributable to the built environment sector. Looking ahead, the sector's emissions are expected to grow by approximately 38 per cent by 2029-30 from 2009-10 levels (under a Business-as-usual scenario).

Energy consumption in buildings is the fundamental source of emissions. Apart from the amount of energy used, the building sector's relatively high emissions contribution is due to its heavy reliance on coal fired electricity generation located at the end of long transmission networks.

BIM offers a practical solution to reducing emissions in the building sector, as the technology drives sustainable building design. BIM can also facilitate the implementation of energy efficient initiatives by allowing users to study the performance of a building throughout the construction process.

Source: ASBEC, 2008 and Allen Consulting Group.

BIM technology facilitates reliable performance analysis based on accurate model data, timely whole-life costs, and readily available environmental data. This leads to sustainable performance across a range of metrics, including thermal performance, waste minimisation during construction, and effective management during both construction and operation.

Other benefits of BIM technology (such as reduced costs associated with errors and omissions) enhance the sustainability of the construction and operation phases of the building life cycle. For example, the higher production quality (through improved documentation) facilitated by BIM technology means that drawings are more consistent and accurate and help to avoid clashes — that waste materials and resources — that may otherwise occur.

BIM technology facilitates sustainable design as it (Lesniewski et al., n.d., p. 11):

- reduces the costs associated with design and construction complexity;
- reduces material waste;
- reduces errors and omissions;
- increases the ability to quantify and test variables;
- increases precision in fabrication; and
- increases opportunities for new design breakthroughs.

Through digital documentation, users of BIM are able to study the performance of the building, including energy efficiency and sustainable materials. BIM technology also has a fundamental role to play in the monitoring and reporting of energy efficiency and other sustainability reporting requirements. As noted by McGraw Hill, ‘BIM should help integrate ongoing measurement and verification of actual building energy use and compare it to the predicted model to inform owners how their building is performing against the designed energy standard’ (BuildingSMART Australasia, 2010; McGraw Hill, 2009, p. 49).

BIM removes the duplication and waste from the business processes involved in design and construction. Analysis of environmental impacts and life-cycle costs can also be carried out at an early stage, with design changes to enhance sustainability early in the construction phase offering long term benefit. Furthermore, independent BIM models can be created for specific purposes with the decisions fed back into the central BIM (Dinesan, 2008, p. 10).

3.5 Labour market improvements

Labour market productivity improvements are one of the central benefits of BIM technology. This is because BIM technology encourages more collaborative working practices, where all design team members are engaged at an earlier stage in the design process. For example, architects and engineers may use BIM data to enhance design opportunities and seek synergies between the drafting and design professions (McGraw Hill, 2008, p. 27).

During the construction phase, schedule changes due to site conditions may be coordinated by BIM technology, assisting operators schedule personnel decisions in advance, at least cost. The potential of BIM to offer scheduling functions — also referred to as 4D — is an emerging benefit. Although the design capabilities of BIM are widely employed by users, the industry is still in the early phases of adopting BIM for scheduling. This is likely due to the large investments that firms have already made in project management software. As BIM use among contractors expands faster than among other users, greater use of 4D can be expected in the near future. It should be noted that contractors are most likely to see the benefit of BIM technology in terms of scheduling, and other participants along the supply chain, including architects, engineers and owners, may see less benefit in this aspect of the technology (McGraw Hill, 2008, p. 16).

3.6 Wider benefits of digital modelling

The use of digital modelling tools can deliver benefits that extend beyond the potential to streamline processes throughout a building's lifecycle. Indeed, the use of these tools can have wider benefits for the Australian community when the use of this technology is extended to, for instance, urban planning, infrastructure development and the designing and understanding of city environments. It is already possible to model new developments at precinct, suburban and in the near future, larger urban scales.

Widespread use of digital modelling tools can also increase the performance of new and renovated buildings by improving material consumption, energy efficiency, carbon emissions and the productivity of the occupants (BEDP, 2007).

Further, the emergence of next generation digital modelling tools that make better use of performance data and are able to deal with the large data sets will enable dynamic analysis and optimisation of designs. In an issues paper on the topic of technology, innovation and sustainability, the Australian Council of Built Environment Design Professions (BEDP) suggests that a set of high-level performance objectives for the built environment 'should, for example, address energy consumption, water usage, waste disposal, public transport and social development, and take heed of projected changes in key related domains such as demography, availability of resources, technology, etc.' (BEDP, 2007, p.12).

Finally, some essential systems (transport, electricity grids and water supply, for example) can be optimised in real time using sensors, networks and computers. These advances can underpin, for example, more efficient solutions, use of innovative materials, and support more sophisticated modes of manufacturing, assembly and asset management.

3.7 The Australian experience

Pilots in various countries have demonstrated significant time, costs savings and quality enhancements. There are however significant barriers and costs, which need to be addressed in order for these benefits to be realised on a broad scale. It is therefore recommended that several small and some larger pilot projects are undertaken first, in order to assess the benefits of the technology.

Brown, 2008, p. 29.

In 2007, a BIM application test case was conducted on the Sydney Opera House. The Facilities Management Exemplar Project confirmed that structural, architectural and analysis benefits were likely to result from the use of BIM technology (CRC for Construction Innovation, 2007b). Box 3.3 examines the use of such BIM technology in the Sydney Opera House.

Box 3.3**CASE STUDY: BIM AND THE SYDNEY OPERA HOUSE**

As a part of the CRC for Construction Innovation's 'Facilities Management Exemplar Project', a BIM was developed for the Sydney Opera House. The purpose of the project was to determine whether such a model could support the asset and facilities management functions of the building.

The vast amount of information generated over the Sydney Opera House's 35 years of construction and renovation was integrated into one model. Prior to the development of this model, the Sydney Opera House utilised several independent information systems.

The BIM model developed integrated information from disparate software systems and combined this with a spatial 3D design and geographical platform, which facilitated a streamlined information exchange between each aspect of the building.

The CRC for Construction Innovation found that the BIM 'clearly demonstrated benefits in the support of [facility management] processes, asset management applications and broader organisational objectives.' Tests showed that the data collected and exchanged was reasonably geometrically accurate and supported the configuration of building elemental properties and relationships.

Given the positive results for the Sydney Opera House resulting from the use of BIM technology, it is likely that the use of standardised BIM technology could reap significant sector industry benefits.

Source: CRC for Construction Innovation, 2007b; CRC for Construction Innovation, 2007c.

Box 3.4 provides a second case study of the use of BIM technology in Australia.

Box 3.4**CASE STUDY: A MULTISTOREY OFFICE TOWER**

A BIM was developed for the construction of a multistorey office tower located in Melbourne's CBD.

The company had previously used CAD technology, and while many employees were not aware of the full capabilities of BIM technology, the concept was not unfamiliar.

BIM was seen as a way of documenting projects more accurately, achieving a higher degree of reuse of design objects, and reducing Requests for Information. However, a number of factors were nominated as deterrents to BIM adoption, including resource implications and internal company politics. In particular, BIM was seen as an ideal platform for a national project with complex relational documentation.

With around 45 CAD operators, in-house training was seen as more efficient and less disruptive for the 20-25 hours needed for general BIM software and other specialised training. Staff retention and turnover was another issue since loss of expertise and the subsequent need to train new staff members.

BIM technology was implemented early in the Schematic Design stage of this project, and the peak of the effort versus time was moved to earlier in the project.

The BIM reduced the amount of internal communication required to understand and explain the project and increased the levels of collaboration within the team and with the client, allowing quick visualisations to be produced.

Key stakeholders felt that this opportunity to better explain things was significant, however there is no incentive for designers to share the information. However, BIM was considered an important tool to form strategic alliances and share intellectual property between collaborators.

Over the course of the project, the use of BIM technology required specialised software with certain characteristics, as well as a significant process re-structure (internal and external).

However, the use of BIM technology was also found to improve design and efficiency, as well as communication and information management.

Source: CRC for Construction Innovation, 2007a.

To further stimulate the adoption of BIM technology in Australia and enable potential users to leverage the inherent benefits of BIM technology, the CRC for Construction Innovation published *BIM Digital Modelling Guidelines* and the *Case Studies for Digital Modelling* in 2009 (CRC for Construction Innovation, 2009).

3.8 Lessons from the United States

The use of BIM technology in the buildings network industry has increased in recent years, with many countries, including the United States, adopting this technology.

In the United States, research indicates that half of the industry in 2009 was using BIM and BIM-related tools, which represents a 75 per cent increase from 2007. Indeed, 42 per cent of users consider themselves being able to use BIM at an advanced or expert level, three times the amount in 2007 (McGraw Hill, 2009, p. 5; 36).

Other key findings about the adoption of BIM technology in the United States include (McGraw Hill, 2009, p. 37):

- users expect the rate at which BIM is used will double between 2009 and 2011;
- the use of BIM by contractors quadrupled between 2007 and 2009; and
- those who do not use BIM are more open to adopting BIM technology than ever before.

Support for BIM technology in the United States increased substantially following the publication of two reports by the National Institute of Standards and Technology. The reports focused on measuring the cost savings due to inadequate interoperability in the capital facilities segment of the United States construction industry (Brown, 2008), and estimated the annual cost burden to be US\$15.8 billion (Chapman, 2005). These cost impacts are relevant throughout the buildings network — including to owners and operators of capital facilities, as well as design, construction, operation and maintenance services (Chapman, 2005. p. 1).

The Stanford University Centre for Integrated Facility Engineering (CIFE, 2007) reviewed 32 major projects and attributed the following benefits to the use of BIM technology (Brown, 2008, p. 12):

- 7 per cent reduction in project time;
- 10 per cent saving of the contract value through clash detection;
- 40 per cent elimination of unbudgeted change; and
- 80 per cent reduction in the time taken to generate a cost estimate, with cost estimation accuracy within 3 per cent.

Finally, in the United States, BIM technology is associated with a decrease in the percentage spent on change orders relative to coordination errors, and 47 per cent of users (particularly contractors) see this as a significant benefit (McGraw Hill, 2009, p. 15).

However, it should be noted that different sections of the United States market value BIM in different ways. The key points to note are (McGraw Hill, 2009, p. 29):

- architects are perceived to reap the highest value from the use of BIM;
- engineers see the most value in marketing BIM services and the most productivity gains (although civil engineers lag behind structural and mechanical, electrical and plumbing engineers in adoption);
- contractors reap the highest value from benefits related to costs; and
- owners see BIM as a valuable communication tool.

Chapter 4

Costs of BIM adoption

Chapter 4 examines the costs involved in the implementation of BIM technology. These costs include start up and administration, education and training, and transition and behavioural costs.

4.1 Education and training costs

Adequate training is a barrier to the adoption of BIM technology, as only a limited number of users are adequately trained. However, as more experience is gained within the industry, training will become less of a challenge (McGraw Hill, 2008, p. 9). Education and training costs for companies looking to adopt BIM technology will be, to a degree, eliminated when universities and other education providers incorporate BIM training into degrees and coursework.

Education and training costs have two broad elements — ensuring a company has the required personnel (either by hiring new staff or by retraining existing staff) to establish and integrate BIM technology into a company's operations, and retraining the majority of existing staff to support the behavioural and organisational change required to fully adopt BIM technology within a business model.

There are few degrees with a dedicated and specific education and training BIM course component in operation at present in Australia (although it should be recognised that several universities teach the basic principles of BIM technology). However, a pilot project has begun to explore these issues. The University of South Australia, together with the University of Newcastle and the University of NSW, are set to carry out a survey of current BIM education practice in selected academic institutions in Australia and Europe in order to develop a collaborative building design elective course to be offered in the later years of engineering, architecture and building university courses. Indeed, future graduates proficient in BIM technology are likely to drive the adoption of BIM technology.

4.2 Administration and start up costs

The implementation of BIM technology requires specialised software and data storage, and may initially represent a significant cost to a company — depending of course on the size of the company. The purchase of BIM software may therefore present a barrier to smaller firms. The cost of software and required hardware upgrades are also considered significant hurdles by smaller companies.

Another concern is the fact that not all applications are interoperable. Ensuring interoperability requires significant start up costs. This is particularly problematic when individual project teams involved in the design, construction and operation phases have based their business model around pre-existing technology, much of which represents a capital investment. To avoid issues down the track, at the start of a project, unless the client sets out the platform to be used, participants will need to establish how compatible their applications are.

The manageability of a complex BIM project is a major information management challenge. In particular, the size and complexity of the files created by use of BIM technology — despite advances in technology storage devices — continue to be unwieldy.

Nevertheless, in the McGraw Hill 2009 survey, a comparison of costs and benefits found that users of BIM technology perceive the benefits to outweigh the costs involved. For example, 41 per cent of users report that their project profitability increased, while only 12 per cent reported that it decreased. The costs specifically included in this survey included the costs of hiring external BIM consultants, additional office space, additional staff, and of course, the BIM software itself (McGraw Hill, 2009, p. 13).

4.3 Transition and behavioural costs

The support of senior management is essential to the widespread adoption of BIM technology, as senior managers are more likely to be required to justify the costs and efforts associated with bringing BIM into practice. Furthermore, there may be disinterest among more experienced veterans of the industry, who have been operating in a certain way for many years (McGraw Hill, 2008, p. 9).

To date, the standard practice in the built environment sector involves the appointment of an architect, who produces the initial drawing set, then the appointment of structural and services engineers. Importantly, the levels of design activity (and associated fees) increase as the project nears and enters the construction phase. However, changes during the construction phase of a project are relatively costly. BIM technology would help to mitigate such costs by drawing all parties together in the project at an earlier stage, and facilitating information sharing.

BIM cannot be implemented through a gradual progression from legacy CAD to BIM [...] adopting BIM concepts and technologies requires a mindset of 'revolution'; a process that cannot evolve from replicating legacy CAD standards and procedures.

CRC for Construction Innovation, 2009, Digital Modelling Guidelines, p. 17.

Chapter 5

BIM in Australia: State of Play in 2010

Chapter 5 summarises the key findings of a survey undertaken by buildingSMART Australasia, the School of Natural and Built Environment (University of South Australia) and NATSPEC on the adoption, usage, costs and benefits of BIM in Australia.

5.1 BIM survey 2010

To find the current state of play about adoption, usage, costs and benefits of BIM in Australia in 2010 a survey has been conducted. The survey was conducted by buildingSMART Australasia, the School of Natural and Built Environment (University of South Australia) and NATSPEC.

The survey was voluntary and conducted by sending uncontrolled emails via professional organisations. The results of this survey need to be interpreted with caution because of the following issues.

- The survey was conducted by sending uncontrolled emails via professional organisations, there is no information on the response rate of the survey.
- The survey results ‘appear to show more BIM users than expected through anecdotal evidence’ and have a ‘positive bias likely due to voluntary responders being interested in BIM’ (buildingSMART Australasia et al., 2010).
- Answering each individual survey question was not compulsory. For example, while the total number of survey responses was 400, the actual number of respondents for any one question ranged roughly between 180 and 280.
- There is limited information about the buildings network industry in Australia, both in terms of total number of businesses in the industry and their size in terms of employment and turnover. Therefore, it is not possible to know what proportion of the buildings network industry answered the survey (that is, it is not possible to know the representativeness of the survey sample).
- The survey authors did not undertake any statistical analysis of the results, so there is no information available about confidence intervals or variances of the results. In light of this, this report only reports headline survey results, while noting that some of these results may not be statistically significant.

While the limitations outlined above mean that the survey results cannot be treated as ‘representative’ of what is currently happening in the buildings network industry (especially with regards to the level of BIM adoption and its frequency of use), they provide a useful illustration of the costs and benefits experienced by those who are already using BIM in Australia.

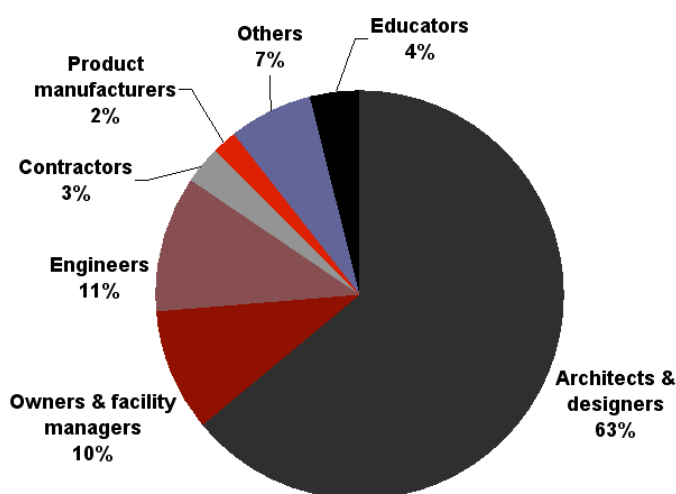
This chapter provides a summary of some of the key results of this survey. Notably, the response data provided below represents the proportion of actual respondents for each question, and not necessarily of the entire survey sample.

5.2 Who answered the survey?

As shown in Figure 5.1, architects and designers made up a significant majority of those who answered the survey, with 255 respondents (equivalent to 63 per cent of survey respondents). The next best-represented industries were engineers and owners and facility managers, with 44 and 39 respondents respectively. In addition, there were 12 contractor respondents, 8 product manufacturers, 16 educators and 26 respondents from other industry areas.

Figure 5.1

SURVEY RESPONDENTS



Source: buildingSMART Australasia et al. 2010. Note: Architects and designers include: Architects, building designers, interior designs and landscape architects. Contractors include: Builders, contractors and subcontractors. Engineers include: Engineering, cost estimating, quantity surveyors and building inspection services. Others include: Building inspection services, building modelling/detailing, project management, industry body/representative, building software supplier, other.

5.3 BIM adoption and usage

Figure 5.2 shows the proportion of people in each subsector of the buildings network that is currently using BIM technology. As mentioned, the survey questions were not compulsory and as such, not all respondents answered the question about BIM adoption. Indeed, for some categories, up to 59 per cent of the respondents did not answer the question. For completeness, Figure 5.2 shows the answers to this question as a percentage of total respondents, with the proportion of respondents who did not answer the question clearly identified.

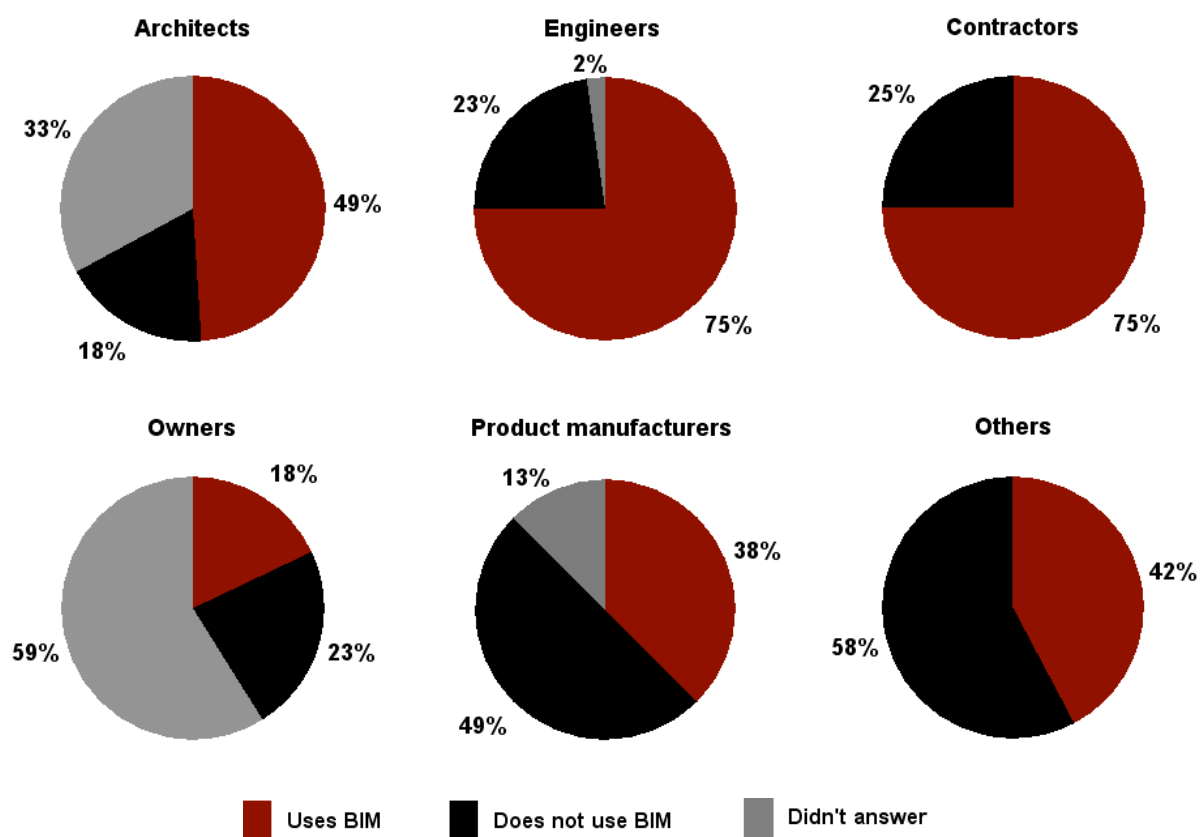
According to the survey, engineers and contractors are the highest users of BIM. Indeed, of the engineers and contractors that answered the survey (a total of 44 and 12 respectively), 75 per cent are currently using BIM. Notably, all of the surveyed contractors and almost all of the engineers responded to this question.

Although 255 architects responded to the survey, a high proportion (33 per cent) did not answer this question. Nonetheless, 49 per cent of architects indicated that they currently use BIM, while 18 per cent indicated that they do not.

A total of 39 owners participated in this survey, and 16 (or 41 per cent) answered this question. Of the owners who answered the survey, 18 per cent indicated that they use BIM.

A significant proportion of respondents in the product manufacturers and 'others' categories does not use BIM. Forty-nine per cent of building product manufacturers (from a total of 8) said that they do not use BIM, while 58 per cent of respondents in the 'other' area indicated that they do not use BIM.

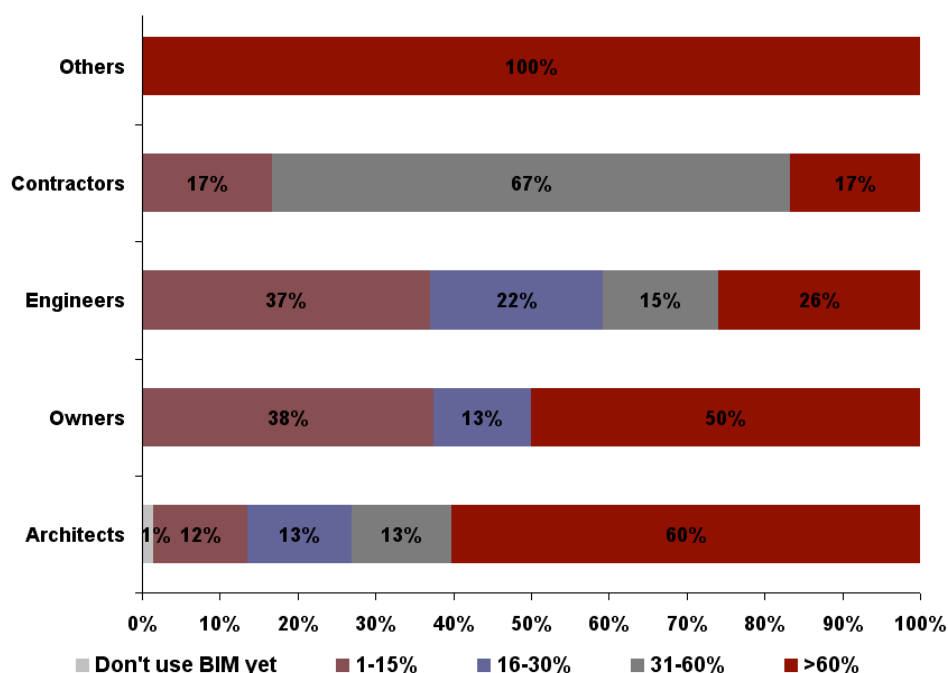
Figure 5.2

BIM ADOPTION — DOES YOUR COMPANY USE BIM?

Source: buildingSMART Australasia et al. 2010. Note: The pie charts present the survey results as a percentage of total respondents to the survey. The light grey areas illustrate the proportion of respondents who did not answer this question. Percentages may not add to 100 due to rounding.

The survey also attempted to measure the frequency of the use of BIM by asking respondents about the proportion of projects in which they currently use BIM. Figure 5.3 illustrates the answers to this question as a percentage of respondents who answered. There were 141 architects, 27 engineers, 8 owners, 6 contractors and 6 'other' responses to this question.

Figure 5.3

CURRENT USE OF BIM — ON WHAT PROPORTION OF YOUR CURRENT PROJECTS DO YOU USE BIM?

Source: buildingSMART Australasia et al. 2010 Note: The bar chart presents the survey results as percentage of total respondents to this question. There are 141 architects, 27 engineers, 8 owners, 6 contractors and 6 people from the 'other' category who answered this question. Percentages may not add to 100 due to rounding.

A key point to note is that 100 per cent of the respondents from the 'other' industry said they use BIM technology on more than 60 per cent of their projects. Furthermore, around 60 per cent of architects use BIM on more than 60 per cent of their projects. This compares with 50 per cent of owners, 26 per cent of engineers and 17 per cent of contractors using BIM in more than 60 per cent of their projects.

Findings by individual industry within the buildings network include:

- **Contractors** — 67 per cent estimated that between 31-60 per cent of current projects use BIM technology. 17 per cent put this figure at between 1-15 per cent, while 17 per cent of the respondents said that they use BIM in 60 per cent or more of current projects.
- **Engineers** — 37 per cent estimated that they use BIM on 1-15 per cent of current projects. Twenty-two per cent put this figure at between 16-30 per cent, while 15 per cent of respondents said that between 31-60 of current projects use BIM. A further 26 per cent of engineers said that more than 60 per cent of current projects use BIM.
- **Owners** — 38 per cent of owners estimated that 1-15 per cent of current projects use BIM. Thirteen per cent put this figure between 16-30 per cent, while 50 per cent of owners estimated that at least 60 per cent of current projects use BIM.

- Architects — 1 per cent of architects said that they do not use BIM. Twelve per cent said that 1-15 per cent of projects use BIM, 13 per cent placed this figure at between 16-30 per cent, and 60 per cent placed the figure at greater than 60 per cent.

5.4 Impacts of BIM

Respondent's benefits

One of the objectives of undertaking the BIM survey was to gather information about the type and magnitude of benefits experienced by BIM users. As such, the survey asked respondents to provide information about the influence of BIM on the following areas:

- project delivery timeframes;
- site variations, queries, problems and requests for information;
- man-hours devoted to project delivery;
- data repetition and duplication; and
- time spent in repetitive tasks and data re-entry.

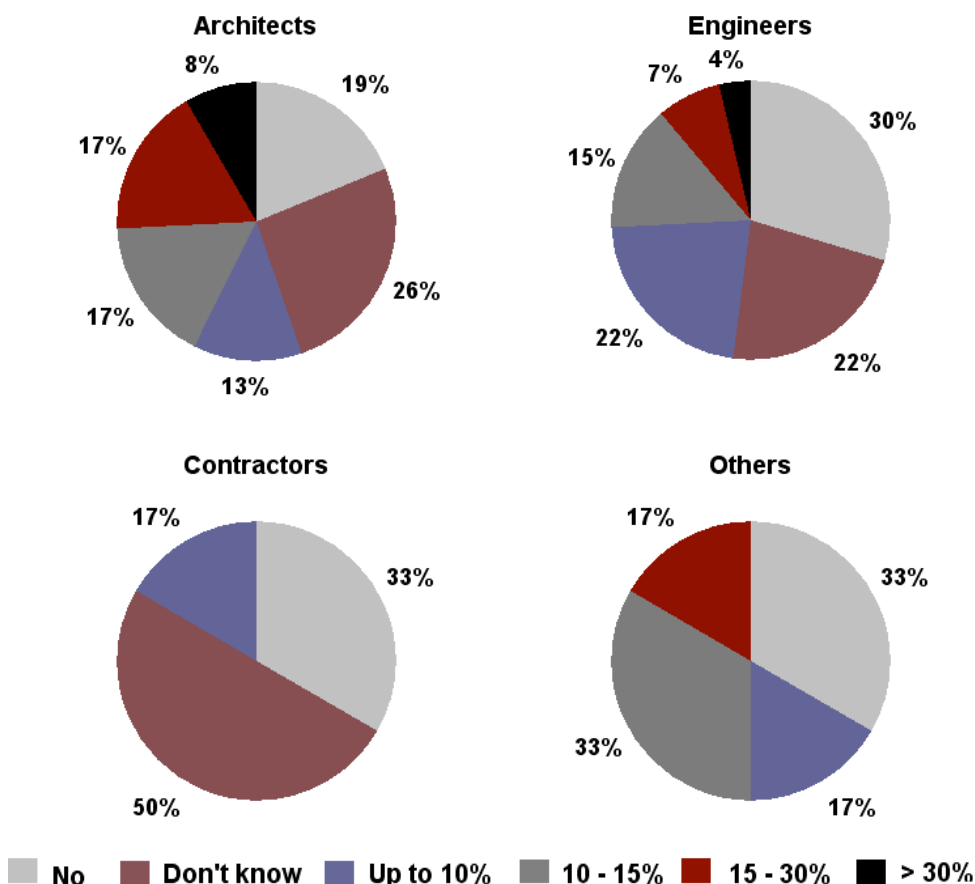
The responses to these questions are summarised below.

Project delivery timeframes

Figure 5.4 shows the savings achieved by using BIM for each industry in terms of reduced project delivery timeframes, and those who have not noticed any saving. The answers are reported as a percentage of respondents who answered this question — 143 architects, 27 engineers, 6 contractors and 6 people from the 'other' category.

- Architects — 19 per cent of architects said they have not noticed any saving from the use of BIM, while a further 26 per cent do not know if there have been any savings. Fifty-five per cent of architects said that they have noticed a saving, with 13 per cent estimating a saving of up to 10 per cent, 8 per cent estimating a saving of greater than 30 per cent, and the remaining 34 per cent estimating a saving of between 10 and 30 per cent.
- Engineers — Approximately half of engineers either have not noticed any saving from BIM or do not know if there have been any savings. Of those who noticed a saving, 4 per cent put the savings at above 30 per cent. Of the remaining 44 per cent, half noticed a saving below 10 per cent, and half noticed a saving of 10-30 per cent.
- Contractors — 17 per cent of contractors noticed a saving from BIM in terms of project delivery timeframes, and all of these respondents put this number at less than 10 per cent. One third of contractors have not noticed any saving, while half do not know.

Figure 5.4

BIM BENEFITS — HAS BIM REDUCED PROJECT DELIVERY TIMEFRAMES?

Source: buildingSMART Australasia et al. 2010. Note: The pie charts present the survey results as percentage of total respondents to this question. There are 143 architects, 27 engineers, 6 contractors and 6 people from the 'other' category who answered this question. Percentages may not add to 100 due to rounding.

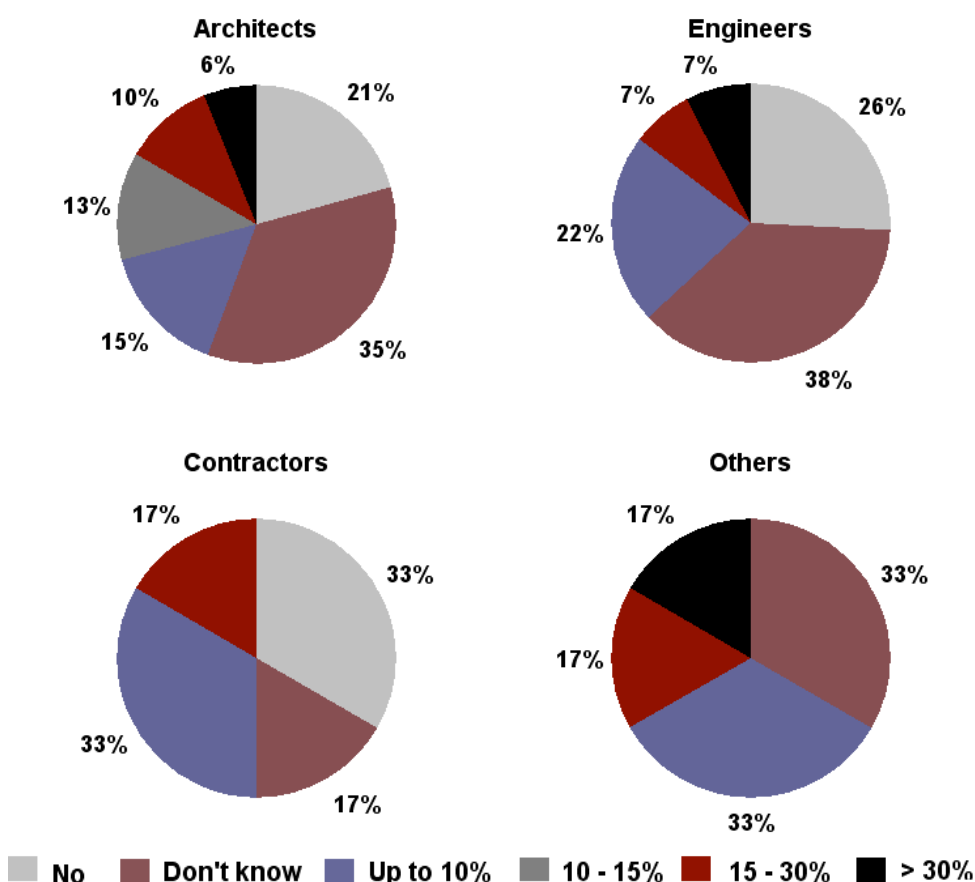
Site variations, queries, problems and requests for information

Figure 5.5 shows what proportion of each industry area has experienced a reduction in the number of site variations, queries, problems and requests for information as a result of BIM usage, and if so, the size of this reduction. Responses are reported as a percentage of total answer this question — 144 architects, 27 engineers, 6 contractors and 6 people from the 'other' category.

Twenty-one per cent of architects said that they had not observed a reduction in site problems as a result of BIM usage, and 35 per cent said that they did not know. Of the 44 per cent who had noticed a reduction, 15 per cent put the value of the reduction at less than 10 per cent, 13 per cent noticed a reduction of 10-15 per cent, 10 per cent noticed a reduction of 15-30 per cent, and 6 per cent noticed a reduction of more than 30 per cent.

Twenty-six per cent of engineers said that they had not seen a reduction in site variations as a result of BIM, and 38 per cent said that they did not know. Of the 36 per cent who noticed a reduction, 22 per cent put the value of this reduction at less than 10 per cent, 7 per cent noticed a reduction of 15-30 per cent, and 7 per cent noticed a reduction of more than 30 per cent.

Figure 5.5

BIM BENEFITS — HAS BIM REDUCED THE NUMBER OF SITE VARIATIONS, QUERIES, PROBLEMS OR REQUESTS FOR INFORMATION?

Source: buildingSMART Australasia et al. 2010. Note: The pie charts show the answers to this question as a percentage of respondents who answer this question. There are 144 architects, 27 engineers, 6 contractors and 6 people from the 'other' category who answered this question. Percentages may not add to 100 due to rounding.

Of the contractors who answered this question, 33 per cent said that they did observe any reduction in site variations as a result of BIM, and 17 per cent said that they did not know. Of the 50 per cent who noticed a reduction, 33 per cent put the value of this reduction at less than 10 per cent, and 17 per cent noticed a reduction of 15-30 per cent.

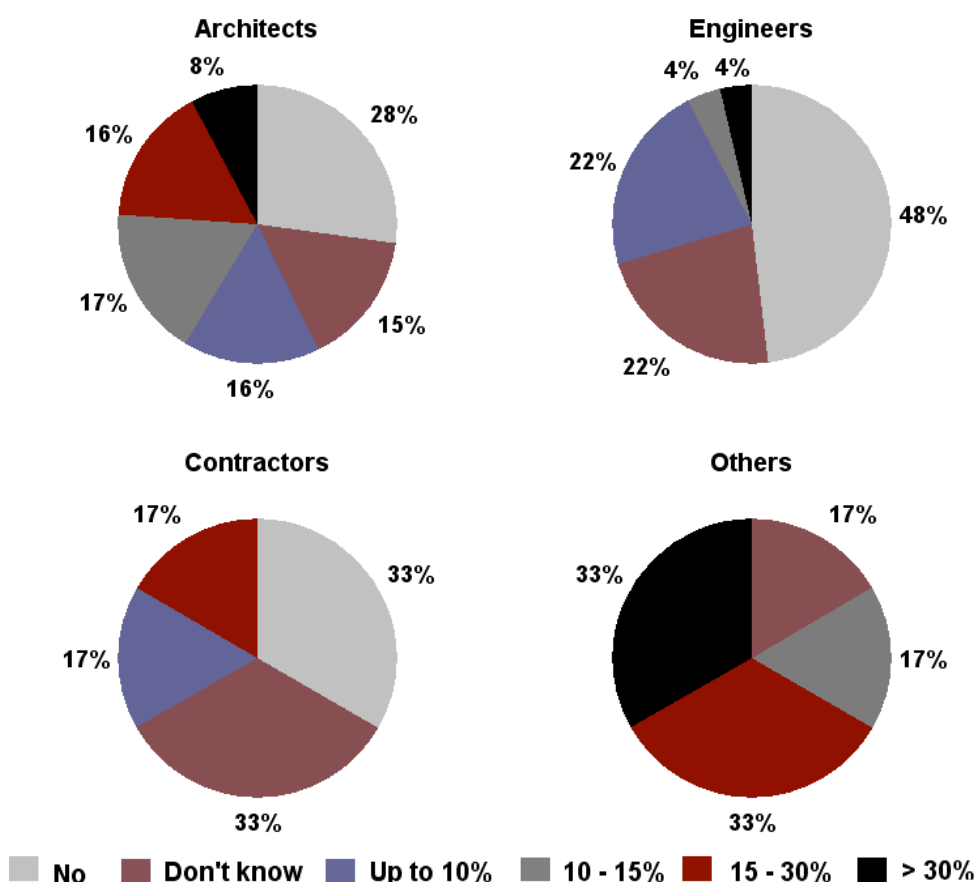
A third of the respondents from the 'other' category did not know if there has been a reduction in site variations. A further third of respondents said that they noticed a reduction of less than 10 per cent, while the remaining third was split evenly between those who noticed a reduction of 15-30 per cent, and those who saw savings greater than 30 per cent.

Man-hours devoted to project delivery

Figure 5.6 shows the proportion of respondents in each industry area who reported a reduction in the number of man-hours devoted to project delivery as a result of BIM, and the size of any such reductions. Responses are reported as a percentage of total responses to this question — 143 architects, 27 engineers, 6 contractors and 6 from the 'other' category.

Figure 5.6

BIM BENEFITS — HAS BIM REDUCED THE NUMBER OF MAN-HOURS DEVOTED TO PROJECT DELIVERY?



Source: buildingSMART Australasia et al. 2010. Note: The pie charts show the answers to this question as a percentage of respondents who answer this question. There are 143 architects, 27 engineers, 6 contractors and 6 people from the 'other' category who answered this question. Percentages may not add to 100 due to rounding.

Findings by individual industry within the buildings network include:

- Architects — 28 per cent of architects said that BIM has not reduced the number of man-hours typically expected in project delivery, while 15 per cent did not know. Of those who saw a reduction, 16 per cent reported a reduction of less than 10 per cent, 17 per cent reported a reduction of 10-15 per cent, 16 per cent reported a reduction of 15-30 per cent, and 8 per cent reported a reduction of more than 30 per cent.
- Engineers — 48 per cent of engineers said that BIM has not reduced the number of man-hours typically expected in project delivery, while 22 per cent did not know. Of those who observed a reduction, 22 per cent reported a reduction of less than 10 per cent, 4 per cent reported a reduction of 10-15 per cent, and 4 per cent reported a reduction of more than 30 per cent.

- Contractors — 33 per cent of contractors said that BIM has not reduced the number of man-hours typically expected in project delivery, while a further 33 per cent did not know. Of those who had seen a reduction, 17 per cent reported a reduction of less than 10 per cent and 17 per cent reported a reduction of 15- 30 per cent.
- Others — Of the respondents to this question, 17 per cent said that BIM did not reduce the number of man-hours typically expected in project delivery. Of those who had seen a reduction, 17 per cent reported a reduction of 10-15 per cent, 33 per cent reported a reduction of 15-30 per cent, and a further 33 per cent reported a reduction of more than 30 per cent.

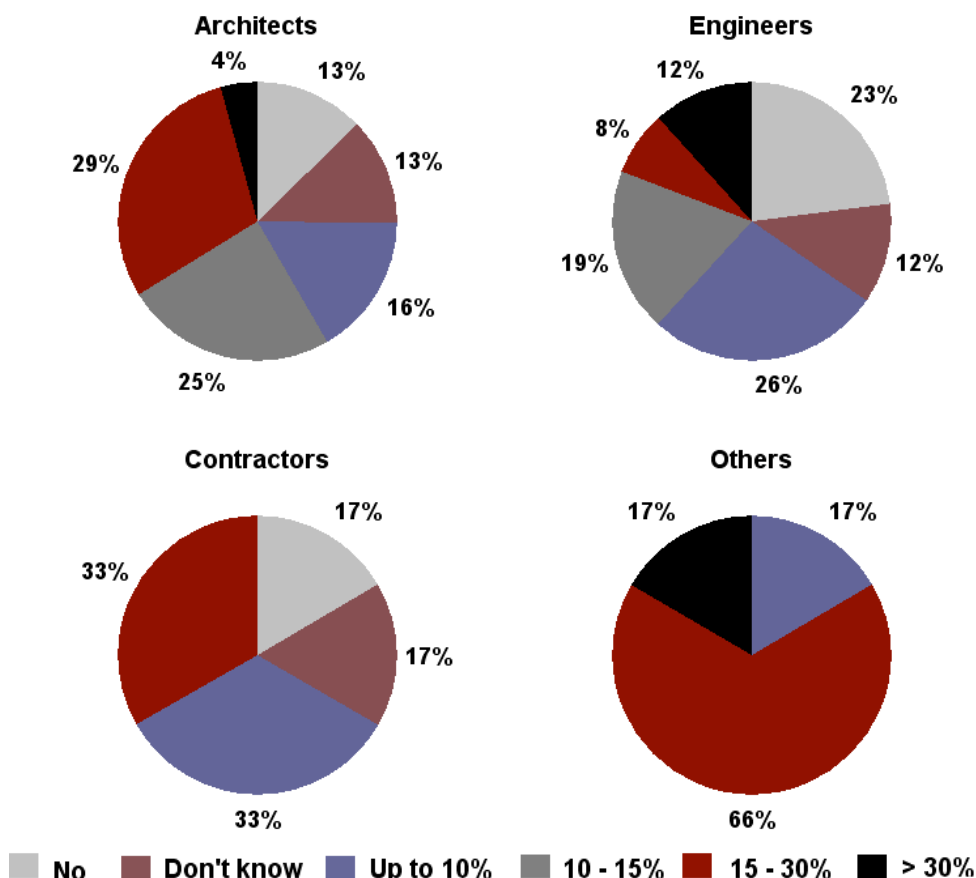
Data repetition and duplication

Figure 5.7 illustrates the proportion of respondents in each industry area who reported a reduction in duplication and repetition of data typically associated with projects. The responses are reported as a percentage of total responses to this question — 142 architects, 26 engineers, 6 contractors and 6 people from the ‘other’ category.

- Architects — 13 per cent of architects said that BIM has not reduced the amount of repetition of data typically expected in project delivery, while 13 per cent did not know. Of those who have observed a reduction, 16 per cent reported a reduction of less than 10 per cent, 25 per cent reported a reduction of 10-15 per cent, 29 per cent reported a reduction of 15-30 per cent, and 4 per cent reported a reduction of more than 30 per cent.
- Engineers — Almost two-third of engineers observed a reduction in data repetition or duplication. Specifically, 26 per cent reported a reduction of less than 10 per cent, 19 per cent reported a reduction of 10-15 per cent, 8 per cent reported a reduction of 15-30 per cent, and 12 per cent reported a reduction of more than 30 per cent. The remaining one-third either did not observe any reduction or did not know.
- Contractors — 17 per cent of contractors said that BIM has not reduced the amount of repetition of data typically expected in project delivery, while 17 per cent did not know. Of those who had seen a reduction, 33 per cent reported a reduction of less than 10 per cent, and 33 per cent reported a reduction of 15- 30 per cent.
- Others — Of the responses from the other industry areas, 17 per cent reported a reduction of 10-15 per cent, 66 per cent reported a reduction of 15-30 per cent, and 17 per cent reported a reduction of more than 30 per cent.

Figure 5.7

BIM BENEFITS — HAS BIM REDUCED DATA REPETITION/DUPLICATION?



Source: buildingSMART Australasia et al. 2010. Note: The pie charts show the answers to this question as a percentage of respondents who answer this question. There are 142 architects, 26 engineers, 6 contractors and 6 people from the 'other' category who answered this question. Percentages may not add to 100 due to rounding.

Time spent in repetitive tasks and data re-entry

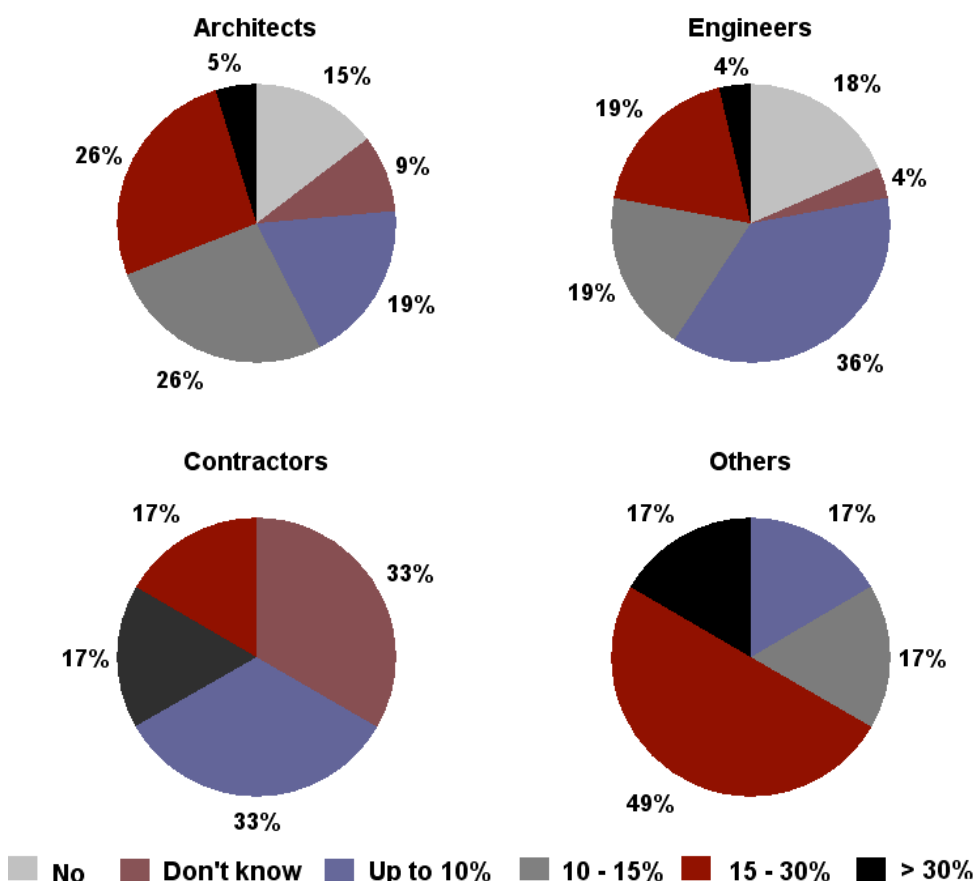
Figure 5.8 illustrates the proportion of respondents who reported a reduction in the time spent on repetitive and non-value adding tasks typically carried out in projects. Responses to this question are reported as a percentage of total responses to this question — 144 architects, 27 engineers, 6 contractors and 6 people from the 'other' category.

- Architects — 15 per cent of architects said that BIM has not reduced the time spent on repetitive tasks typically expected in project delivery, while 9 per cent did not know. Of those who observed a reduction, 19 per cent reported a reduction of less than 10 per cent, 26 per cent reported a reduction of 10-15 per cent, 26 per cent reported a reduction of 15-30 per cent, and 5 per cent reported a reduction of more than 30 per cent.

- **Engineers** — 18 per cent of engineers said that BIM has not reduced the time spent on repetitive tasks typically expected in project delivery, while 4 per cent did not know. Of those who had seen a reduction, 36 per cent reported a reduction of less than 10 per cent, 19 per cent reported a reduction of 10-15 per cent, 19 per cent reported a reduction of 15-30 per cent, and 4 per cent reported a reduction of more than 30 per cent.
- **Contractors** — 33 per cent of contractors said that they do not know if BIM has reduced the time spent on repetitive tasks typically expected in project delivery. Of those who had seen a reduction, 33 per cent reported a reduction of less than 10 per cent, 17 per cent reported a reduction of 10- 15 per cent, and 17 per cent reported a reduction of 15-30 per cent.
- **Other** — All respondents from the other industry areas observed a reduction in the time spent on repetitive tasks. Almost half reported a reduction of 15-30 per cent, with the remaining respondents evenly split between the potential answers.

Figure 5.8

BIM BENEFITS — HAS BIM REDUCED THE AMOUNT OF REPETITIVE TASKS OR DATA RE-ENTRY?



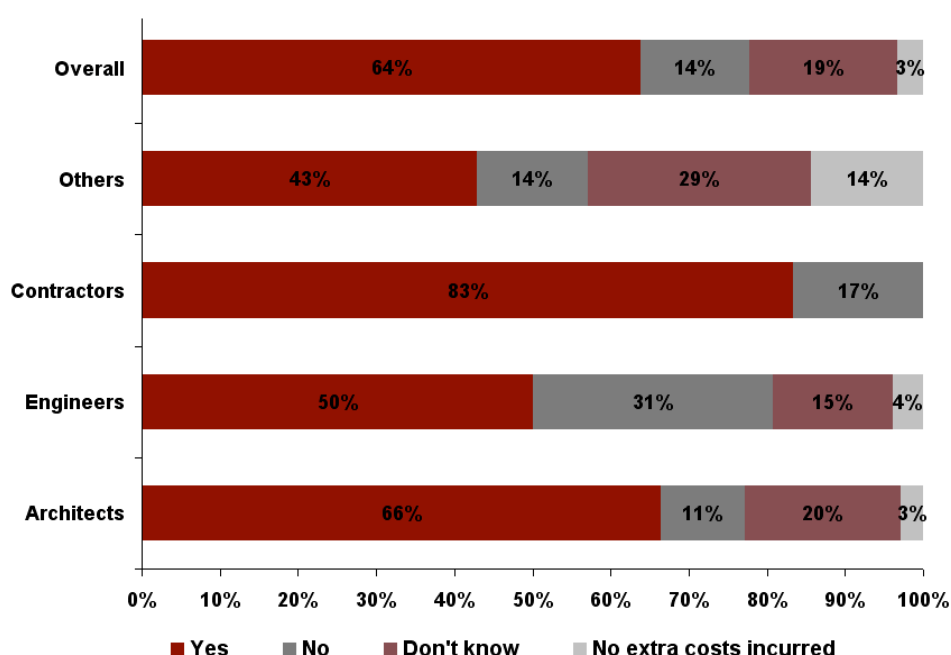
Source: buildingSMART Australasia et al. 2010. Note: The pie charts show the answers to this question as a percentage of respondents who answer this question. There are 144 architects, 27 engineers, 6 contractors and 6 people from the 'other' category who answered this question. Percentages may not add to 100 due to rounding.

Respondent's costs

The BIM survey was designed to capture information about the costs facing the industry in relation to the adoption and use of BIM. In general, a relatively small proportion of respondents (14 per cent) indicated that the costs of using BIM have not been balanced by the benefits. In comparison 64 per cent of users believed that the costs of using BIM are balanced by the benefits (see Figure 5.9).

Figure 5.9

BIM COSTS — HAVE THE COSTS TO YOUR ORGANISATION IN USING BIM BEEN BALANCED BY THE BENEFITS GAINED?



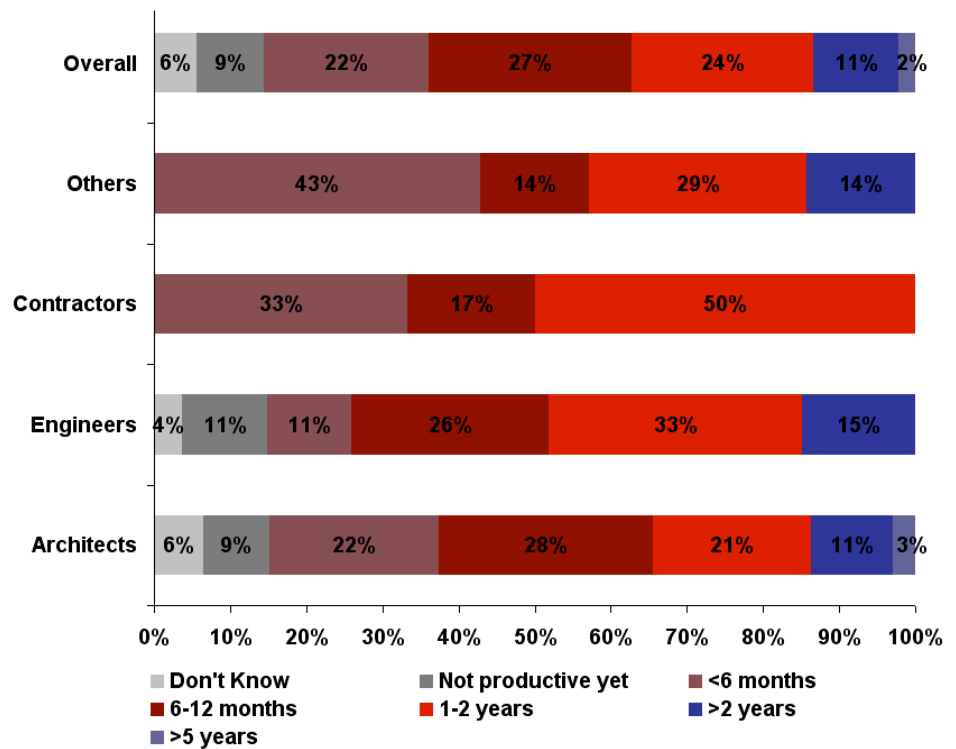
Source: buildingSMART Australasia et al. 2010. Note: The bar chart shows the answers to this question as a percentage of respondents who answer this question. There are a total of 179 responses to this question — 140 architects, 26 engineers, 6 contractors and 7 people from the 'other' category. Percentages may not add to 100 due to rounding.

Labour costs, in terms of loss in productivity during the initial period of BIM adoption, is often viewed as the key 'cost' to businesses in adopting BIM. Findings from the survey show that 72 per cent of respondents are productive in using BIM within two years of adoption (see Figure 5.10). This finding is consistent across categories.

All respondents who indicated that it took up to five years to become proficient in the use of BIM were architects. Architects are most likely the early adopters of BIM, and therefore faced with the greatest obstacles. As more firms embrace BIM technology, the time taken for firms to be productive in using BIM is expected to decrease reflecting traditional gains from 'learning by doing'.

Figure 5.10

BIM COSTS — HOW LONG HAS IT TAKEN YOUR COMPANY TO BECOME PRODUCTIVE IN USING BIM?



Source: buildingSMART Australasia et al. 2010. Note: The bar chart shows the answers to this question as a percentage of respondents who answer this question. There are a total of 179 responses to this question — 139 architects, 27 engineers, 6 contractors and 7 people from the 'other' category. Percentages may not add to 100 due to rounding.

Chapter 6

Challenges and the means to overcome them

While BIM is expected to deliver many benefits and the costs are not materially higher than traditional or alternative management approaches, there are many factors that impede widespread adoption at present. This chapter briefly outlines the key factors limiting BIM adoption in Australia and actions suggested by industry to overcome them.

The basic dilemma in the deployment of integrated BIM can be described as a paradoxical loop: there is not enough market demand for integrated BIM, because there is not enough measured evidence of benefits of the integrated BIM, because there are no adequate software tools to use integrated BIM in real projects.

Kiviniemi et al., 2008, p.56.

6.1 New technologies and barriers

The adoption of a new technology in any industry poses challenges that need to be overcome. Many of these barriers can be technological in nature, but they can also be related to the need for organisational changes or changes to business processes or even just the speed of implementation (Burgess et al. 2007, cited in CRC for Construction Innovation 2008). Consultations held with key industry stakeholders familiar with BIM point to the following factors playing a role in impeding adoption of BIM.

- *Lack of BIM object libraries* — accessibility to product information from building product manufacturers for use in all types of model-based applications is a crucial issue for the successful adoption of BIM by the buildings network industry.
- *Lack of model building protocols*— while some model building guidelines have been developed (see CRC for Construction Innovation 2009) a formal standard that codifies industry practice does not exist.
- *Legal and insurance impediments* — digital practice has a significant effect on a range of consulting services. Issues of risk, fees, responsibilities, intellectual property, legal liability and insurance are seen as an impediment to integrated project delivery.
- *Information sharing* — the lack of a national standard for sharing data between all of the participants in the facility development process is also seen as a barrier to BIM implementation.
- *Skills gaps* — widespread use of BIM requires a good level of knowledge and expertise in the use of specific software and the capability or ‘know how’ in terms of connecting the systems. Further, new skills and knowledge are required to create and manage the process of modelling (CRC for Construction Innovation 2009). This is a barrier to higher BIM adoption as it is perceived that only a limited number of users are currently adequately trained to use BIM.
- *Strategic research focus* — current research activity is based on individual research initiatives, but no strategic focus exists to support development of next generation digital technologies for the built environment.

- *Process change* — as it is costly to learn to use new products and develop trust and confidence, parties involved in the different stages of a building's life cycle may be reluctant to use an alternative technology and may retain a bias towards using the existing systems and processes. This is an important barrier to the adoption of BIM.

Analysis in the earlier chapters of this report flag that investing in BIM brings costs. Naturally, costs present a barrier to change. Factors identified and discussed include the following:

- education and training costs;
- administration and start-up costs; and
- transition and behavioural costs.

While these costs may in time be offset by benefits, costs will force investors and potential adopters of BIM to carefully consider the options.

Experience with other enabling technologies suggest that while technological and organisational barriers may appear daunting and even insurmountable at first, they have been overcome in time where the benefits from innovation exceed the costs.

6.2 Market failures

Market failures may present a more formidable set of barriers to the adoption of BIM. The common theme with market failures in the adoption of BIM is that because of market failure associated with research, development and commercialisations of new technologies, private inventors and innovators are not able to capture for themselves a sufficient proportion of the full or social value of their innovations.

Key possible market failures could include the following:

- *External benefits* — interoperability and standards involve significant benefits for third parties beyond the actual producers of goods and buyers. These benefits arise in many ways where, for example, products made to a common standard reduce costs for third parties that may make interconnecting or compatible supplementary products at lower cost, or increase the scope for competition for many producers and therefore reducing the costs for all players. External benefits are often seen in the development of networks where synergies raise benefits above those of the price or cost of an incremental addition to the network. These benefits are termed externalities because they are often not factored into internal decision-making. If the internal decision makers do not capture sufficient benefit from externalities it is likely that they will not have an incentive to provide or supply such goods.

- *Public goods* — in economics, a public good is a good that is non-rivalrous and non-excludable. Non-rivalry means that consumption of the good by one individual does not reduce availability of the good for consumption by others; and non-excludability that no one can be effectively excluded from using the good. The knowledge that underpins some BIM systems may have the characteristics of non-rivalry and non-excludability. Firms that research the adoption and application of BIM may incur some costs that may be passed on to customers in a competitive market. Others that follow early adopters may be able to do so without bearing similar costs (essentially copying the early adopters and taking advantage of the non-excludable nature of some knowledge) and they may raise their market share by not raising prices. The original adopters/innovators may end up being uncompetitive and many businesses that are inclined to be an early adopter may be questioning the viability of this investment. In general, it is likely that there would be under investment in public goods without intervention.
- *Information asymmetries* — potential adopters and investors in BIM may assume that investment in BIM performs in much the same way as other non-interoperable technologies and approaches to building information management. This may create a ‘paradoxical loop’ where firms do not invest in BIM because there is no evidence of the benefits and there is no evidence of the benefits because there is not widespread adoption of BIM. The potential users of BIM do not share the same information as other users or vendors about the performance of BIM.

Public goods and externalities can interact to produce important and difficult barriers where market-like behaviour of individual gain-seeking would not produce efficient results. Where the production of public goods results in positive externalities that are not remunerated, private organisations may not reap all the benefits of a public good which they have produced. Their incentives to produce this good voluntarily might be insufficient. Consumers and purchasers can take advantage of public goods without contributing sufficiently to their creation. This is called the ‘free rider’ problem, or occasionally, the easy rider problem (where a buyer’s contributions will be small but non-zero).

While each firm makes decisions in its best interests, there is an economy-wide or community cost from information asymmetries when there is under-investment and under-purchasing of the technology that brings about higher performance.

The presence of market failure may impose structural and substantial barriers to adoption of innovation such as BIM. Typically these kinds of barriers, if they are present in the case of BIM, take more than time to resolve than other barriers such as technological constraints.

6.3 Government and Industry intervention and coordinated action

It is generally the presence that market failures that fundamentally drives investigation into the potential role that government intervention may play. Certainly, governments are loath to intervene in new areas without clear grounds of market failures.

It is necessary, but not sufficient to establish that there is a market failure to justify government intervention. In Australia, following agreements made between the Australian and state Governments, regulatory reviews needed to change existing legislation and regulation require that a range of alternative options are considered including the ‘do nothing’ option and there is an onus of proof to establish that intervention will lead to the best outcome for the community at large.

Intervention may take a variety of forms. Alternatives to be considered are rarely limited to public expenditure and direct public provision. Very often options include provision for industry solutions and non-regulatory or light-handed intervention.

At this time it is not clear what the preferred options for government or industry action should be regarding BIM. The points below describe a range of actions that can be taken by industry and government to address the barriers outlined above and stimulate greater use of BIM in Australia.

As a regulator, government has a key role in ensuring the development of [...] standards. Ideally multiple governments would [work] collaborative[ly] to [the] development [of] international standards which are then adopted in each jurisdiction in policy or regulatory instruments. As the development of these [...] standards is necessary to advance BIM and enable interoperability to succeed, government policy would need to be in place to facilitate the development and adoption of these standards across industry.

Brown, 2008, p.19

- The development of a national strategy for BIM implementation that sets out national priorities, a plan of adoption and provides guidance across the whole industry. Potential elements of this strategy could include:
 - a national initiative to stimulate pilots and project adoption involving government and private clients together with service delivery organisations;
 - the identification of supply chains in the construction process and targeting of automation, industrialisation and off-site fabrication to improve the quality and speed of construction;
 - a package of clear and targeted information to the key participants in the system about the benefits of using BIM; and
 - an assessment of how widespread adoption of BIM would affect the existing administrative and regulatory processes (for instance, current building standards) and what needs to be done to optimise the benefits across industry and government agencies.
- Actions to support and promote the development of industry standards of practice and information management guidelines.
- Actions to develop and implement new contractual frameworks, such as Integrated Project Delivery, that address issues of risk, fees, responsibilities, intellectual property, legal liability and insurance when using BIM.
- Actions to enable the creation and maintenance of open object libraries with defined product parameters and properties that comply with accepted national classification systems and support for analysis, sustainability, energy efficiency and regulatory compliance.
- Actions to close or reduce the skills gaps. These could include actions to incorporate BIM in the curricula of educational institutions and to promote and deliver training for businesses’ existing staff.

6.4 Summing up

There appear to be many practical impediments to the more rapid, widespread adoption of BIM. Most of the practical factors tend to apply to adoption of many new technologies in general. It is likely that these would be overcome in time by businesses and agencies weighing up the benefits and costs and learning from innovation and investment in BIM by industry leaders. That is generally why, even with clear-cut evidence of improvements in some technologies, industries take time to adopt new technologies (Vanston and Vanston, 1996). Of greater concern is the possibility that the adoption of BIM confronts a significant range of market failures, reflecting external benefits, public good characteristics and information asymmetries. The presence of these would point to the need to have a considered strategy developed by industry and government.

The next chapters of the report examine a key threshold question about what the nature of the opportunity may be from accelerated widespread adoption of BIM. That is, how worthwhile would the change be and why effort to raise the adoption of BIM would be warranted.

Chapter 7

Exploring the opportunity: approach to measuring the impacts of BIM

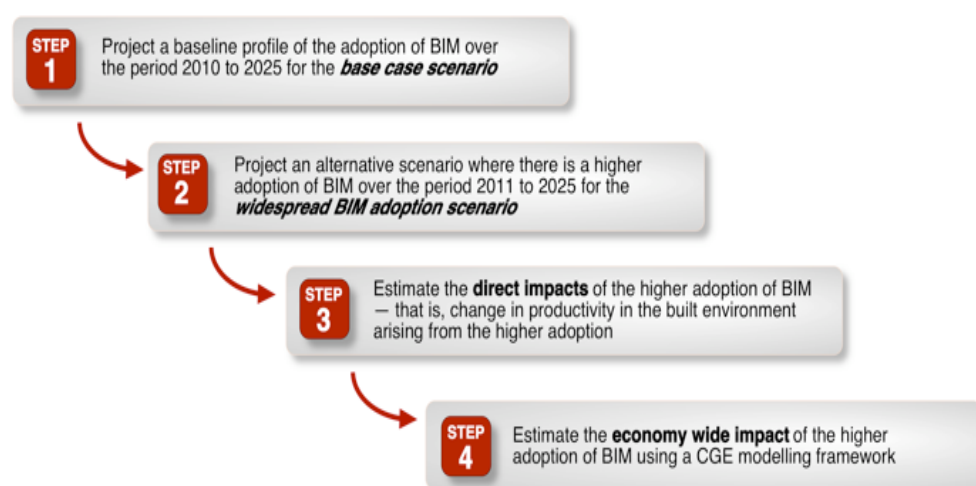
Chapter 7 explains the methodology used in this report to model the economic impacts of widespread adoption of BIM in Australia.

7.1 Modelling framework

Earlier chapters discussed surveys from the United States and Australia that indicate that the adoption of BIM is likely to benefit users by facilitating lower costs and increasing productivity. This increase in productivity, in turn, is expected to have an impact on the economy as a whole. This chapter sets out the methodology used to examine the economy-wide impacts of an increase in the adoption of BIM in the buildings network industry in Australia. Figure 7.1 sets out the modelling framework for the analysis.

Figure 7.1

MODELLING FRAMEWORK



Source: Allen Consulting Group analysis, 2010.

As mentioned earlier in this report, the buildings network industry covers a wide range of building activities, including design, engineering, contractors and sub-contractors, owners and facilities managers. The analysis of the impact of widespread BIM adoption relies on information available on four main user groups of BIM:

- architects (including building designers);
- engineers (including building consultants and quantity surveyors);
- contractors (includes sub-contractors); and
- owners (includes facility managers).

7.2 Modelling scenarios

It is necessary to set up modelling scenarios for estimating the impacts of accelerated widespread adoption of BIM on the Australian economy (Step 1 and Step 2 in Figure 7.1). In this report, two scenarios are modelled.

- **BAU scenario** — This refers to the ‘business as usual’ (BAU) scenario where the adoption rate of BIM in the buildings network industry is based on current BIM market settings, without additional support from the government or major changes in the industry.
- **Widespread BIM adoption scenario** — This refers to a scenario where there is widespread adoption of BIM in the buildings network industry. This means the adoption rate of BIM would be higher over the period 2011 to 2025 than in the BAU scenario. This increase in BIM take up could arise from additional support for BIM from the government or major changes in the industry.

Setting up the BAU scenario

The first step to set up the BAU scenario is to determine the current level of adoption of BIM in Australia. There is no official information on the current usage of BIM in Australia, be it at the industry-wide level or by different industry groups. In light of this, the current BIM adoption rates used in this report were estimated by industry experts and representatives from the buildings network industry in a series of workshops conducted by the Allen Consulting Group in August 2010. To guide the production of these estimates, industry stakeholders used two main sources of information:

- the 2009 McGraw Hill survey, which provides information about current adoption rates by key users in the United States; and
- the 2010 BIM survey by buildingSMART Australasia et al. described in Chapter 4.

At the workshops, industry experts defined BIM as an integrated technology where several multi-disciplinary model servers are linked and information on the building is collected and managed in a repository (this is Stage 3B as defined in Figure 2.4 in Chapter 2).

Table 7.1 shows the estimated current adoption rates of BIM by the four user groups in the buildings network. It shows the proportion of practices that are using BIM and the proportion of projects that use BIM within these practices. For example, it was estimated that currently around 25 per cent of architects use BIM in 30 per cent of their projects. This implies that the weighted average adoption rate among architects is around 7.5 per cent.

Table 7.1

ESTIMATED ADOPTION RATES OF BIM BY KEY USERS IN AUSTRALIA IN 2010

	Practice	Projects	Weighted average
McGraw Hill (United States 2009)			
Architects	58.0%	44.5%	25.8%
Engineers	50.0%	32.9%	16.4%
Contractors	42.0%	32.9%	13.8%
Owners	37.0%	29.9%	11.0%
buildingSMART Australasia et al. 2010 survey			
Architects	49.0%	58.4%	28.6%
Engineers	75.0%	35.7%	26.8%
Contractors	75.0%	45.1%	33.8%
Owners	17.9%	46.1%	8.3%
Industry consultation 2010			
Architects	25.0%	30.0%	7.5%
Engineers	17.1%	30.0%	5.1%
Contractors	11.8%	30.0%	3.6%
Owners	5.3%	30.0%	1.6%

Source: Allen Consulting Group analysis based on industry consultation, McGraw Hill, 2009 and buildingSMART Australasia et al. 2010.

It is important to note that the adoption levels from the McGraw Hill survey and the buildingSMART Australasia et al. survey are not directly comparable, as the scope of the surveys and their definition of BIM are not consistent. Industry stakeholders also considered that the adoption rates in the buildingSMART Australasia et al. survey were an overestimation of the current adoption of BIM in Australia. This may be due to several reasons. First, the survey respondents may not have defined BIM as Stage 3B, but at some earlier stages. Second, the survey may contain some upward bias partly reflecting the adverse selection in the respondents. As the survey is not compulsory, it is likely that users of BIM are more likely to complete the survey, giving a higher response rate for this group than its actual share of the business community. Third, according to representatives from the buildings network industry who attended the consultation workshops, many people in the industry often mistook the 3D CAD technologies as BIM, which could lead to over optimistic adoption rates reported in the survey results.

In terms of the findings of the McGraw Hill 2009 survey, stakeholders who attended the consultation workshops considered that the figures from the United States market were not be representative of Australia because BIM technology is more established in the United States (which results in higher adoption estimates for that market).

In light of this, the BIM adoption rates used in the economic modelling are those estimated through the industry consultations. The experts felt that the current level of adoption rates of BIM in Australia are low, with weighted average adoption rates ranging between 1.6 per cent and 7.5 per cent across user groups (see last panel of Table 7.1).

The future adoption rates of BIM under the BAU scenario were also sourced from these industry consultations. These projections of the rate of BIM adoption under the BAU are based on current market settings, without additional support for BIM from the government or changes in the market.

International studies suggest that BIM adoption is likely to accelerate over the next few years (McGraw Hill, 2009; Holness, 2008). In fact, some expect the adoption rate of BIM to hit 100 per cent in the next ten years. However, industry representatives who attended the consultation workshops believe that a 100 per cent BIM adoption across all users is unlikely to be achieved over the next 15 years in Australia. This is due to the fact that, for some firms within the Australian buildings network industry, BIM adoption may not be financially viable. Nevertheless, the adoption rates of BIM by key users are expected to increase substantially over the period 2011-2025 (see Table 7.2).

Table 7.2

INDUSTRY PROJECTION OF ADOPTION RATES OF BIM IN 2025 (BAU SCENARIO)

	Practice	Projects	Weighted average
Architects	95.0%	80.0%	76.0%
Engineers	65.0%	80.0%	52.0%
Contractors	45.0%	80.0%	36.0%
Owners	20.0%	80.0%	16.0%

Source: Allen Consulting Group analysis based on industry consultation.

Setting up the widespread BIM adoption scenario

In the widespread BIM adoption scenario, the BIM adoption rate in the buildings network industry is higher than the BAU scenario. This increase in take up rate could arise from additional support for BIM from the government or major changes in the industry. Consultation with industry experts suggested that additional support from the government and industry could potentially lift the adoption rates of BIM by between 6.5 to 15.5 percentage points across the different user groups (see Table 7.3).

Table 7.3

INDUSTRY PROJECTION OF ADOPTION RATES OF BIM IN 2025 (WIDESPREAD BIM ADOPTION SCENARIO)

	Practice	Projects	Weighted average
Architects	98.0%	90.0%	88.2%
Engineers	75.0%	90.0%	67.5%
Contractors	50.0%	90.0%	45.0%
Owners	25.0%	90.0%	22.5%

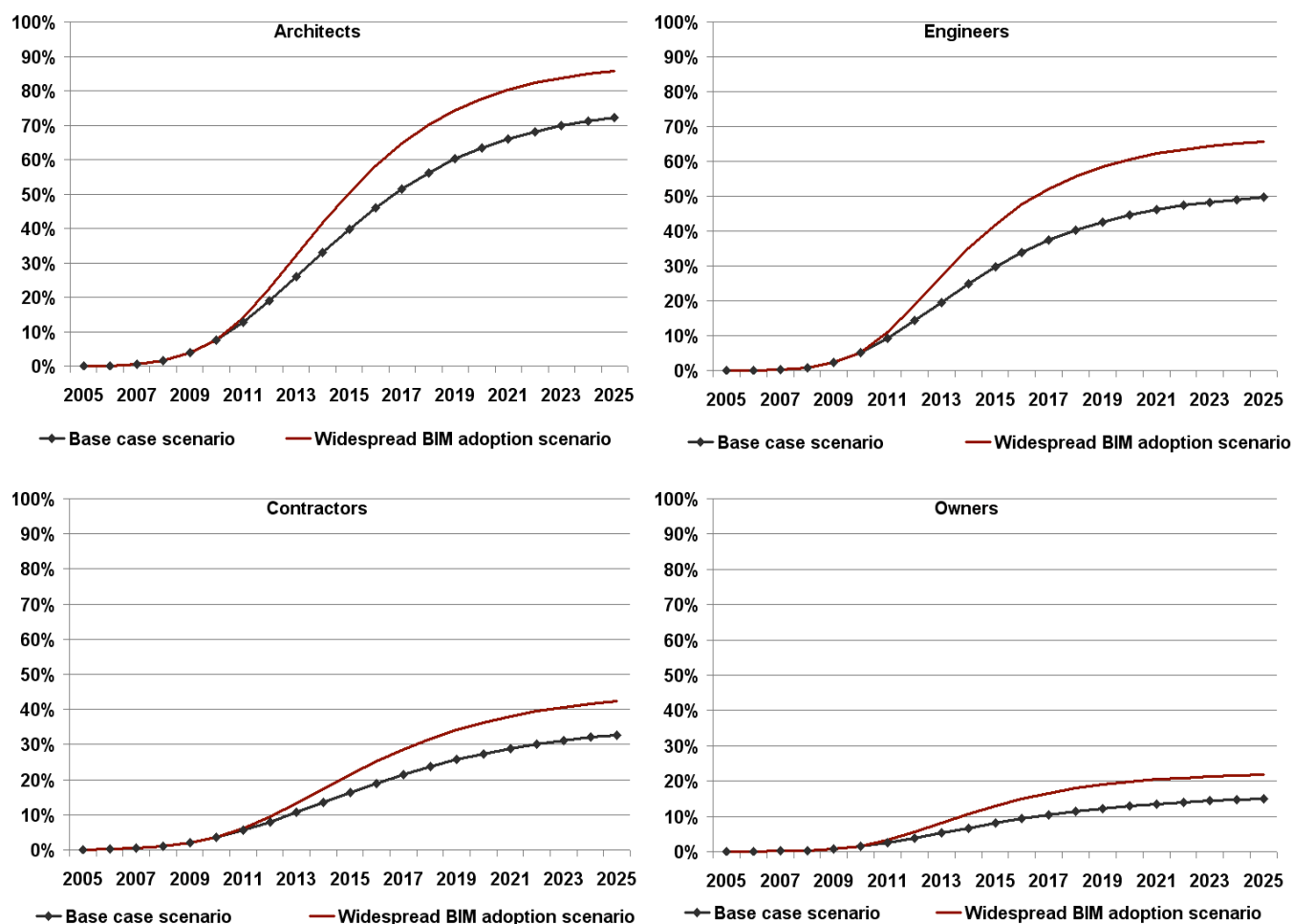
Source: Allen Consulting Group analysis based on industry consultation.

7.3 Estimating the direct impact of widespread BIM adoption

The higher BIM adoption rates in 2025, under both scenarios, are likely to be the result of a gradual increase over time. Experience in many areas of technological change shows that adoption of new or improved technologies tends to follow reasonably predictable patterns. Three processes — technology driven adoption, diffusion and mortality — are likely to be at work in most cases. The general pattern of change implied by each of these processes is a S-shaped curve when the percentage of the potential market (in this case, the share of the buildings network industry) captured by the new technology is plotted over time (Vanstons and Vanstons, 1996).

A mathematical model that has proven to be robust in tracking and predicting technological change is the Gompertz model. The Gompertz model has been used to project the BIM adoption rates under both the BAU and the widespread BIM adoption scenarios over the period 2011-2025. These projected adoption rates are shown in Table 7.2. Notably, this analysis is not a forecast, but shows a possible adoption trajectory based on experience with the adoption of other technologies. The differences in the adoption rates are captured by the gaps between the red and black lines.

Figure 7.2

PROJECTION OF WEIGHTED AVERAGE BIM ADOPTION RATE BY USERS

Source: Allen Consulting Group analysis, 2010 based on industry consultation.

Cost of using BIM

Based on the 2010 survey by buildingSMART Australasia et al., the key cost facing firms that adopt BIM is the initial loss in productivity when first learning the technology. However, as discussed in previous sections, this cost is relatively small, with less than 14 per cent of the people who responded the 2010 BIM survey indicating that the costs of using BIM have not been balanced by the associated benefits. Further, almost half of respondents indicated that they become fully productive within a year, and 72 per cent of respondents within two years.

Industry consultation also indicated that the marginal software cost between BIM and current 3D CAD is not significant. In terms of human capital, training is often on-the-job training and not a formal training course about the software. Importantly, industry experts felt that the actual cost of adopting BIM is not significant, although there is a perceived cost of adopting BIM among the non-BIM users.

Therefore, given that the costs of adoption BIM over existing approaches and technologies are viewed as insignificant, they are not included in the economic modelling.

Benefits of using BIM

As indicated in earlier chapters, BIM is expected to bring about significant benefits to its users. Estimates in the literature indicate that the construction industry in Australia and overseas wastes over 30 per cent of its efforts, and this waste can be reduced by using BIM (APCC 2009). Further, the use of BIM could potentially shorten projects' delivery timeframes from around 60 weeks to 48 weeks, which is equivalent to a 20 per cent saving in time (Smith, 2010).

The 2010 BIM survey shows that on average, BIM users believe that there are cost savings stemming from BIM use. The second column in Table 7.4 shows the average gains to users, and the last two columns provide the estimated maximum and minimum cost savings experienced by different BIM users in Australia.

Table 7.4

ESTIMATED COST SAVINGS BY KEY USERS IN AUSTRALIA

	Cost savings		
	Average	Minimum	Maximum
Architects	9.6%	6.5%	11.8%
Engineers	6.4%	2.7%	9.4%
Contractors	5.5%	0.8%	9.2%
Owners*	5.5%	0.0	9.2%

Source: Allen Consulting Group analysis based on buildingSMART Australasia et al. 2010. Note: * Assumes that cost savings for owners are the same as for contractors.

Not surprisingly, the survey results indicate that among the different user groups, architects receive the largest savings (9.6 per cent). This largely reflects the reduction in repetitive tasks in using BIM. The average cost savings experienced by engineers and contractors are lower, at 6.4 per cent and 5.5 per cent respectively. Due to the small sample size, the survey could not provide useable and reliable information on the cost savings accruing to owners. However, industry stakeholders indicated during the consultations that gains received by contractors are likely to be passed forward to owners. Hence, the estimated average and maximum productivity gains for owners are set to be the same as those received by the contractors. The estimated minimum productivity gain is set to be zero in the event where no benefits are passed to facility owners.

Consultations with industry experts indicated that the survey findings on cost savings experienced by BIM users are broadly inline with industry expectations.

7.4 Estimating the economy-wide impact of higher BIM adoption

The economy-wide impacts of higher BIM adoption on Australia over the period 2011 to 2025 were estimated using a Computable General Equilibrium (CGE) model of the Australian economy, the Monash Multi Regional Forecasting (MMRF) Model. Box 7.1 provides a brief description of the MMRF model. Appendix A provides a detailed write-up on the MMRF model.

Box 7.1

THE MMRF MODEL

The MMRF is a multi-sector dynamic CGE model of the Australian economy, covering the six states and two territories. It models each region as an economy in its own right, with region-specific prices, region-specific consumers, region-specific industries, and so on. Since MMRF is dynamic, it is able to produce sequences of annual solutions connected by dynamic relationships.

The MMRF contains 58 industrial sectors, which produce 63 commodities. The sectoral details allow the benefits of higher BIM adoption rate to be allocated appropriately across the different sectors.

The MMRF model is a high-level representation of the Australian economy, facilitating measurement of the wider effects of changes in economic activity in key industries and regions. To the extent that economic activity is interlinked, the MMRF model captures any indirect effects that arise from direct measures. In this instance, the direct impact of higher BIM adoption is the increase in productivity in the buildings network. The MMRF captures the flow-on impacts of these higher productivity to upstream and downstream sectors.

Importantly, the MMRF model is widely known and has been used for a wide range of policy studies. The Productivity Commission used the model to examine the potential benefits of the National Reform Agenda, and the Commonwealth Treasury used a version of the MMRF to produce the 2008 report, *Australia's Low Pollution Future*, which was a companion report to the Climate Change White Paper. The MMRF model has therefore demonstrated its ability to estimate economy-wide impacts of industry or policy changes.

Key assumption on the labour market

At the national level, the deviation in the consumer's real wage rate from its BAU forecast level increases in proportion to the deviation in employment from its BAU level. The coefficient of proportionality is chosen such that after about five years, the benefits of widespread BIM adoption are realised almost entirely as an increase in the real wage rate, rather than as an increase in employment.

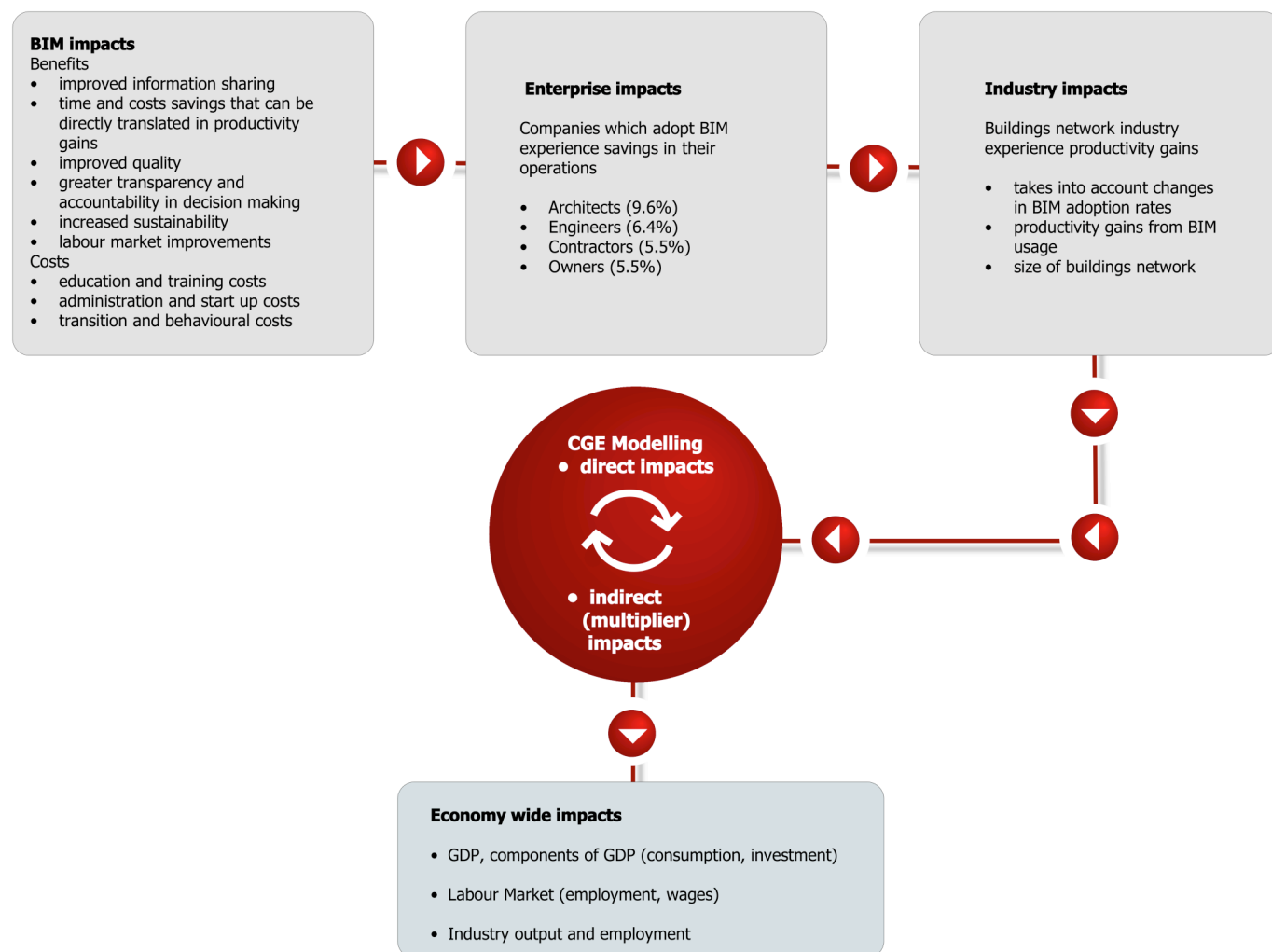
This assumption reflects the idea that in the long run national employment is determined by demographic factors (birth and death rates, the level of international migration). It is also consistent with conventional macro-economic modelling in which the unemployment rate reverts to its natural rate in the long run.

While Australia-wide employment in the long run is unaffected, there are changes to the sectoral distribution of employment. In other words, labour moves between different sectors so as to maintain the unemployment rate differentials at their BAU levels.

Source: Allen Consulting Group, 2010.

The MMRF model is a high-level representation of the Australian economy, facilitating measurement of the wider effects of changes in economic activity in key industries and regions. To the extent that economic activity is interlinked, the MMRF model captures any indirect effects that arise from direct measures. In this instance, the direct impact of higher BIM adoption is the increase in productivity in the buildings network. The MMRF then captures the flow-on impacts of this higher productivity to upstream and downstream sectors (see Figure 7.3).

Figure 7.3

THE CGE MODELLING APPROACH

Source: Allen Consulting Group, 2010.

Modelling inputs

Broadly, a projection of the Australian economy under the BAU scenario was applied to the MMRF model. This scenario takes into account the steady rate growth assumption of the Australian model.

The direct impacts of higher BIM adoption are used as modelling inputs for the higher BIM adoption scenario. Specifically, productivity gains accrued to four main user groups were used as inputs to the model. The modelling inputs for the CGE modelling were estimated in the following steps.

- The differences in the adoption rates under the widespread BIM adoption scenario and the BAU scenario were estimated.
- The direct benefits of higher BIM adoption to the four main user groups — the cost savings to the additional firms that adopted BIM — were estimated (see Table 7.4).

- The estimated cost savings to the buildings network were distributed proportionally amongst the group of sectors that represents the buildings network industry within the MMRF model (see Table 7.5). Specifically, the impacts of the savings were applied proportionally to the size of each user group in its represented industry sector in the MMRF model.

Table 7.5

SECTORAL MAPPING —BUILDINGS NETWORK INDUSTRY IN THE MMRF MODEL

Users	Sector in the MMRF model	Proportion
Architects	Business services sector	1.5%
Engineers	Business services sector	2.9%
Contractors	Construction services sector	69.5%
Owners	Business services sector	23.0%

Source: Allen Consulting Group analysis, 2010.

- Table 7.6 shows the estimated productivity gains arising from higher BIM adoption in different sectors of the economy. These productivity gains take into account the average cost savings experienced by individual user groups, the proportion that each of these user groups represent in industry sectors in the MMRF model and the changes in BIM adoption rate between the BAU scenario and widespread BIM adoption scenario.

Table 7.6

MODELLING INPUTS — AVERAGE PRODUCTIVITY GAINS

	Business services sector (Architects)	Business services sector (Engineers)	Construction sector (Contractors)	Business services sector (Owners)
2011	0.00%	0.01%	0.02%	0.01%
2012	0.01%	0.02%	0.06%	0.02%
2013	0.01%	0.04%	0.11%	0.04%
2014	0.01%	0.05%	0.15%	0.05%
2015	0.02%	0.06%	0.20%	0.06%
2016	0.02%	0.07%	0.24%	0.07%
2017	0.02%	0.07%	0.27%	0.08%
2018	0.02%	0.08%	0.30%	0.08%
2019	0.02%	0.08%	0.32%	0.09%
2020	0.02%	0.08%	0.34%	0.09%
2021	0.02%	0.08%	0.35%	0.09%
2022	0.02%	0.08%	0.36%	0.09%
2023	0.02%	0.08%	0.36%	0.09%
2024	0.02%	0.08%	0.36%	0.09%
2025	0.02%	0.08%	0.36%	0.09%

Source: Allen Consulting Group analysis, 2010.

- The estimated productivity gains were introduced as exogenous (i.e. from outside the model) shifts in the production functions in the MMRF model. These gains were modelled as an improvement in labour productivity where one unit of labour could now produce more units of output. Notably, if different assumptions about cost savings or changes in adoption rate were used, these inputs and the modelling results would also be changed.

A summary of the CGE modelling approach is provided in Box 7.2, and it shows that the modelling approach used is conservative. It is also important to note that the public sector builds, owns and administers significant number of buildings. These two public sector activities have been accounted in the economic analysis in the following way.

- Public sector building management — There is little information on the proportion of government administration that involves buildings management. The analysis takes into account public sector spending on building management where services are provided by other sector such as business services. That is, the economic analysis allocates the BIM benefits to the sectors from which the public sector purchases these building management services.
- Public sector building construction — While the public sector has many buildings built in areas spanning health, education, defence and others, the analysis has applied the BIM impacts to the construction sector, rather than the activity type for which the buildings were built. That is, the economic modelling has not analysed the public sector as if it is the direct producer of the buildings, but as if the public sector buys these services from the construction industry. In this way, the economic modelling captures the productivity gains on construction activities provided by government.

The results in this report detail the deviations in key macroeconomic variables attributable to the widespread BIM adoption in the buildings network industry. These deviations are calculated by comparing the time paths for the economic variables in the widespread BIM adoption scenario against the BAU scenario. A convenient way of reporting these deviations is as percentage changes from where the MMRF projects the economy would otherwise have been (i.e. the ‘base case’) if there was no additional BIM adoption.

Box 7.2

THE CGE MODELLING APPROACH USED IN THIS STUDY

The points below summarise key features of the CGE modelling approach used in this study.

- The economic impacts of the widespread adoption of BIM have been calculated using estimates about productivity improvements stemming from BIM use by four main user groups in the buildings network, rather than on the entire supply chain.
- The impacts of these gains were applied proportionally to the size of each user group in its represented sector in the MMRF model.
- The economic impacts modelled are based on the differences between a higher BIM adoption rate and a BAU projection of BIM adoption in Australia. Importantly, in the BAU projection, BIM adoption in Australia is expected to increase substantially. The implication of this is that the difference between the higher BIM adoption rate and the BAU projection is fairly conservative.
- The economic modelling captures the productivity gains on construction activities provided by government and the benefits to the sectors from which the public sector purchases these building management services.
- The long term national employment figure is fixed, and labour market adjusts via changes in real wages. However, labour is perfectly mobile across industry and states, thus there can be changes in industry and state employment.
- Real government consumption (Commonwealth and States) is fixed. This implies productivity gains arising from higher BIM adoption would not affect government consumption.
- The economic modelling does not account for the cost involved in achieving the widespread adoption of BIM in the buildings network.

Source: Allen Consulting Group analysis, 2010.

Chapter 8

Benefits of change: impacts of widespread use of BIM

Chapter 8 presents the modelling results examining the impacts of widespread BIM adoption on the Australian economy.

The results in this chapter show the economic impacts attributable to the accelerated widespread adoption of BIM in the buildings network industry.

Differences in economic outcomes between the widespread BIM scenario and the BAU scenario are calculated to determine the economic benefits stemming from higher BIM adoption over the period 2011 to 2025. These deviations are calculated by comparing the time paths for the economic variables in the widespread BIM adoption scenario against the BAU scenario.

It is important to note that the results from the economic analysis described in the sections below are in 2008-09 dollars and that all net present valuations of the impacts refer to Net Present Value (NPVs) in the year 2010.⁵

8.1 Economy-wide results

Impacts on GDP

As indicated in Chapter 7, adoption of BIM under the widespread BIM adoption is higher from 2011 to 2025. As such, the benefits (in terms of higher productivity) stemming from widespread BIM adoption start to flow on to the Australian economy from year one (2011).

The higher productivity enjoyed by the buildings network industry is expected to provide a stimulus to the Australian economy. Indeed, as shown in Figure 8.1, the higher productivity experienced by the buildings network industry would boost national output (as measured by Gross Domestic Product, i.e. GDP).

As the difference in adoption of BIM increases over time, impacts on productivity also become larger. This flows on to higher GDP over time. Importantly, in 2011 GDP would be 0.002 per cent higher than the BAU scenario. By 2025, GDP would be 0.052 per cent higher than the BAU scenario (see Figure 8.1).

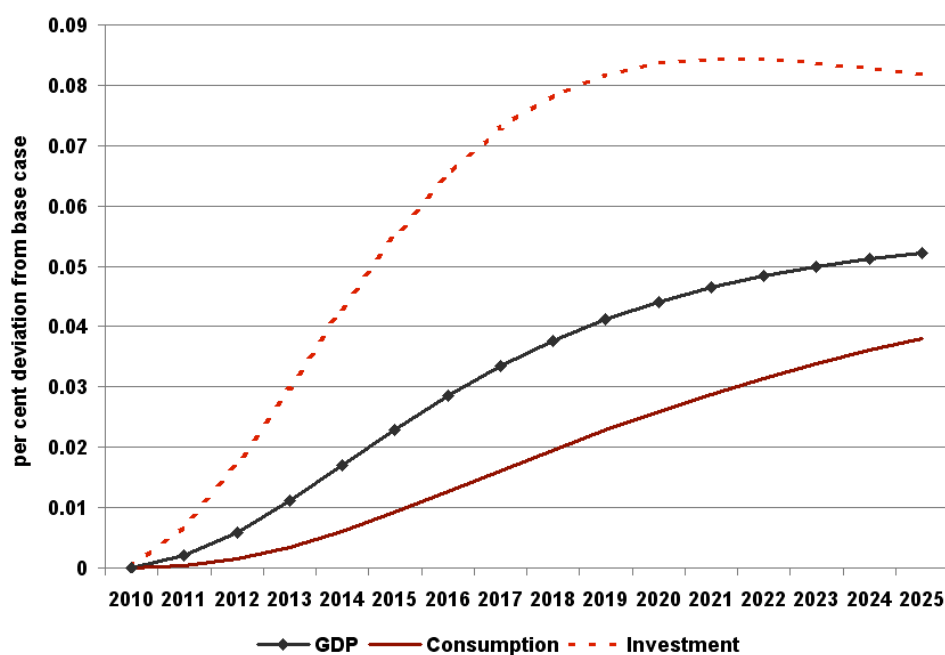
In dollar terms, Australia's GDP would be expected to be \$1,005 million higher in 2025, relative to the BAU scenario (see Table 8.1). In fact, the NPV in 2010 of the impact on GDP of widespread BIM adoption over the period 2011-2025 would be \$4,794 million (2008-09 dollars).

⁵ The NPVs are calculated using a real discount rate of 5 per cent.

GDP is the sum of consumption, government spending, investment and net exports. Therefore, changes in GDP largely reflect changes in these economic variables, particularly those of investment and consumption. Hence, the modelling shows that accelerated widespread adoption of BIM would have a positive economic impact on Australia's economy. Overall economic output would be higher when more people in the buildings network adopt BIM.

Figure 8.1

IMPACTS ON GDP, CONSUMPTION AND INVESTMENT



Source: Allen Consulting Group analysis, 2010.

Table 8.1

IMPACT OF ACCELERATED WIDESPREAD BIM ADOPTION ON KEY ECONOMIC VARIABLES (ABSOLUTE DEVIATION FROM BAU, 2008-09 DOLLARS)

	In 2025	NPV (2011-2025)
GDP	\$1,005 million	\$4,794 million
Private consumption	\$377 million	\$1,446 million
Investment	\$497 million	\$3,022 million
Exports	\$222 million	\$1,020 million
Imports	\$201 million	\$1,123 million
Employment	366 jobs	N/A

Source: Allen Consulting Group analysis, 2010. Note: NPV is expressed in 2008-09 dollars in 2010 and calculated using a real discount rate of 5 per cent.

Impacts on investment

The projected impacts on investment and consumption are also shown in Figure 8.1. Much of the boost to GDP under the widespread BIM adoption scenario would stem from a higher investment profile. In fact, investment would be expected to be 0.081 per cent (or \$497 million) higher than in the BAU scenario by 2025. The total increase in investment over the period 2011-2025 would be around \$3 billion (NPV terms, 2008-09 dollars).

Higher investment in the Australian economy reflects the expectation that over time there is an incentive to use more capital. This is due to the fact that raising labour productivity leads in time to a higher cost of labour, and thus producers would switch to use more capital over time.

Importantly, higher investment leads to faster capital accumulation, which creates a larger capital stock in the economy. This implies that the economy would have greater production capacity, and thus boosts output.

Impacts on consumption

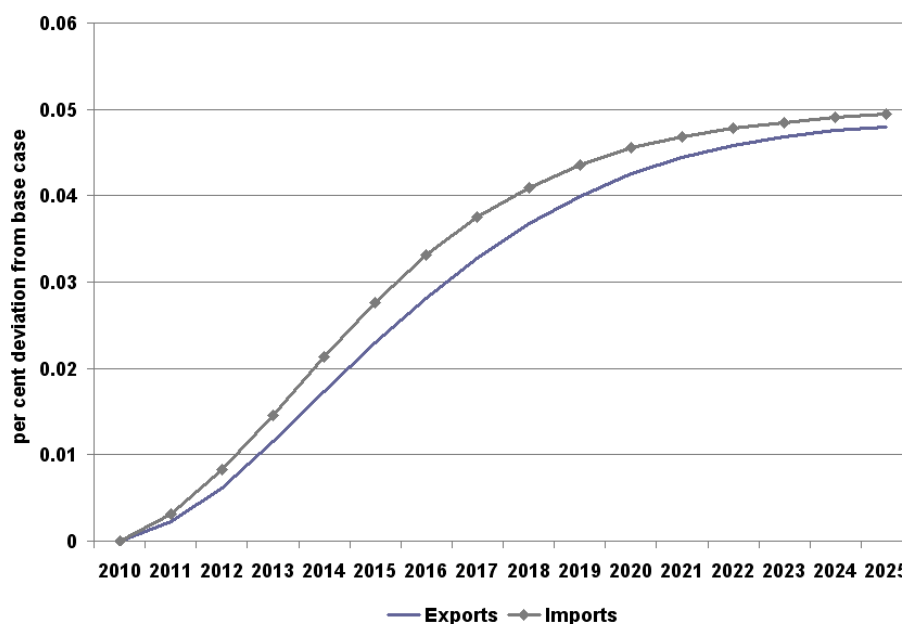
Private consumption is a core component of GDP. More importantly, private consumption is also often cited as a better proxy for welfare than GDP. A strong increase in consumption indicates an increase in utility for the community in the classic economic sense.

Consumption follows a similar path to GDP and investment, albeit to a smaller extent. This suggests that raising the adoption rate of BIM in Australia would have a positive affect on Australian's welfare. By 2025, it is estimated that private consumption would be higher by 0.038 per cent (equivalent to \$377 million). The cumulative boost in real consumption over the period 2011-25 is equivalent to a one off increase in private consumption of \$1.4 billion in 2010.

Impacts on net exports

The higher output arising from the boost to the productivity of the buildings network industry means that there would be increased capacity for exports. Indeed, the simulation results indicate that exports would be higher under the widespread BIM adoption scenario (see Figure 8.2). Imports would also be higher than under the BAU scenario, reflecting the lift in domestic demand. Higher investment boost imports as a sizable proportion of investment good are imported. Similarly, higher private consumption is expected to boost imports.

Figure 8.2

IMPACTS ON EXPORTS AND IMPORTS

Source: Allen Consulting Group analysis, 2010.

Impacts on the labour market

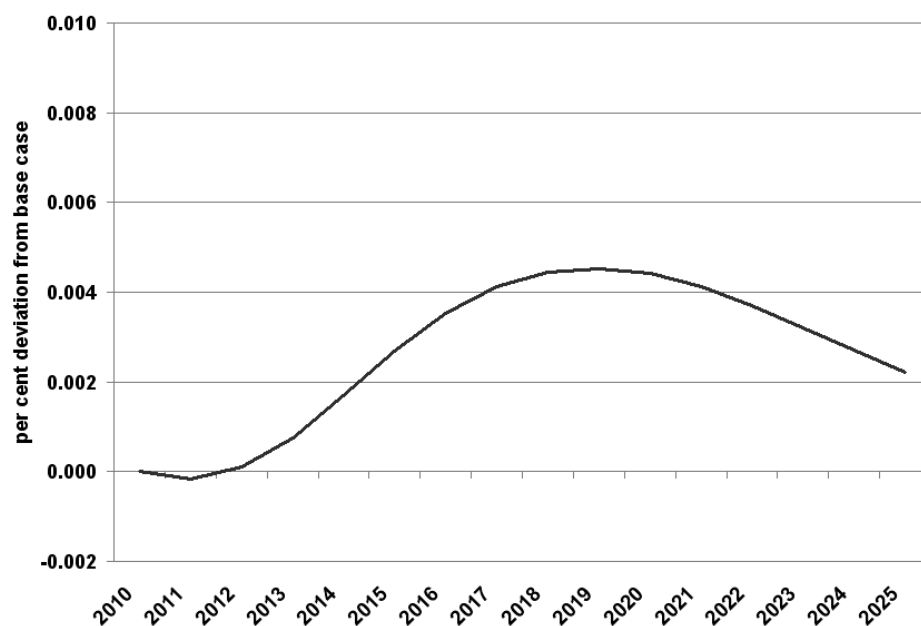
In the short term, employment is closely linked with economic activity and investment. As the demand for a firm's goods increases, it can expand its operations and increase its levels of capital and labour. Hence, as shown in Figure 8.3, in the initial period of the forecast horizon, there would be an increase in employment (measured as number of jobs).

In the long run, national employment is relatively unchanged, and deviations from the BAU scenario in percentage terms are close to zero. This reflects the idea that in the long run national employment is dominated, if not determined, by demographic factors, such as birth and death rates, and the level of international migration. It is also consistent with conventional macro-economic modelling, in which the unemployment rate reverts to its natural rate over the long run.

Although employment is unchanged in the long run, the labour market is projected to adjust via changes in wages. Raising productivity would lead to higher wages in the long run (see Figure 8.4). That is, the benefits of widespread BIM adoption would be realised mostly as an increase in the real wage rate, rather than as an increase in employment. Indeed, it is estimated that, compared with the BAU scenario, productivity improvements stemming from higher BIM adoption would lead to an increase in real wages of 3 basis points in 2025.

Figure 8.3

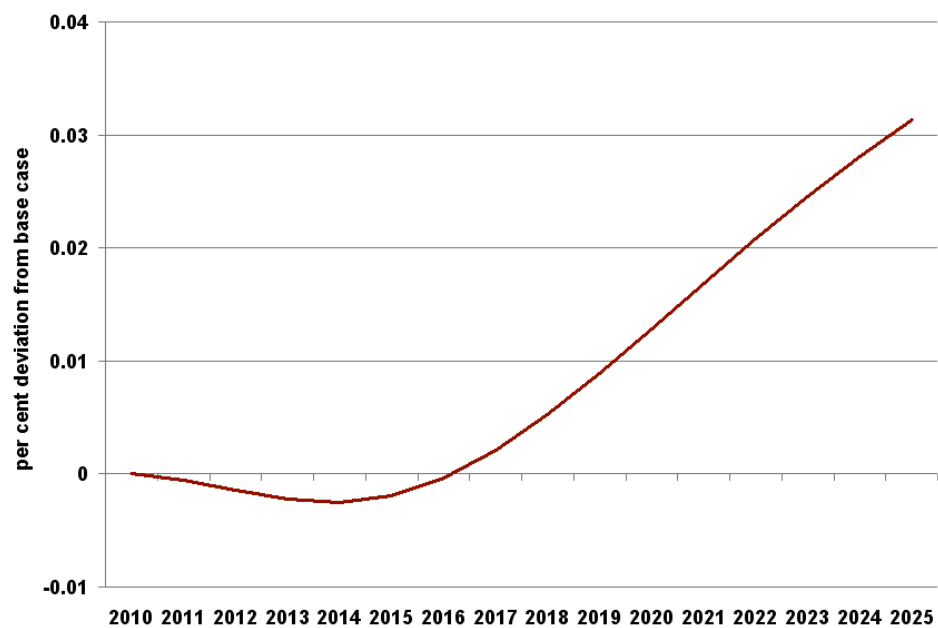
IMPACTS ON EMPLOYMENT



Source: Allen Consulting Group analysis, 2010.

Figure 8.4

IMPACTS ON WAGES



Source: Allen Consulting Group analysis, 2010.

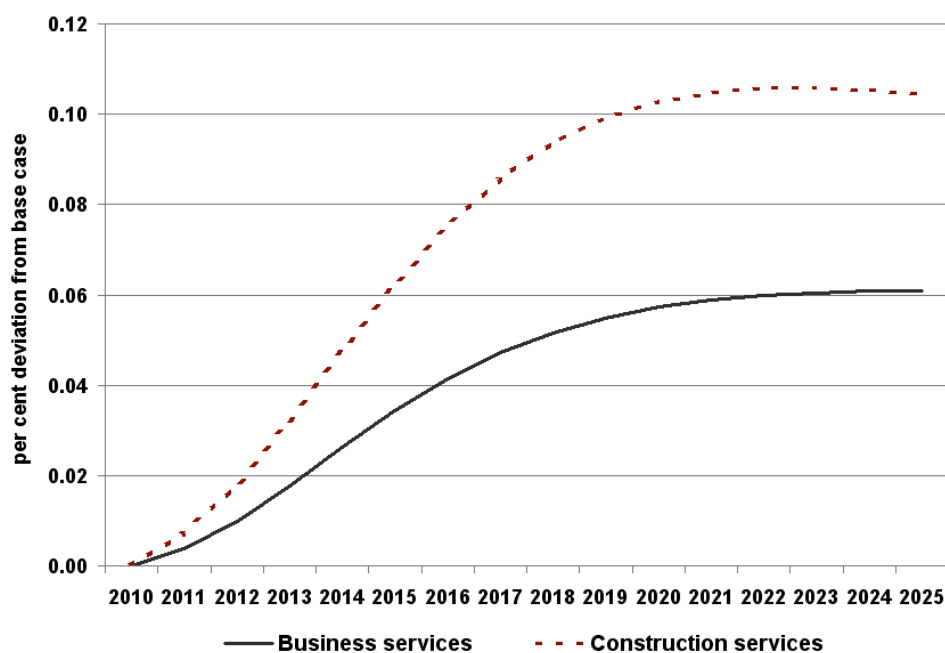
8.2 Industry results

The sectoral impacts of widespread adoption of BIM vary across different sectors. The buildings network industry would reap the highest benefits from higher BIM adoption. Indeed, the simulation results show that output of the business services and construction services sectors — the two sectors within the MMRF that encompass most of the buildings network — would be higher than the BAU scenario (see Figure 8.5).

Specifically, the output of the business services sector, which includes architects, engineers and owners, would be higher by 0.061 per cent in 2025, compared with the BAU scenario. The construction sector would also expand, as its output would increase by 0.105 per cent in 2025.

Figure 8.5

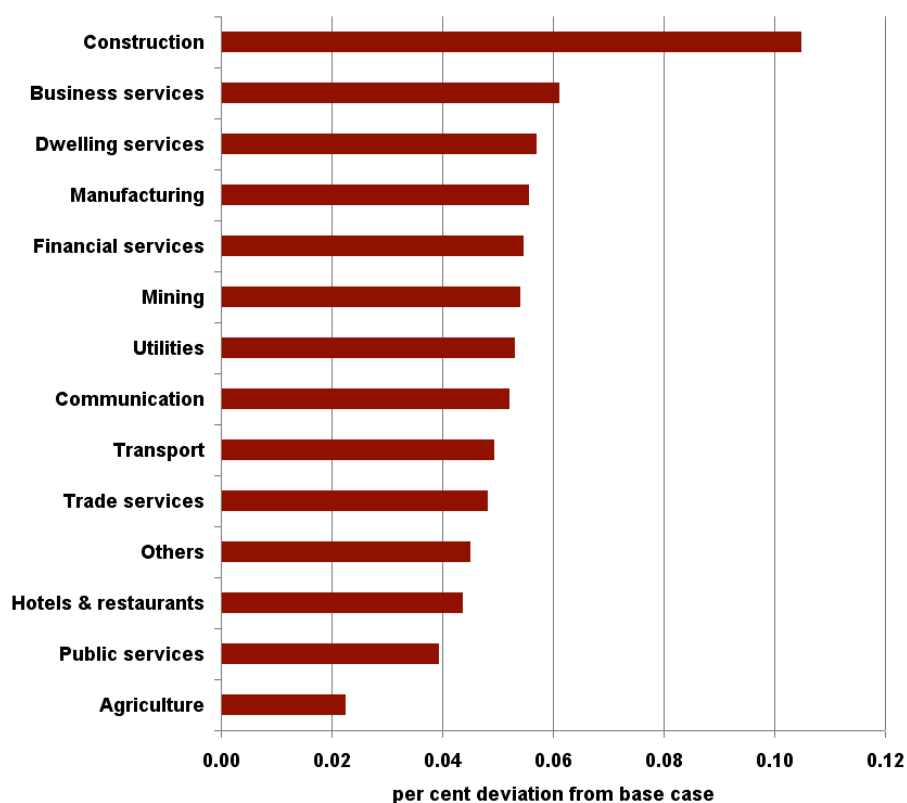
IMPACTS ON BUSINESS AND CONSTRUCTION SERVICES OUTPUT



Source: Allen Consulting Group analysis, 2010.

Figure 8.6 highlights the estimated average impacts of accelerated widespread BIM adoption on the output of other industries. Importantly, although higher BIM adoption *directly* raises productivity only in the buildings network industry, it also *indirectly* benefits all other Australian industries as the effect of higher productivity in the buildings network is passed on to other industries in the form of lower prices for inputs. For instance, there would be an increase in output in the manufacturing sector, partly due to an increase in the demand for construction materials. The financial sector would also expand due to increased economic activity.

Figure 8.6

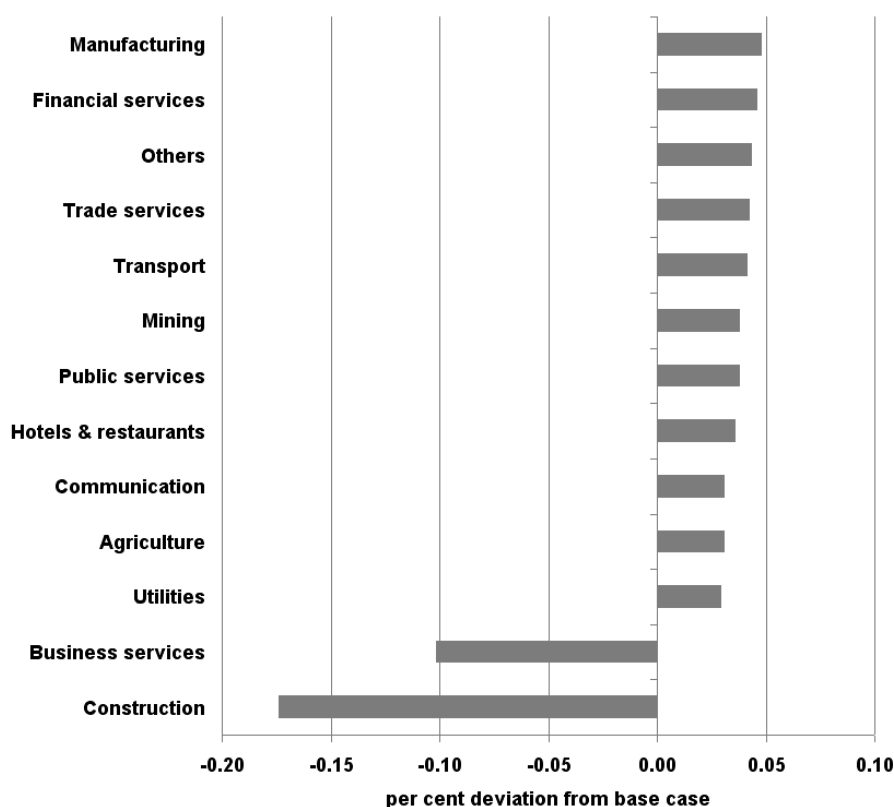
IMPACTS ON INDUSTRY OUTPUT, IN 2025

Source: Allen Consulting Group analysis, 2010.

As previously mentioned, in the long run, the national labour market reverts to its natural rate of unemployment, which means there would be no impact on national employment. Essentially, BIM is not projected to change the fundamental factors that change the employment figures, such as the number of people living in Australia. However, employment impacts on different industries would differ as resources (in this case labour) are reallocated across different sectors (see Figure 8.7).

An improvement in the labour productivity of the construction and business services sectors means that these sectors would produce the same amount of output with less labour. In fact, the modelling results indicate that in 2025, the number of jobs in these sectors would be lower than in the BAU scenario. However, labour would be re-distributed to other sectors of the economy that indirectly benefited from the higher BIM adoption, such as the manufacturing and financial services sectors.

Figure 8.7

IMPACTS ON INDUSTRY EMPLOYMENT, IN 2025

Source: Allen Consulting Group analysis, 2010.

8.3 Sensitivity analysis

The results presented in Section 8.1 and Section 8.2 are based on the average cost savings experienced by the key user groups of BIM. However, as indicated in Chapter 7, applying different productivity gains and adoption rates would have an impact on the economic modelling.

There is a range of potential productivity gains. Applying the maximum and minimum expected productivity gains provides the range of likely impacts on the economy. Table 8.2 sets out the lower and upper bound of the estimated impacts on key economic variables.

Using the minimum productivity gains as the proxy for lower bound economic impacts, raising the adoption rate on BIM would lift GDP by 0.011 per cent in 2025, even if the productivity gain is at the lower end of the estimates. If the actual productivity gains across the industry turn out to be higher, GDP would potentially be 0.083 per cent higher than the BAU scenario.

Table 8.3 shows the estimated range of impacts on GDP, investment and consumption in NPV terms. As shown in this table, over the period 2011-2025, accelerated widespread BIM adoption could potentially boost GDP by between \$1 billion and \$7.6 billion (in NPV terms). Welfare of Australian households (consumption), would be higher by at least \$328 million (in NPV terms) over the 15 years assessment period.

This analysis shows that, while the economy-wide impacts vary in magnitude depending on the productivity estimates being used, the accelerated widespread use of BIM consistently translates into higher output (GDP), higher wages and higher living standards (household consumption).

Table 8.2

IMPACT ON KEY ECONOMIC VARIABLES IN 2025 (PER CENT DEVIATION FROM THE BAU SCENARIO)

	Lower	Average	Upper
GDP	0.011%	0.052%	0.083%
Consumption	0.008%	0.038%	0.060%
Investment	0.017%	0.081%	0.131%
Wages	0.007%	0.031%	0.050%
Business services output	0.013%	0.061%	0.097%
Construction services output	0.021%	0.105%	0.169%

Source: Allen Consulting Group analysis, 2010.

Table 8.3

NPV OF ABSOLUTE IMPACT ON KEY ECONOMIC VARIABLES OVER 2011-2025

	Lower	Average	Upper
GDP	\$1,037million	\$4,794 million	\$7,633 million
Consumption	\$328 million	\$1,446 million	\$2,276 million
Investment	\$636 million	\$3,022 million	\$4,831 million

Source: Allen Consulting Group analysis, 2010. Note: NPV is expressed in 2008-09 dollars in 2010, and calculated using a real discount rate of 5 per cent.

Chapter 9

Conclusion

9.1 Key findings

BIM in an industry context

- BIM technology offers the potential for many direct and indirect benefits to the buildings network industry, including:
 - improved information sharing;
 - time and costs savings that can be directly translated into productivity gains;
 - improved quality;
 - greater transparency and accountability in decision making;
 - increased sustainability; and
 - labour market improvements.
- According to the BIM Survey 2010, average savings to businesses from BIM use across the four main user groups is between 5.5 per cent and 9.6 per cent. When put into context, it is clear that these savings are significant (see Table 9.1). Suppose all the employees in an architectural firm do not take any sick leave in a year, this would imply an increase in the productivity level of the firm of 4.3 per cent. Achieving a 9.6 per cent productivity gain would be equivalent to all employees of this firm not taking any sick leave *and* taking only eight days of annual leave in a year.

Sceptics may paint BIM as just an advanced version of 3D design tools, but it is more than that. [...] BIM systems integrate design, specification and construction in a virtual space. They allow teams at all stages of a project's lifecycle to access designs in real time. The potential efficiency and productivity gains are enormous.

Property Council of Australia, 2009.

Table 9.1

COMPARISON ON PRODUCTIVITY GAINS ON INDIVIDUAL COMPANY

Productivity enhancement	Productivity gains
Healthy workplace where employees do not take sick leave	4.3% p.a.
<i>BIM adoption labour productivity gain</i>	<i>5.5% - 9.6% p.a.</i>

Source: Allen Consulting Group 2010.

- While BIM is expected to deliver important benefits to the buildings network, it is clear that its adoption would also have costs. The perceived costs of adopting BIM technology identified in the literature (e.g. McGraw Hill, 2008, 2009) include:
 - education and training costs;
 - administration and start up costs; and
 - transition and behavioural costs.

- These costs are common to the adoption of many new technologies. Further, the literature suggests that users of BIM technology perceive the benefits to outweigh the costs involved (buildingSMART Australasia et al., 2010; McGraw Hill, 2007). Industry stakeholders consulted for this study also indicated that the marginal cost of BIM software compared to current 3D CAD is not significant.
- While BIM is expected to deliver many benefits and the costs are not materially higher than traditional or alternative management approaches, there are many further factors that currently impede its widespread adoption. Consultations held with key industry stakeholders familiar with BIM point to the following factors playing a role in impeding adoption of BIM:
 - lack of BIM object libraries;
 - lack of model building standards;
 - legal and insurance impediments;
 - lack of standards for information exchange and management and inconsistencies in information handover protocols;
 - skills gaps;
 - lack of strategic research focus; and
 - industry resistance to process change.

A wider perspective — BIM and the Australian economy

This study found that BIM not only delivers benefits to industry, but that it has macroeconomic significance and that its accelerated widespread adoption would make a significant difference to national economic performance. The points below summarise the impacts that accelerated widespread BIM adoption would have on key macroeconomic variables.

- Accelerated widespread adoption of BIM technology would enhance the productivity of different players in the buildings network and have a significant expansionary effect on the Australian economy. Indeed, it is estimated that the benefits of accelerated widespread BIM adoption over the period 2011 to 2025 are equivalent to a one off increase in GDP of \$4.8 billion in 2010. The gains may be as large as \$7.6 billion depending on the uncertainties in estimating the actual size of expected productivity gains.
- There are many ways to put these impacts into context.
 - One way of putting this impact into context is to look at the benefit cost ratio (BCR) of this change. Industry experts have advised that the incremental costs of adopting BIM are not materially higher than the costs of alternative technological approaches being used by the buildings network. However, even if for illustrative purposes it was assumed that the incremental costs of adopting BIM are \$500 million, the BCR of this change would be almost ten. A BCR of ten implies that this change would provide a benefit that is ten times higher than the alternative investment (e.g. repaying government bonds).
 - Another way of putting this into context is to consider the fact that government applies a BCR threshold of two for road infrastructure projects

(such as the black spot sites) to qualify for federal funding (Department of Infrastructure, Transport, Regional Development and Local Government, 2008).

- A third approach to gain context is to compare the impact of accelerated widespread BIM adoption to the impact of other major transformative technologies. Table 9.2 shows the impacts of changes that have happened in history and the impacts of other transformative technologies recently estimated and it also compares them to Australia's average productivity growth. BIM is not the largest change in this table. However, it is useful to compare it to other changes that have been viewed as being revolutionary in their magnitude. The long run change brought about by BIM of five basis points still represents a significant addition to the Australian average labour productivity growth of 150 basis points. The five basis points provided by BIM will provide a substantial stepping stone to the improvement of Australia's productivity in the long term.

Table 9.2

EXAMPLES OF PRODUCTIVITY GAINS FROM HISTORY AND IN PROSPECT

Technology/Productivity enhancement	Productivity gains
Industrial revolution: Railways (UK)	0.26% p.a.
e-Commerce	0.27% p.a.
Industrial revolution: Steam technology (UK)	0.38% p.a.
ICT (capital deepening)	1.19% p.a.
Average labour productivity growth in Australia (last 3 decades)	1.50% p.a.
BIM adoption (long term)	0.05% p.a.

Source: Allen Consulting Group 2000 and 2010, Crafts 2003, OECD 2008.

- The gains from the acceleration of widespread BIM adoption compare favourably with other reforms that have been pursued by government in the past. For example, in a milestone report, the Productivity Commission (then the Industry Commission) used the ORANI model to estimate the effects of the Hilmer reform agenda. This found that introducing road pricing would raise GDP by 0.01 per cent; ports by 0.02 per cent and the news agents reforms by 0.03 per cent (Industry Commission 1995). Australian governments pursued most of these reforms. More recently, the Productivity Commission has estimated the benefits of a National Reform Agenda using the MMRF model and among many reforms it found that further reform of the energy sector would raise GDP by 0.05 per cent and further ports and associated infrastructure reforms by 0.02 per cent (Productivity Commission 2006).
- The best single measure of the impact of accelerated widespread BIM adoption on the Australian community is consumption. Consumption, the best indicator of wellbeing, is also expected to rise as a result of higher BIM adoption. The cumulative boost in real consumption over the period 2011-25 is equivalent to a one off increase in private consumption of \$1.4 billion in 2010.

- Investment, an indicator of the future productive capacity of the Australian economy, would also be boosted by accelerated widespread BIM adoption. The increase in investment Australia-wide is equivalent to a one off increase of \$3 billion in 2010.
- Another way in which the community would benefit from higher BIM adoption is via wages. Compared with a BAU scenario, productivity improvements stemming from higher BIM adoption would lead to an increase of real wage of 3 basis points in 2025.
- Although higher BIM adoption *directly* raises productivity only in the buildings network industry, it also *indirectly* benefits all other Australian industries as the effect of higher productivity in the buildings network is passed on to other industries in the form of lower prices for inputs. Indeed, production increases across all industries, with the biggest gains concentrated in the business services and construction sectors (the two sectors within MMRF that contain most of the buildings network's players).
- A sensitivity analysis of these results using lower and higher estimates of productivity gains stemming from BIM was undertaken. This analysis shows that, while the economy-wide impacts vary in magnitude depending on the productivity estimates being used, the accelerated widespread use of BIM consistently translates into higher output (GDP), higher wages and higher living standards (household consumption).
- In conclusion, BIM is expected to deliver many benefits to industry at costs that are not materially higher than traditional or alternative management approaches. Accelerated widespread BIM adoption can also make a significant difference to national economic performance and raise the economic wellbeing of the Australian community. However, there are many factors that currently impede BIM accelerated widespread adoption. If these barriers are overcome, the buildings network industry and the Australian community will be better off.

9.2 Limitations

The findings presented in this report provide valuable evidence of the economic impacts of the accelerated widespread adoption of BIM technology on the Australian economy. Nonetheless, as with any modelling exercise, there are some limitations in this analysis. The key limitations of this study are:

- The economic impacts of the widespread adoption of BIM have been calculated using estimates about productivity improvements stemming from BIM use by four main players in the buildings network, rather than on the entire supply chain. This translates into a more conservative estimate of the benefits of BIM than if the full range of benefits that this technology provides across the entire buildings supply chain were included.

- The economic impacts modelled are based on the differences between a higher BIM adoption rate and a BAU projection of BIM adoption in Australia. The aim of this study was not to provide projections of future BIM adoption, and the authors of this report did not attempt to do so. Instead, information about future BIM adoption under a BAU scenario, as well as about adoption under the ‘higher adoption scenario’, was sourced from a survey conducted by buildingSMART Australasia (buildingSMART Australasia et al., 2010) and consultations with industry stakeholders. Changes to these projections would have an impact on the economic modelling.
- The economic modelling assumes that the productivity gains for firms using BIM would remain the same over time. Potentially, as more and more firms adopt BIM, there may be higher productivity gains over time — due to increased integration and connectivity.
- The economic modelling is conservative as estimates about productivity gains stemming from BIM were sourced from the 2010 BIM survey undertaken by buildingSMART Australasia et al. and these estimates mainly capture the gains of Stages 1A-2A of BIM technology. It is likely that the productivity gains would be even higher under Stages 3B of the BIM technology.
- The economic modelling does not account for the cost involved in achieving the widespread adoption of BIM in the buildings network. These costs could involve policies such as tax incentives to promote BIM and/or industry efforts to increase awareness about and adoption of BIM (e.g. training and conferences).
- The economic modelling captures the productivity gains on public sector construction activities, but not the gains from lower facility management costs incurred by the public sector. This is because the *construction services sector* includes construction activities arising from government procurement, and its subsequent spillover effects.
- It is important to note that the public sector owns a significant numbers of buildings. However, there is no information on the proportion of government administration that involves buildings management. For example, it is difficult to estimate the value-added of defence housing services as a share of total government administration. Hence, in the economic modelling, the impact of BIM on potential savings to the government in term of lower facility cost was not estimated. This implies that the modelling approach is conservative. Potentially, estimated savings from using BIM would impact on government budget, in terms of reduction in government expenditure. This in turn could lead to higher economic and social benefits as the funds can be channelled to other areas such as education and health, or returned to taxpayers in the form of income tax cut.
- Finally, it is important to note that the findings in this report are subject to unavoidable statistical variation. While all care has been taken to ensure that the statistical variation is kept to a minimum, care should be taken whenever using this information. This report only takes into account information available to the Allen Consulting Group up to the date of this report and the findings may be affected by new information.

9.3 Areas for further investigation

This report focused on the potential benefits that might arise from accelerated widespread adoption of BIM in the buildings network. The extent to which these benefits can be realised will be contingent on addressing many additional issues that require further exploration. These issues include:

- Risk analysis — There are a number of potential risks inherent in the use of BIM technology. The increased interdependence of project teams increases the number of parties relying upon the data contributions of other parties, and therefore entails a high degree of trust. Other potential risks associated with BIM technology include (McGraw Hill, 2008, p. 33):
 - liability and legal issues;
 - inexperience of users — BIM is an emerging technology, and expertise varies within project teams and within firms; and
 - ownership of the model —the debate over who owns the BIM database is a debate that needs to be resolved, particularly as project teams become more integrated.

The risks involved in widespread adoption of BIM and potential ways in which these risks could be shared and minimised need to be explored in detail.

- The need for standards — A key issue in the adoption of intelligent, model based tools, such as BIM technology, is to ensure that the information created is of high quality and readily accessible to all individuals, organisations and government agencies across the building life cycle. This requires the adoption of national standards for information exchange (BIM Standards) (CIE, 2009, p. 4.). The creation and implementation of these standards need to be analysed. Key questions that would need to be explored include: How would the structure, format and presentation of the data be determined? What are the compatibility difficulties with legacy software systems?
- The role of different stakeholders — What role is there for government to address potential structural barriers and encourage increase adoption of BIM in Australia's buildings network? What role is there for client groups, industry organisations and government building procurement agencies?
- Pathways for increased adoption — What are the pathways that could be pursued to increase BIM adoption in Australia's buildings network?

Appendix A

The MMRF Model

A.1 The MMRF model

The Monash Multi-Regional Forecasting (MMRF) model is a Computable General Equilibrium (CGE) model of Australia's regional economies developed by the Centre of Policy Studies (CoPS) at Monash University (CoPS, 2008). It is a model of the entire Australian economy and it captures the interactions between different regions and sectors. For a detailed description of the theoretical structure of the model see Peter et. al., 1996.

The MMRF model is used for a wide range of policy studies, including the analysis of state tax reforms and the potential benefits of the National Reform Agenda. More recently, the Department of the Treasury and the *Garnaut Climate Change Review* applied the MMRF model to the national climate change modelling to assess the impacts of the proposed CPRS on the Australian economy.

Appendix A provides an overview of the MMRF model, detailing its modelling capabilities, core structure and economic principles.

A.2 Introduction to the MMRF model

The MMRF is a dynamic model of the Australian economy that models the behaviour of economic agents within each of Australia's eight states and territories. Each region is modelled as an economy in its own right, with region-specific commodities, prices and industries. The model contains explicit representations of intra-regional, inter-regional and international trade flows.

Each sector produces capital that is specific to the region in which it is located. In each region, there is a single representative household and a regional government. At the national level, the Commonwealth Government is also represented. Finally, the rest of the world is represented as a single agent, whose behaviour is driven by regional international exports and imports. The regions are linked through inter-regional trade, labour and capital mobility, and the taxing and spending of the federal government.

A.3 The database

There are many versions of the MMRF model. The version of MMRF used for this project provides a representation of the Australian economy as it was in 2005-06.

The model allows for joint production — where one industry can produce a number of different commodities. Specifically, the model contains 58 industrial sectors, which produce 63 commodities. The industries and their related commodities are detailed in Table A.1 and Table A.2 respectively.

Table A.1

MMRF: INDUSTRIES

Industry	
Agriculture, Forestry and fishing	30. Motor vehicles and parts
1. Sheep and beef cattle (high emissions)	31. Other manufacturing
2. Dairy cattle	Utilities
3. Other livestock (low emissions)	32. Electricity generation: Coal
4. Broadacre agriculture except for animal	33. Electricity generation: Gas
5. Other agriculture	34. Electricity generation: Oil products
6. Agricultural services and fishing	35. Electricity generation: Nuclear
7. Forestry	36. Electricity generation: Hydro
Mining	37. Electricity generation: Other
8. Coal mining	38. Electricity supply
9. Oil mining	39. Gas supply
10. Gas mining	40. Water supply
11. Iron ore mining	Services
12. Non-ferrous ore mining	41. Construction services
13. Other mining	42. Trade services
Manufacturing	51. Financial services
14. Meat and meat products	52. Business services
15. Other food, beverages and tobacco	53. Dwelling services
16. Textiles, clothing and footwear	54. Public services
17. Wood products	50. Communication services
18. Paper products	43. Accommodation, hotels and cafes
19. Printing and publishing	55. Other services
20. Petroleum and coal products	56. Private transport services
21. Chemicals	57. Private electricity equipment services
22. Rubber and plastic products	58. Private heating services
23. Non-metal construction products	Transport
24. Cement	44. Road passenger transport
25. Iron and steel	45. Road freight transport
26. Alumina	46. Rail passenger transport
27. Aluminium	47. Rail freight transport
28. Other non-ferrous metals	48. Water, pipeline and transport services
29. Metal products	49. Air transport

Source: CoPS, MMRF database.

Table A.2

MMRF: COMMODITIES

Commodities	
1. Sheep and beef cattle (high emissions)	33. Other non-ferrous metals
2. Dairy cattle	34. Metal products
3. Other livestock (low emissions)	35. Motor vehicles and parts
4. Broadacre agriculture except for animal	36. Other manufacturing
5. Bio fuel	37. Electricity generation: Coal
6. Other agriculture	38. Electricity generation: Gas
7. Agricultural services and fishing	39. Electricity generation: Oil products
8. Forestry	40. Electricity generation: Nuclear
9. Coal mining	41. Electricity generation: Hydro
10. Oil mining	42. Electricity generation: Other
11. Gas mining	43. Electricity supply
12. Iron ore mining	44. Gas supply
13. Non-ferrous ore mining	45. Water supply
14. Other mining	46. Construction services
15. Meat and meat products	47. Trade services
16. Other food, beverages and tobacco	48. Accommodation, hotels and cafes
17. Textiles, clothing and footwear	49. Road passenger transport
18. Wood products	50. Road freight transport
19. Paper products	51. Rail passenger transport
20. Printing and publishing	52. Rail freight transport
21. Petrol	53. Water, pipeline and transport services
22. Diesel	54. Air transport
23. LPG	55. Communication services
24. Aviation fuel	56. Financial services
25. Petroleum and coal products nec	57. Business services
26. Chemicals	58. Dwelling services
27. Rubber and plastic products	59. Public services
28. Non-metal construction products	60. Other services
29. Cement	61. Private transport services
30. Iron and steel	62. Private electricity equipment services
31. Alumina	63. Private heating services
32. Aluminium	—

Source: CoPS, MMRF database.

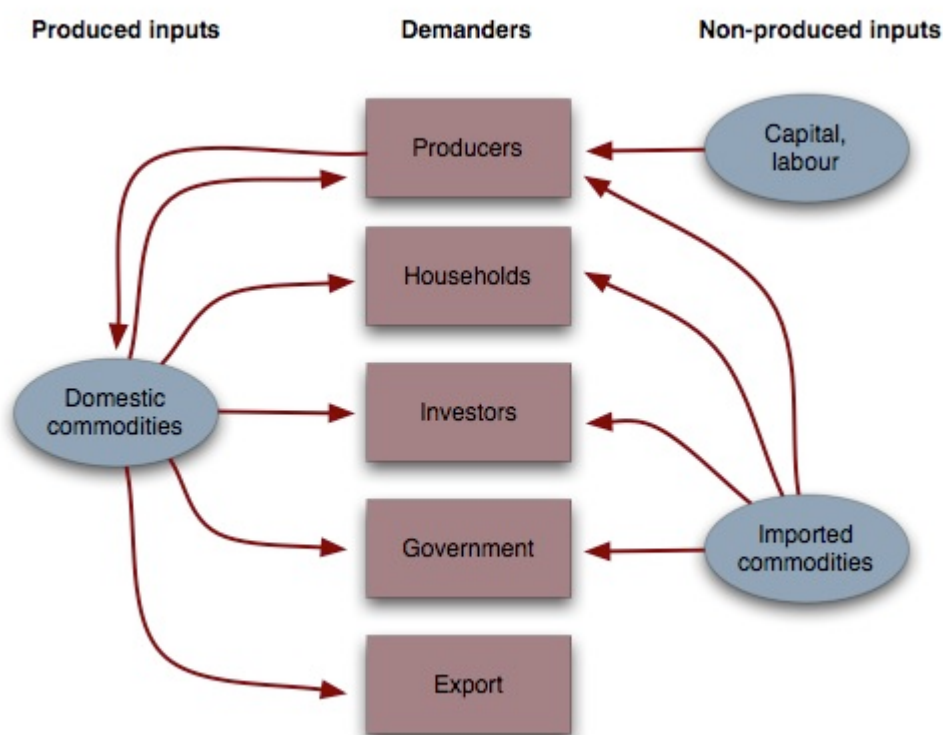
The MMRF database is comprised of detailed input-output tables for each state and territory as well as a set of government fiscal accounts. Each of the eight input-output tables details the core cost structure of each region specific industry and how each industry in each state economy is linked to other industries within that state and other states. Further, they show the flow of goods through the economy and the final demands of the principal economic agents.

A.4 Structure of the model

The core structure of the MMRF model is illustrated in Figure A.1. Producers use primary factors (labour, land and capital), region specific intermediate goods, and imports to produce domestic commodities. Domestic commodities and imported commodities flow to households, investors, and governments. In addition a proportion of domestic commodities flow to foreigners as exports. As well as demand schedules, the MMRF model has a detailed government budget and a set of regional labour markets.

Figure A.1

STRUCTURE OF THE MMRF MODEL



Source: Allen Consulting Group analysis, 2010, adapted from Monash.

The MMRF model is built on the core assumptions of neoclassical economics. Consumers aim to maximise utility within a fixed budget constraint, while firms select the mix of inputs that minimises costs for their level of output. This optimising behaviour determines the regional supplies and demands of commodities and the demand for primary factors within the model. Labour supply at the national level is governed by demographic factors and national capital supply is determined by rates of return. Both labour and capital can cross regional borders such that each region's stock of productive resources reflects relative employment opportunities and relative rates of return.

Assumptions regarding the economic behaviour of agents together with detailed input-output tables for each of the eight regions are linked by mathematical equations. This allows for second round impacts or feedback responses to be accounted for in the modelling framework. For instance, it allows for price response adjustments across all industries and factors. In this way, the results detail the actual effect of a change on the entire economy, not just within the region or industry that is directly affected. This allows a more sophisticated insight into policy analysis than is possible from partial equilibrium analysis or input-output analysis.

The model is driven by the assumption of competitive markets. That is, all markets clear and there exists equality between the producer's price and marginal cost for each sector in each region (all markets clear with the exception of the labour market). The purchasers price and producers price differs by the size of any government taxes and associated margins. All government taxes are levied as ad valorem sales taxes on commodities. Margins are additional costs associated with transport or retail trade required for market transactions.

Aggregate demand

Demand for goods from households, investors, governments and foreigners together comprise aggregate demand as represented in the equation below.

$$Y = C + I + G + (X - M)$$

Where:

- Y is aggregate demand;
- C is household consumption;
- I is investment;
- G is government spending;
- X is exports; and
- M is imports.

The components of aggregated demand and how they are represented within the model are discussed below.

Household demand

There exists a utility maximising representative household in each of the eight regions. Households consume bundles of goods from either domestically produced or imported commodities. Domestically consumed goods are a combination of goods from the eight regions. Total household demand is disaggregated into essential goods and luxury goods, as represented in the equation below.

$$X_i = X_i^{Sub} + X_i^{Lux}$$

Where:

- X_i is total household demand;
- X_i^{Sub} is essential consumption; and
- X_i^{Lux} is luxury consumption.

In MMRF it is assumed that a household will first purchase all essential goods before purchasing any luxury goods such that disposable income for luxury goods is a function of total income and the summed value of essential consumption.

$$Y^{Lux} = Y - \sum P_i X_i^{Sub}$$

Where:

- Y^{Lux} is income for luxury goods;
- Y is total disposable income
- P_i is price of good i; and
- X_i^{Sub} is quantity of essential good X.

MMRF assumes a non-homothetic utility function (MMRF applies a Klein-Rubin utility function), which allows both income and relative prices to affect consumption.

Capital creation

Investors in each regional sector combine inputs to generate capital. Investors are limited to the technology set that is available for production in that regional sector. Rates of return are used as a signal for capital investment or disinvestment.

Government demands

There are nine governments represented in MMRF — the eight regional governments and a federal government — each demanding commodities. Government demands are either imposed on the model or determined endogenously by setting government expenditure rules. For example, government expenditure could be linked to aggregate consumption.

Foreign demand

Most exports can be categorised as either traditional exports, non-traditional exports or tourism exports. Demand for traditional exports is characterised by a downward sloping demand curve and associated assumptions regarding foreigners' preferences for Australian goods. Each regional sector has an associated export market, which faces a downward sloping foreign demand curve. It is assumed that the foreign demand schedules are specific to the regional sector; as such movement in world prices can differ across different regions.

The demand for non-traditional export goods is driven by the average price of the collective non-traditional export bundle. In the MMRF database, non-traditional exports account for two per cent of total national exports and include: electricity generation, gas and water, construction, trade services, rail transport and dwellings.

Within MMRF, it is assumed that the tourism sectors — hotels and cafes, road transport, air transport and other services — do not face their own individual demand schedules. Rather, foreigners purchase a holiday bundle, the quantity of which is determined by the average price of the tourism goods.

Demands for inputs used in production

Producers in each region utilise primary factors — land, labour and capital — intermediate goods and imported goods to produce domestic commodities. Producers are assumed to choose the mix of inputs that minimises costs for a given level of production. The MMRF model assumes a multi-stage nested structure of production. At the first stage the optimal combination of region specific intermediate goods and the optimal combination of occupational specific labour is selected. At the second stage, producers make decisions regarding the optimal combination of the three primary factors and the combination of imported and domestically sourced goods. Finally, producers combine primary inputs and intermediate goods to produce a level of output at minimum cost.

A.5 Government finances

MMRF contains a set of equations detailing government revenues and government expenditures for each government. Government revenues are comprised of income taxes, sales taxes, excise taxes, taxes on interregional trade and receipts from government assets. Government expenditures include — as detailed above — expenditure on commodities as well as transfer payments to households. In addition, for the Federal government there is a set of equations describing fiscal transfers to the states.

A.6 MMRF dynamics

There are two main types of inter-temporal links incorporated into MMRF: physical capital accumulation and lagged adjustment processes.

Physical capital accumulation

It is assumed that investment undertaken in year t becomes operational at the start of year $t+1$. Thus, given a starting point value for capital in $t=0$, and with a mechanism for explaining investment through time, the model can be used to trace out the time paths of industry capital stocks.

Capital stock in industry i in state/territory s in year $t+1$ is determined by the equation below.

$$K_{i,s}(t+1) = (1 - DEP_{i,s}) * K_{i,s}(t) + INV_{i,s}(t)$$

Where:

- $K_{i,s}(t)$ is the quantity of capital available in industry i located in state/territory s at the start of year t ;
- $INV_{i,s}(t)$ is the quantity of new capital created through investment for industry i in state/territory s during year t ; and
- $DEP_{i,s}$ is the rate of capital depreciation in industry i , treated as a fixed parameter.

Investment in industry i in state/territory s in year t is explained via a mechanism that relates investment to expected rates of return. The expected rate of return in year t can be specified in a variety of ways. In MMRF two possibilities are allowed: static expectations and forward-looking model-consistent expectations. Under static expectations, it is assumed that investors take account only of current rentals and asset prices when forming current expectations about rates of return. Under rational expectations the expected rate of return is set equal to the present value in year t of investing \$1 in industry i in state/territory s , taking account of both the rental earnings and depreciated asset value of this investment in year $t+1$ as calculated in the model.

Lagged adjustment processes

One lagged adjustment process is included in MMRF. This relates to the operation of the labour market in year-to-year simulations.

In comparative static analysis, one of the following two assumptions is made about the national real wage rate and national employment:

- the national real wage rate adjusts so that any policy shock has no effect on aggregate employment; or
- the national real wage rate is unaffected by the shock and employment adjusts.

MMRF's treatment of the labour market allows for a third, intermediate position, in which real wages can be sticky in the short-run but flexible in the long run and employment can be flexible in the short-run but sticky in the long run. For year-to-year simulations, it is assumed that the deviation in the national real wage rate increases through time in proportion to the deviation in aggregate employment from its baseline-forecast level. The coefficient of adjustment is chosen so that the employment effects of a shock are largely eliminated after about ten years. This is consistent with macroeconomic modelling in which the Non Accelerating Inflation Rate of Unemployment (NAIRU) is exogenous.

A.7 Closure assumptions of MMRF

In MMRF, there are more endogenous variables than the number of equations. For the model to generate a solution, the number of endogenous variables must match the number of equations. Hence, some endogenous variables are set to be exogenous to ensure the number of endogenous variables matches the number of equations.

The desired economic environment/assumption for the policy scenario determines the choice of exogenous variables. These choices are also known as the closure assumptions. The most common closure assumptions are the long run, short-run economic closure and fiscal closure.

Short-run closure

In the short-run, the economy is less able to respond to policy changes, as prices and wages are sticky (or fixed). Labour market (in terms of employment) is flexible and unemployment rate can be above or under its natural rate. Capital stock is fixed in the short-run, and investment responds to changes in rates of return.

Long run closure

The key elements of a typical long run economic environment are:

- At the national level, long run employment is determined by demographic factors (birth and death rates, the level of international migration, etc.). Additionally, the unemployment rate reverts to its natural rate or NAIRU in the long run. Therefore, the national employment figure is fixed. However, labour is perfectly mobile across industry and states, thus there can be changes in industry and state employment.
- Labour market adjusts via changes in real wages.
- Capital stock in each industry adjusts to equilibrate its expected and actual rates of return on capital. The baseline expected rates of return are determined by values in the MMRF database. Industries' demands for investment goods are linked by an exogenous investment/capital ratio to changes in their capital stock.
- Nominal household consumption in each region is a constant share of post-tax household disposable income.

Fiscal closure

The role of government also plays a part in determining the impacts of a simulation. A typical fiscal closure will have the following assumptions:

- real government consumption (Commonwealth and States) is fixed; and
- government budget balances (Commonwealth and States) are fixed, via changes in the fiscal item 'Government transfers to households'.

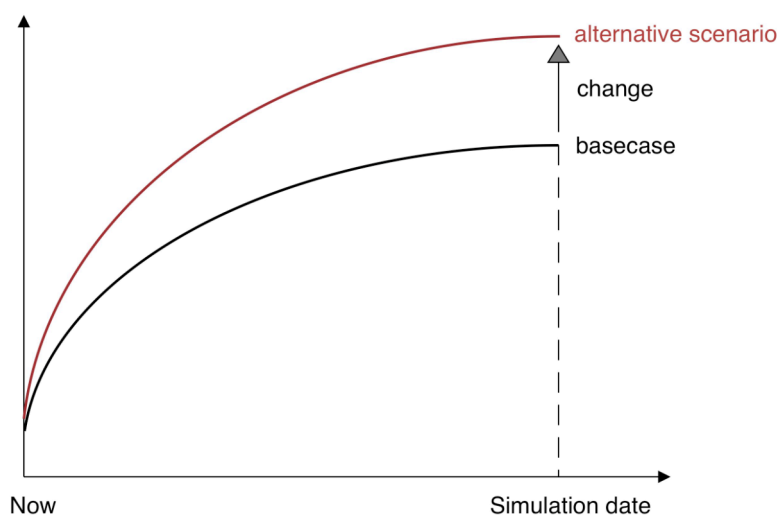
A.8 Interpretation of MMRF simulations

The MMRF can be solved in comparative static or recursive dynamic modes. Comparative static modelling shows the effect of a policy shock only. That is, it answers ‘what happens when this happens?’ without stating the adjustment process.

A dynamic CGE model would provide answers on the forecast structure of the economy under the baseline and the alternative case. It provides an explicit baseline over time against which the impact of a policy change can be compared. The model could incorporate more up to date data and the timing and policy paths are clear.

Figure A.2

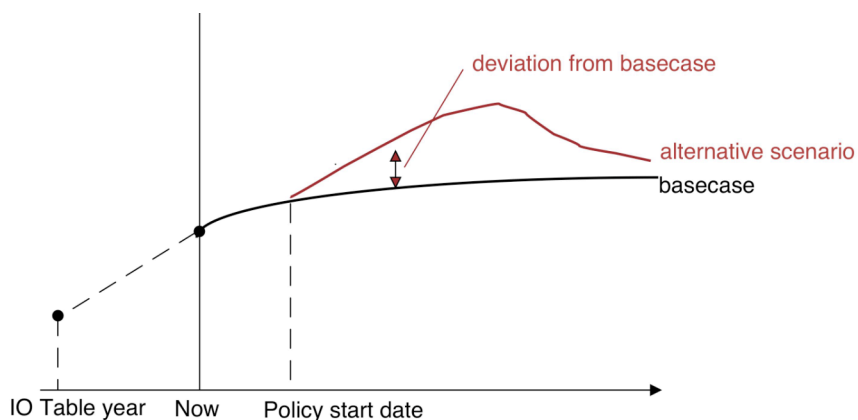
COMPARATIVE STATIC INTERPRETATION OF RESULTS



Source: Allen Consulting Group analysis, 2010.

Figure A.3

DYNAMIC INTERPRETATION OF RESULTS



Source: Allen Consulting Group analysis, 2010.

References

- Allen Consulting Group 2000, *e-commerce beyond 2000*, report prepared for the National Office for the Information Economy
- American Institute of Architects (AIA) 2007, *Integrated Project Delivery: A Guide*, United States.
- Australia Bureau of Statistics (ABS), 2004, '*Business Use of Information Technology*', Catalogue No. 8129.0, Australia.
- Australia Bureau of Statistics (ABS), 2008, '*2006 Census of Population and Housing*' Australia.
- Australia Bureau of Statistics (ABS), 2009a, '*Australian National Accounts: Input-Output Tables - Electronic Publication, 2005-06 Final*', Catalogue No. 5209.0.55.001, Australia.
- Australia Bureau of Statistics (ABS), 2009b, '*Australian System of National Accounts*', Catalogue No. 5204.0, Australia.
- Australia Bureau of Statistics (ABS), 2009c, '*Labour Force, Australia, Detailed, Quarterly*', Catalogue No. 6291.0.55.003 Australia.
- Australian Council of Built Environment Design Professions (BEDP) 2007, *Issues Paper*, September, Australia.
- Australian Procurement and Construction Council (APCC), 2009, *Integrated Project Teams and Building Information Modelling in the Australia Construction Industry*, draft version 8.
- Australian Sustainable Built Environment Council (ASBEC), 2008, *The Second Plank: Building a Low Carbon Economy with Energy Efficient Buildings*, Australia.
- Autodesk 2008, 'Improving Building Industry Results through Integrated Project Delivery and Building Information Modelling,' Autodesk White Paper, 2008, Australia.
- BIM Journal*, 2009, 'Interoperability: An Overview', June 2009, see bimjournal.com/art.asp?art=14&issue=5.
- Brown, Kerry (Ed.), 2008, 'BIM: Implications for Government', CRC Construction Innovation, Commonwealth of Australia.
- BuildingSMART Australasia, 2010, *Submission to the Public Commentary on the NBESARF*, 11 May 2010, Australia.
- buildingSMART Australasia, the School of Natural and Built Environment (University of South Australia) and NATSPEC 2010, *BIM Survey 2010*, unpublished, Australia.

BuildingSMART UK, 2010, *Constructing the Business Case, Building Information Modelling*, London.

Burgess, J., C. W. Furneaux, et al. 2007, *Streamlining Local Government: Evaluating an eGovernment Initiative in South East Queensland*, Report #5 - CIBE Research Project. P. K. Brown. Brisbane, Icon.Net.

Centre for International Economics (CIE), 2009, *National Standards for Building Information Exchange: Exploring the Impacts of Improved Information Management and Networking in the Built Environment*, March 2009, prepared for industry sponsors, Australia.

Chapman, R. E., 2005, *Inadequate Interoperability: A Closer Look at the Costs*, 22nd International Symposium on Automation and Robotics in Construction, September 11-14, 2005, Ferrara, Italy.

Centre for Integrated Facility Engineering (CIFE), 2007, *BIM Guide for Spatial Program Validation*, Stanford University, United States, see www.gsa.gov/BIM.

Collaborative Working in Construction (CWIC), 2005, *The Building and Construction Industry Technology Roadmap*, Revision 4, November 2005, Victoria, Australia.

Construction Industry Business Environment, 2008, *BIM: Implications for Government*, Case Study 5, Kerry Brown, Australia, 27 May 2008.

Construction Users Roundtable (CURT), 2004, *Collaboration, Integrated Information, and the Project Lifecycle in Building Design, Construction and Operation*, August 2004, United States.

Crafts, N. 2003, *Steam as a general purpose technology: a growth accounting perspective*, Department of Economic History, London School of Economics, Working Paper 75/03, May 2003

CRC for Construction Innovation, 2007a, *Business Drivers for BIM*, Brisbane, Commonwealth of Australia.

CRC for Construction Innovation, 2007b, *FM as a Business Enabler: Solutions for Managing the Built Environment*, Brisbane, Commonwealth of Australia.

CRC for Construction Innovation, 2007c, *Adopting BIM for Facilities Management: Solutions for Managing the Sydney Opera House*, Brisbane, Commonwealth of Australia.

CRC for Construction Innovation, 2008, *Construction Industry Business Environment: BIM — Implications for Government*, Brisbane, Commonwealth of Australia.

CRC for Construction Innovation, 2009, *Digital Modelling Guidelines*, Brisbane, Commonwealth of Australia.

Department of Infrastructure, transport, regional development and local government, 2008, *AUSLINK Black Spot Projects — Notes on Administration*, Canberra, Australia.

Dinesan, B., 2008, *The STAND-INN Handbook: Standards for Innovation and Sustainability in Construction and Facilities Management*, Europe Innova STAND-INN project, October 2008.

Dubois, A., Gadde, L., 2002, *The construction industry as a loosely coupled system: implications for productivity and innovation*, Construction Management and Economics, 20, pp 621-631.

Eastman, C., P. Teicholz, R. Sacks, K. Liston, 2008, *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers, and Contractors*, Australia (published in the United States as Hoboken, N. J, 2008, Wiley).

Engineers Australia, 2005, *Getting It Right The First Time: A Plan to Reverse Declining Standards in Project Design Documentation within the Building and Construction Industry*, prepared by an industry-wide task force, October 2005, Brisbane, Australia.

Erabuild, 2008, *Review of the Development and Implementation of IFC Compatible BIM*.

Farley, M., 2007, *State of the Building and Construction Industry 2007*, Building and Construction Industry Council, Tasmania, Australia.

Griffiths, R. 2004, *Knowledge production and the research-teaching nexus: the case of the built environment disciplines*, Studies in Higher Education, 29(6), 709-726.

Hedges, Keith E., n.d., *How BIM May Approach the Counterfactual Scenario of Inadequate Interoperability*, University of Wyoming, United States.

Higher Education Funding Council for England (HEFCE), 2005, *RAE 2008 Consultation on Assessment Panels' Draft Criteria and Working Methods: UOA 30, Architecture and the Built Environment*, London.

Holness, Gordon, 2008, *BIM Gaining Momentum*, ASHRAE Journal, United States.

Howell, Ian and Bob Batcheler, n.d., *Building Information Modelling Two Years Later: Huge Potential Some Success, and Several Limitations*, United States.

Industry Commission 1995, *The Growth and Revenue Implications of Hilmer and related reforms*, a report by the Industry Commission to the Council of Australian Governments, March.

Kiviniemi, A., V. Tarandi, et al. 2008, *Review of the Development and Implementation of IFC compatible BIM*, Erabuild.

Lesniewski, Laura, Eddy Krygiel and Bob Berkebile, n.d., 'Roadmap for Integration', in American Institute of Architects' *Report on Integrated Practice*, United States.

McGraw Hill Construction, 2007, *Interoperability in the Construction Industry*, SmartMarket Report, New York, United States.

McGraw Hill Construction, 2008, *Building Information Modelling (BIM): Transforming Design and Construction to Achieve Greater Industry Productivity*, New York, United States.

McGraw Hill Construction, 2009, *The Business Value of BIM: Getting Building Information Modeling to the Bottom Line*, SmartMarket Report, United States.

National Academy of Sciences (NAS), 2009, *Advancing the Competitiveness and Efficiency of the U.S. Construction Industry*, report by the Committee on Advancing the Competitiveness and Productivity of the U.S. Construction Industry, National Research Council, United States, see www.nap.edu.

Organisation for Economic Co-operation and Development (OECD) 2008, *Broadband and the Economy*, Ministerial Background Report DSTI/ICCP/IE(2007)3/FINAL.

Peter, M.W, Horridge, M., Meagher, G.A., Fazana, N., and Parmenter, B.R. (1996), *The Theoretical Structure of Monash-MRF*, Preliminary working paper no. OP-85, Centre of Policy Studies, Monash University, Melbourne.

Productivity Commission 2006, *Potential Benefits of the National Reform Agenda*, Report to the Council of Australian Governments, Canberra.

Productivity Commission (PC), 2010, 'Australia's productivity performance' Canberra, Australia, <http://www.pc.gov.au/research/productivity>, accessed October 2010.

Property Council of Australia, 2009, 'Betting on a BIM Boom', 1 October 2009, see www.propertyoz.com.au/Profiles/ProfileDetail.aspx?pid=36.

Smith, Dana K., 2010, *Business Benefits of Building Information Models*, presentation at buildingSMART Korea International Forum 2010.

United States Army Corps of Engineers, 2009, 'Cutting Edge Technology Speeds, Improves Facility Design Process', *Engineer Update*, United States.

Vanston, L. and Vanston, J. 1996, *Introduction to Technology Market Forecasting, Technology Futures Inc*, Austin, Texas, US.

What's Critical 2010, *Understanding What's Critical: Building Information Modelling*, 5 August.