

CSQ



Are you ready for change?

FARSIGHT FOR CONSTRUCTION

Exploratory scenarios for Queensland's
construction industry to 2036.

Citation

Quezada G, Bratanova A, Boughen N, and Hajkowicz S. 2016. Farsight for construction: Exploratory scenarios for Queensland's construction industry to 2036. CSIRO, Australia.

Copyright

© Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Construction Skills Queensland (CSQ) 2016. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO or CSQ.

Important disclaimer

CSIRO and CSQ advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO and CSQ (including their employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it. CSIRO is committed to providing web accessible content wherever possible. If you are having difficulties with accessing this document please contact csiroyenquiries@csiro.au.

Acknowledgements

The authors would like to express gratitude to the many experts who shared their time and knowledge in a series of interviews and consultative workshops in Brisbane, Cairns, Mackay and Toowoomba. The authors would also like to express gratitude to CSQ staff, including Robert Sobyra, Andrew McDougall, Evan Maughan, Susan Armstrong, Stacey Ozolins and Bruce Fyfe who actively participated in the research.

Thanks also to Leonie Hodggers and Lachlan Rudd who contributed the horizon scan and trends analysis.

Authors are grateful to P.G. Hope and QBCC for sharing their data, research outcomes and industry insights.

Welcome
to the
future.

CSQ





Brett Schimming Chief Executive Officer Construction Skills Queensland

The world of work is facing a period of significant change and disruption. Several studies have suggested advanced technologies could automate up to 75% of jobs in the coming decades.

CSQ began The Farsight Project because we believe the construction industry will be affected more than most by the coming transformation. This landmark study from the CSIRO forms the cornerstone of our project, providing a vital roadmap for the conversation our industry must have if we are going to harness the opportunities of these changes, rather than be engulfed by their risks.

The study finds big changes are afoot. Smart machines that accomplish routine tasks, such as tiling and bricklaying, are likely to be a fixture of the industry within a decade. Driverless plant has already reached the civil construction market. Exosuits, which allow humans to lift very heavy items, offer obvious benefits to ageing construction workers. Increases in computing power promise to engulf construction sites in big data, driving efficiency and productivity.

Despite the scale of these potential changes, we are generally ill prepared for them.

Studies that show 75% of jobs could be automated in the future are not predicting that the workforce will be slashed by 75%. They are simply saying the jobs of the future will not be the jobs of today. Existing jobs will be replaced, not erased. Technology makes some roles redundant, but it creates entirely new jobs as well.

This will bring an enormous skilling, reskilling and upskilling challenge. Australia's construction industry faces a period of significant disorientation as we reorganise ourselves around the new realities. The task before us is to get ahead of this change.

The timeframes suggested in this study put significant change within the career-spans of many current workers. And it will certainly affect the next generation of apprentices. So the time to act is now.

We must create a workforce that is comfortable working with sophisticated technology, and embodies a spirit of continuous learning. Because in a future of rapidly evolving technology, it will not be good enough to stop learning after the first four years of your career.

This study confirms our current models for training and skilling need to change. They need to become continuous and truly industry-driven. And the task cannot be left to one stakeholder alone. New training models must be born of partnerships between industry, government, suppliers, training providers and—more than ever before—the workers themselves.

This important report only begins to mark out the road ahead. CSQ is committed to taking industry on the journey. We are forming partnerships across the spectrum to do the thinking and planning needed to ensure our industry has a workforce to thrive into the future.

Join us on the journey at csq.org.au/farsight.

Brett Schimming



Adrian Turner
CEO CSIRO | Data61



Dr Simon Toze
Research Director

Australian cities and infrastructure are facing an increasing need to innovate and transform in an era of volatility and disruption. Great changes are afoot from the digital revolution through to demographic shifts and changes in climate. Entire nations and economies, industries and communities are recognising these challenges and opportunities, and are proactively planning for the decades ahead. CSIRO is committed to producing research outcomes that can inform strategic decisions.

This report provides an important analysis and discussion on the future of construction, which can be a useful reference point for charting exciting futures. While it is impossible to accurately predict what will come in the decades ahead, the researchers have identified important sign posts and developed compelling scenarios.

This information can be used to start conversations not only on what type of building and engineering construction we want in our future, but how that construction will be done, and the implications for the existing and future workforce.

I recommend this report to anyone with an interest in shaping positive futures for construction, and hope that it is used productively in the debates and decisions that will ensure the strength and vitality of our industry, and the resilience and sustainability of our cities and infrastructure long into the future.

Adrian Turner

Dr Simon Toze

A handwritten signature in black ink that reads "Adrian Turner".

A handwritten signature in black ink, appearing to be "S. Toze".

Executive Summary

The future of work and employment is a global hot topic with interconnected and powerful forces shaping jobs, industries and entire economies.

Farsight, prepared in partnership with Construction Skills Queensland, examines the future of construction work in the state. Specifically, the report discusses critical trends and alternative scenarios for the future of Queensland's construction workforce. Eighty leading experts across the state contributed to this future through a range of thinking and participation in interviews and workshops - where they considered what the industry could look like in 2036, and how job profiles and skills requirements might change to align with that future. A comprehensive scan of trends impacting the industry was undertaken, 25 of which are discussed in this report.

This industry input and trends scan culminated in the development of four scenarios (Figure 1) that capture key areas of uncertainty and impact for jobs and skills in the industry.

Each scenario is possible and takes the reader down an evidence-based journey about a plausible future. Because the future is not exact, there are multiple paths leading to multiple scenarios. Our scenarios describe a range of futures - some we would like to happen or others we would like to avoid. The aim in scenario planning is to be objective and inform decision-makers to identify, select and implement optimal strategies to achieve a better future - for all involved.

Farsight was designed to help the industry understand what could happen in the future, and to identify what future(s) the industry wants and what steps could be taken to move toward desired futures.

The scenarios were defined using a strategic foresight process that involves the identification of two spectrums that capture a range of plausible outcomes. The end points are extreme possibilities, with each relatively independent of the other. The outcomes of Farsight rests upon a set of trends compiled and synthesised by the research team. Crossing the axes defines the scenario space and the four scenarios which detail the tools we will need to keep stay nimble, relevant and effective in a global market.

Task automation - the horizontal axis

The horizontal axis relates to the extent of task automation. Both end points see a world more technologically advanced than today; the distinction is based on the extent of task automation. On the limited end, automation has followed an incremental path of development. Jobs are still recognisable from today's perspective, but digital technology is assisting workers and tradespeople with day-to-day communications, and project and workflow management. The substantial end imagines an industry transformed by smart robots and advanced manufacturing. Many of today's jobs are obsolete, and new jobs in robotics, programming and design have emerged.

Innovation culture - the vertical axis

The vertical axis relates to the extent of the industry's innovation culture, or the values and assumptions that shape whether new ideas will be embraced or resisted. As with the horizontal axis there is a degree of innovation at both end points. However, the approach to innovation activities varies considerably. At the cautious end point, risk aversion across the industry and market shapes a culture that is wary of radically new materials, methods, tools and practices: 'tried and true' is the mantra of the day. The bold end point sees the industry pushing to be at the leading edge of construction innovation, responding proactively to the big challenges facing cities and the built environment.

From the two axes there are four scenarios (Figure 1). These four scenarios represent a generalisation of a much more complex array of future possibilities. As with any model, scenarios must simplify a more complex reality in order to inform decisions.

There are futures in which the landscape for the construction industry in Queensland is substantially reshaped and barely recognisable from today. While this is not the only possible outcome, a major shift in the industry fits within the envelope of plausibility. This is largely due to the accelerating rate of change. The trends and scenarios highlight important implications for the industry's core competencies, education and training system, and data infrastructure.

We need to ensure that as an industry, we stay ahead of the pack and are ready to embrace change as we navigate through an uncertain future - armed with greater knowhow through investment, training and understanding of what lies ahead.

4 scenarios for the year 2036



Figure 1. Four construction workforce scenarios for Queensland for the year 2036

Contents

Executive summary	6
1 Introduction	10
2 Industry profile	12
3 The scenario planning process	18
3.1 Expert interviews and workshops	20
3.2 Making sense of industry change and transition	21
4 Defining the scenario space	24
4.1 Horizontal axis—extent of task automation	27
4.2 Vertical axis—extent of the industry's innovation culture	28
5 The scenarios	30
5.1 Scenario 1: The Digital Evolution	32
5.2 Scenario 2: Smart Collaboration	36
5.3 Scenario 3: Globally Challenged	40
5.4 Scenario 4: Rise of The Robots	44
6 Implications for job and skills	48
6.1 Job competencies	50
6.1.1 Possible jobs of the future in construction	51
6.2 Education and training system	51
6.3 Data infrastructure	55
7 Trends impacting on the construction industry	56
7.1 Social trends	58
7.2 Technological trends	60
7.3 Environmental trends	65
7.4 Economic trends	69
7.5 Educational trends	73
7.6 Political trends	78
8 Conclusion	80
9 References	82



01 Introduction

Building and construction is Queensland's third largest industry by employment (ABS 2015) and largest by gross value-add (ABS 2015), with tens of thousands of businesses across the state (ABS 2015). The industry has benefited from the mining and infrastructure boom of the past 20 years, showing great capacity to ramp up and deliver high-quality projects in a high-pressure environment. Notable achievements include South-East Queensland's water grid, Brisbane's tunnels, liquefied natural gas (LNG) pipelines from the Surat Basin, major freight and passenger rail upgrades across the state, post-flood reconstruction, and construction and renovation of hundreds of thousands of houses. Skillful management of risk has been a defining competency as the industry walks a tightrope of project complexity and slim margins.

However, great challenges and opportunities are emerging as the global population continues to grow and industry relentlessly pushes into new frontiers of technological and economic development. Issues arising from climate change, an ageing workforce, economic volatility, housing affordability and infrastructure cost concerns warrant reflection across the industry. There are also challenges facing Australia's economy due to comparatively low innovation performance and waning exports. Ranked 72nd in the world on innovation efficiency, Australia struggles to convert strong innovation inputs into economic outcomes (Cornell University, INSEAD et al. 2015). Poor collaboration and business culture for innovation, risk aversion and poor management capability are among the main impediments (DI 2014). The construction industry has historically been a weak innovation performer among Australian industries. This is attributed to skills shortages, regulatory environment, lacking workers with problem-solving skills, and being less exposed to foreign competition (Australian Industry Group 2008, IBM - Melbourne Institute 2010).

How could these issues and challenges unfold over the coming decades, and what would be the implications for construction jobs and skills in Queensland? How could the industry respond?

This report explores these questions by reviewing 25 critical trends and describing four evidence-based scenarios for the industry. The narratives are not predictions but stories of alternative futures, framed around two critical uncertainties—task automation and innovation culture. These narratives provide a picture of what could happen over the coming two decades.

Why bother with scenario planning? Scenario planning helps us step out of our daily routines and patterns of thinking, which shape our decisions and behaviour. Scenarios are evidenced-based stories of the future that signal important trends and changes in the world—changes that can have major impacts on economies, industries and jobs. Today's world is complex—arguably more so than at any other time in human history. Great global shifts in social, technological, environmental, economic and political spheres are at play, shaping the future in uncertain ways. What could happen over the next 20 years?

Scenarios provide a big-picture view to help answer that question—to make sense of the complexity and uncertainty. The construction industry, like many other industries, is subject to powerful and complex forces of change—trends and megatrends that influence the future. Over the past few years, CSIRO has been investigating global trends and their impact on various industries, including tourism, sport, retail, health and many others. To our knowledge this report is the first publicly available scenarios report on the construction industry in Australia.

Queensland Construction Industry



THE LARGEST INDUSTRY BY GROSS VALUE ADDED

Contributed around 10%
to the gross state product
in 2014-15



3RD LARGEST INDUSTRY BY EMPLOYMENT

203,800 people employed
182,200 men and
21,600 women



COMPRISES OVER 71,000 BUSINESSES



PRODUCES ESSENTIAL BUILT ENVIRONMENT FOR EVERYDAY LIFE AND ALL ECONOMIC ACTIVITY



02 Industry profile



Foundation for Queensland's prosperity

Building and construction is a significant driver of the national and regional economy in Australia. It is the nation's biggest industry by number of operating businesses, exceeding 330,000 or 16% of businesses in the country (ABS 2015). The industry employs over one million people or nearly 9% of the total workforce. In 2014-15 it contributed over \$124 billion or around 8% of GDP¹ (ABS 2015). The industry produces the essential built environment for everyday life and all economic activity in the country. Infrastructure provided and maintained by the industry underpins productivity and income growth of the nation (Ai Group 2015).

In Queensland, construction is the largest industry by gross value added (at November 2015), contributing around 10% to the gross state product in 2014-15 (ABS 2015). Over 71,000 businesses operate in Queensland construction (ABS 2015). The industry will be challenged to increase skill levels across the workforce as the state transitions from resource-led growth to greater emphasis on the knowledge economy. (Queensland Government 2015a). Population growth coupled with the ambitious state infrastructure plan (DILGP 2016) paints a positive picture for the industry (Queensland Government 2015a). Queensland's population, the major driver of demand for houses and infrastructure, is projected to reach 6.5-7.7 million people by 2036, up from 4.7 million today (Queensland Treasury 2013).

Third largest employer in Queensland

Construction is the third largest industry by employment in Queensland (ABS 2015). In the November quarter of 2015 there were 203,800 people employed in the industry, comprising 182,200 men and 21,600 women (ABS 2015). Between 1984 and 2008 there was a more than three-fold increase in the number of employees, although this number has dropped nearly 18% since then (Figure 2).

The share of construction in the state's total employment has been mostly above the national average over the past three decades (although more cyclical; see Figure 3), and is expected to grow (ABS 2015). By 2019 employment in construction nationally is expected to grow by 13%, making it the third fastest growing industry in terms of employment growth, above the average of 10% growth across industries in the economy (Department of Employment 2015).

An industry of small and diverse businesses

The industry is mostly represented by self-employed workers and small businesses employing up to 19 people.

The profile of the industry workforce by occupation is diverse. The number of employees within the major occupation groups is shown in Table 1 (at February quarter 2015) (ABS 2015).

Riding the economic wave

The construction industry operates in three sectors: residential building, non-residential building and engineering construction. Engineering construction in Queensland has grown rapidly since the global financial crisis (GFC), surpassing building construction during the mining boom, before the rapid fall starting at the end of 2013 (Figure 5). The pattern of investment in engineering projects is similar to Western Australia, where the significance of the mining industry is comparable to Queensland's (ABS 2015). Moving forward, regional construction would appear to be more equally split between engineering and building construction. Maintenance and renovation also play important roles in the industry profile. In 2014 around 37% of residential construction in Australia was made up by renovation activity (HIA 2015).

Although Queensland construction employment is prone to boom-bust cycles, construction employment growth in the state surpasses the growth of total employment (Figure 6). There is also an indication that the industry is currently shifting to a more stable ongoing growth trend after the recent mining boom.

Union membership

Unions have traditionally played an important role in the industry. Around 12% of construction workers in Australia were members of unions in 2013 (ABS 2013, ABS 2015).

This proportion has been mostly stable from 2007, although it has fallen in recent decades in line with national trends (ABS 2013). For example, between 1994 and 2000, membership fell from 34.1% to 26.4% (ABS 2000).

Prosperity comes at a cost

The construction industry generates a significant amount of waste and environmental impact. In 2009-10, construction was the largest contributor to the waste generated in Australia (31% of all waste) followed by households (23%); waste management services cost the industry \$1.64 billion or 1.7% of its gross value added, compared to less than 1% spent by other industries (ABS 2013). The construction industry contributes to greenhouse gas emissions directly as well as through the use of emission-intensive materials including cement, plaster, steel and aluminium. (CIE 2011). The contribution of commercial and domestic buildings as final energy users is estimated at 23% of the national total greenhouse gas emissions (ASBEC 2009).

¹ Measured as industry gross value added - chain volume.

Working in the industry has high risks, and some aspects of the workplace environment and work practices have been shown to have negative impacts on the health of workers and their families (AIFS 2014). Construction is a high-risk industry, accounting for a disproportionately high percentage of workplace injuries, diseases and fatalities based on the size of the workforce. Each year around 12,600 workers' compensation claims are accepted from the construction industry for injuries and diseases involving one or more weeks off work; this annual figure equates to 35 serious claims each day (SWA 2015). Between 2003 and 2013, an average of 36 work-related fatalities were registered in the industry annually (SWA 2015). The mental distress incidence rate among fly-in fly-out workers is 30%, which is significantly higher than the national average of 20% (WA 2015). Suicide rates in the industry are also higher than the national average, impacted by the workforce mobility arrangements, including fly-in fly-out and drive-in drive-out.

However, the rate of serious claims in the industry decreased by 31% between 2001-02 and 2011-12, and the fatality rate decreased by 68% (5.71 to 1.85 per 100,000 workers) over 2003-13 (SWA 2015).

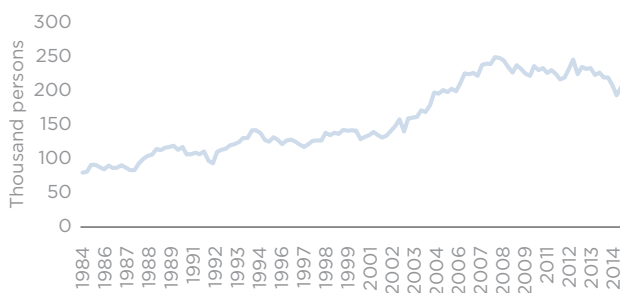


Figure 2: Total number of employees in Queensland's construction industry (thousand persons) Source: ABS (2015)

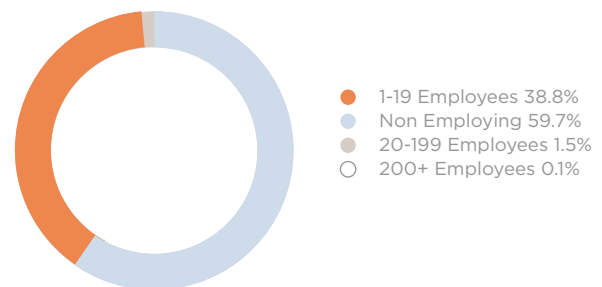


Figure 4: Businesses in Queensland construction industry by employment size. Source: ABS (2015)

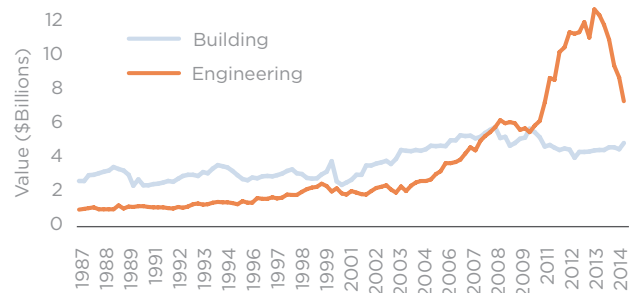


Figure 5: Value of total construction work by sector in Queensland (seasonally adjusted chain volume measure) Source: ABS (2015)

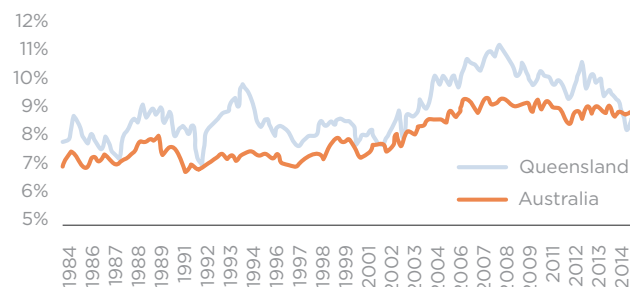


Figure 3: Shares of employment - construction industry in total employment. Source: ABS (2015)

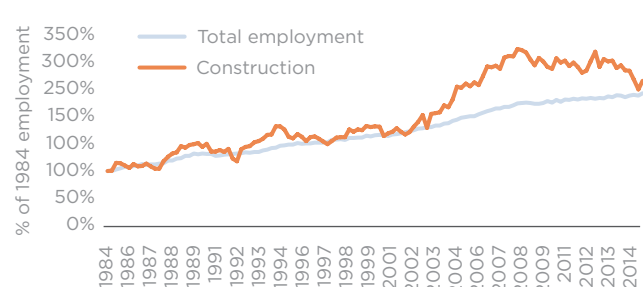



Figure 6: Employment in Queensland: total and in construction industry (indexed, 1984 = 100%) Source: ABS (2015)

Construction
is the **third**
largest
industry by
employment
in Qld.

Table 1. Number of employees in Queensland construction industry by major occupational groups.

Occupation	Employed ('000)
Electricians	33
Carpenters and joiners	20.7
Construction managers	19.6
Plumbers	18.7
Building and plumbing labourers	17.2
Architectural, building and surveying technicians	11.7
Painting trades workers	11.2
Plasterers	9.3
Concreters	8.4
Electronics trades	7.2
Telecommunications trades workers	4.3
Civil engineering draftspersons and technicians	4
Air-conditioning and refrigeration mechanics	3.6
Roof Tilers	3.5
Structural steel construction workers	3.4
Bricklayers and stonemasons	2.9
Wall and floor tilers	2.9
Paving and surfacing labourers	2.8
Electrical distribution trades workers	2.3
Insulation and home improvement installers	1.8
Electrical engineering draftspersons and technicians	1.4
Electronic engineering draftspersons and technicians	1.4
Floor finishers	1.4
Glaziers	1.3
Fencers	1.3
Safety inspectors	1.2
Mechanical engineering draftspersons and technicians	0.5
Railway track workers	0.4

A black and white photograph of a person wearing a white shirt and a high-visibility vest with reflective stripes. The person is holding a tablet computer with both hands. The background is slightly blurred, showing more of the vest and the person's torso.

03 The scenario planning process

Strategic foresight is an emerging field of research and growing profession concerned with exploring and describing plausible future events to help people make wiser choices. It is often described as both an art and a science because foresight studies combine robust analysis of data, facts and theories with creative, compelling and engaging narratives of the future. There is no single established method for doing foresight. Many of the tools and techniques of strategic foresight are still under development by the research community.

However, the application of strategic foresight by private and public sector organisations is widespread and increasing. Global consulting company Bain & Co conduct an annual survey of management tool usage with responses from over 13,000 corporate executives and decision-makers from 70 countries (Bain & Company 2015). This survey finds **scenario and contingency planning** tools are used by 20% to 40% of respondents, with a high average satisfaction rating of 4 out of 5. Usage rates spiked at 70% during the period of geopolitical and economic uncertainty that characterised the early 2000s. The study finds foresight's umbrella framework **strategic planning** has usage rates varying between 40% and 80% over the past 20 years.

Scenario planning is perhaps the most widely applied and well recognised tool used in strategic foresight. The concept was pioneered by energy company Royal Dutch Shell in the 1960s and helped the organisation navigate the oil shocks of the late 1970s and early 1980s (Wilkinson and Kupers 2013). Today, over 45 years later, Shell still has a dedicated scenario planning team. Their current 'new lens' scenario report identifies two scenarios for the future of world energy markets.

Scenarios are evidence-based stories about the future, designed to inform both operational and strategic choices. Because the future is uncertain and unknown, a scenario planning exercise will typically identify multiple futures. In reality there is an infinite number of possible futures. Scenarios represent an abstraction and generalisation of a more complex reality. This is necessary in order to inform decision-makers. Attempting to reproduce the infinite complexity of the real world is counterproductive and inimical to decision-making.

The scenario planning process used in this study is based on the following stages:

1. **Define the focal issue.** The focal issue associated with challenge or opportunity in the future. In this study the focal issue is skills and job profiles in the construction industry.
2. **Horizon scanning to identify trends (drivers of change).** Trends are patterns of change extending into the future. They are classified as social, technological, economic, environmental, educational and political (STEEEP). Trends typically have well defined spatial, temporal and typological definition.
3. **Screen and validate the trends.** Trends must pass the evidence and relevance hurdle to be used in the analysis. Evidence requires a qualitative or quantitative information source demonstrating the trend is real and/or likely to happen. Relevance requires that the trend matters to the focal issue and subsequent operational and strategic choices. The final set of trends should be comprehensive, exhaustive and

non-redundant. The CSIRO team compiled a database of 25 trends in this study.

4. **Identify and construct the axes (continuums of possibility).** The axes represent continuums of plausible outcomes with uncertainty and impact on the focal issue. The end points of the axes are created by the analysis of trends, and map out the scenario space and identify extreme outcomes.
5. **Identify the scenarios.** A scenario exists for every quadrant (or sector) formed by the axes. One axis creates two quadrants, two axes create four quadrants, three axes create eight quadrants and so on. Using more axes runs the risk of making the results complex, hard to visualise and hard to interpret. In this study we generated two axes and four scenarios. As with any model, scenarios represent a simplification of a far more complex reality in order to provide useful information to a decision maker.
6. **Prepare and communicate the narrative.** In the final step, scenarios are briefly described based on the detailed trends and information used to construct the axes. The narrative of the future aims to be descriptive and not prescriptive. It aims to explore what might happen based on the best available data. The key test for scenarios is whether they are plausible and consequential. If they pass these hurdles the scenarios should hold important insights for decision-makers.

3.1 Expert interviews and workshops

As part of the foresight process, CSIRO conducted telephone interviews with 15 industry experts and stakeholders. Interviews used a technique developed by the University of Queensland, known as convergent interviewing (Williams and Lewis 2005). This technique is a conversational style of interview that encourages interviewees to share their experiences, opinions, attitudes, beliefs and knowledge that converge around a set topic. The opening question is purposely kept broad, and in this instance was: 'What do you think the construction industry in Queensland will look like in 20 years and what are the key trends that you can see emerging that will lead to this future?'

The interviews helped identify a range of emerging trends—from the ageing population to climate change, through to advances in automation and robotics. With each interview, a more rigorous and detailed interpretation of the situation emerged. It became clear that while there was a general consensus on which trends are relevant to the industry, there was some divergence around the extent to

which some of the trends would play out. There were, for example, differences in opinion about how far technology would progress, and how many or which tasks could be automated. Some believed that technology was set to progress to a point that would be disruptive, while others believed it would simply enhance current construction techniques. The other point of contention between interviewees was how bold the industry would be in its pursuit of new solutions. Some believed a cautious industry culture would dominate decisions moving into the future, while others believed the industry possessed qualities that could lead to a bold innovative approach. These two points of divergence highlighted two areas with a high level of uncertainty in terms of how the future might unfold and therefore formed the basis for the two axes for scenario development.

These two uncertainties alone lead to a gamut of possible futures, all with different implications for the industry's long-range thinking on matters of skills and workforce planning. What would the world look like if there was substantial task automation and the industry embraced it boldly? Versus, what would it look like if the industry took a cautious approach in a world that has become highly automated? Conversely, what would the world look like if task automation was limited? How could this world differ, based on whether the industry had a bold or cautious approach to innovation?

To road test the resulting draft scenarios, a series of four workshops were undertaken by CSQ and CSIRO with 65 industry representatives from Brisbane, Cairns, Mackay and Toowoomba. A set of draft axes and scenarios were presented to the workshop attendees, who provided feedback via whole group discussion and small focus groups examining specific issues. Feedback from the workshops verified that the scenarios were considered both plausible and relevant to the industry, but also suggested changes and additions. The CSIRO team considered this feedback in the development of the final narratives.

3.2 Making sense of industry change and transition

The logic of scenario narratives in this report is based on a model of large-scale social and technological change called the *multilevel perspective* (Geels 2002). This approach draws on studies of historic transitions of *societal functions*, such as the transition from horse drawn carriage to the automobile for personal mobility, and sailing ships to steamships for overseas freight and passenger transport (Geels 2002, Geels 2005). More recently, this approach has been used to analyse transitions in the water and energy sector (Quezada, Grozev et al. 2014, Quezada, Walton et

al. 2016). These studies show distinct patterns of change, involving the interplay of three conceptual layers that make up any societal function: *landscapes*, *regimes* and *niches*. Figure 8 depicts these layers in the context of the construction industry. CSIRO used these layers to structure and organise the sequence of events that shape jobs and skills in each scenario. The point of the exercise was not to predict the future but rather highlight critical issues and plausible chains of events, and their impacts on the industry.

The landscape level consists of external factors and trends that exert influence on societal functions (and industries) over long periods of time, and are outside the control of industry workers and organisations. For instance, population growth and economic cycles are important in the landscape for housing and infrastructure, determining market demand and availability of capital.

The regime level represents the rules and physical playing field that guides the actions of all the industry players (e.g. companies, workers, customers, regulators, researchers, training organisations and policymakers). That is, the regulations, business and professional practices, market preferences, and physical infrastructure and assets, etc. Regimes are dynamically stable, meaning that innovation and change does occur, but it tends to be incremental and steady. For example, consider the 'housing regime': what home buyers want has not varied for many decades. Housing styles, lot sizes, materials and appliances might change gradually over time, but the essential product elements and construction process has been relatively constant. Buyer preferences have been shaped by childhood experiences, projected images of the Australian dream and regulations. Buyers know there are set steps to building a desirable home, and development and building codes are put in place to protect their long-term interests. Behind that process is a myriad suppliers, builders, tradespeople, training and licensing systems, research and development, engineering practices, standards, planning regulations, all working to ensure that there are no surprises and home owners and residential communities get what they expect.

Niches are where radical invention and experimentation occurs, typically outside or at the margins of an industry. These are groupings of companies, inventors, researchers, policymakers and customers that work together to develop new products and services in an industry. Niche innovation players are loosely arranged, meaning that there are no set rules and regulations, but rather a shared vision to address a common set of challenges and opportunities. At this level, innovations may be 'prototypes' or 'first generation' commercial products; expensive and full of 'teething issues' (e.g. consider the brick-like mobile phones of the 1980s).

**The jobs of
the future
will not be
the jobs of
today.**

Customers in the niche might tolerate low performance and high cost because the prototype still helps solve an important problem. 'Dongas' in remote mining communities might be considered a niche innovation for prefabricated housing during the mining boom. Compared to the dominant housing market, these 'unattractive boxes' are tolerated for mining communities because they solved the problem of providing a home to thousands of workers in areas where tradespeople were scarce and traditional onsite construction infeasible.

Occasionally the regime order can be disrupted by powerful landscape developments or trends—forces of social, political, environmental and economic change that are outside the control of industry players, governments, customers/markets, etc. Past studies of large-scale social and technological change have demonstrated a consistent pattern: pressure from the landscape layer builds up, causing problems in the regime. Solutions are needed to address these problems, which open 'windows

of opportunity' for niche innovations to 'bubble up' and reshape the way things are done in an industry.

One example of this dynamic is the accelerated market penetration of automobiles, which arose from emerging problems with industrialisation, urbanisation, population growth and the rise of large cities (changes at the landscape level), which came to a head in the 19th century (Geels 2005). At the time land-based transportation was dominated by the horse-and-buggy regime. The problem was that large cities had too many horses producing vast amounts of manure, raising public health concerns. Horse-based transport was also expensive, slow and cumbersome. These factors provided a window of opportunity for the diffusion of bicycles, electric trams and later, the automobile. While early autos were expensive 'clunkers', they were much better than the alternative, and gradually became more widely adopted as costs came down with the rise of another niche innovation—mass production via assembly line manufacturing.

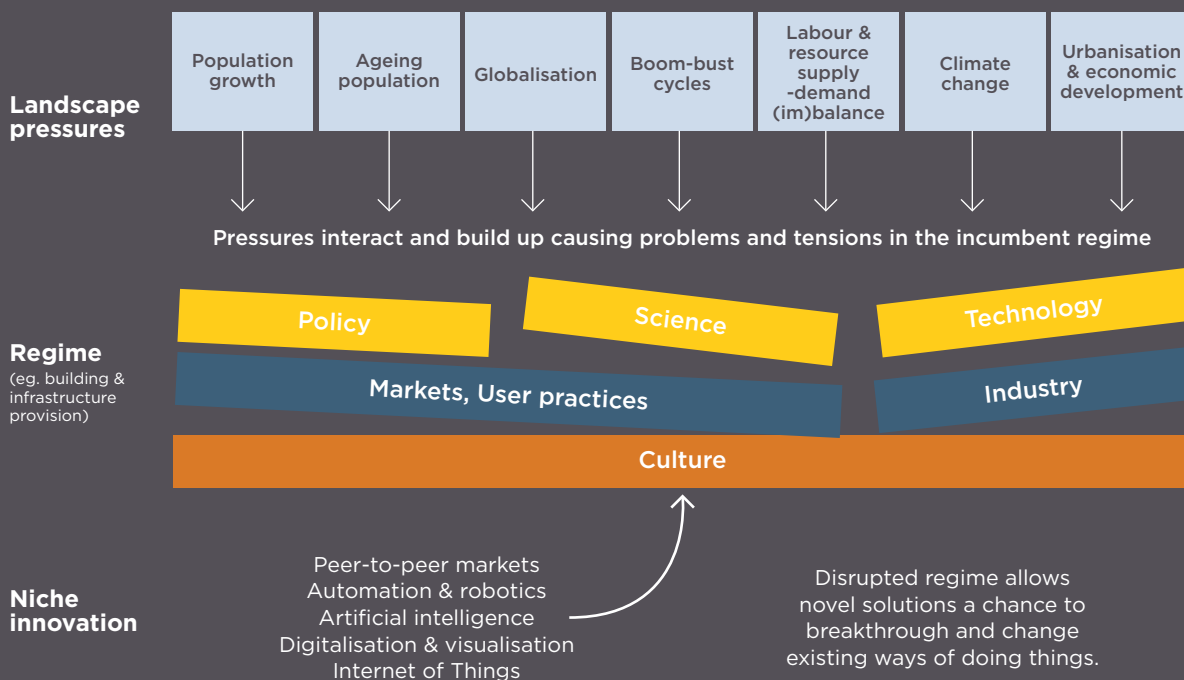


Figure 8 The multilevel perspective on transitions in the context of building construction and infrastructure provision.
Source: Adapted from (Geels 2002), p.1263



04 Defining the scenario space



Development of stories for the future of Queensland's construction industry was based on the selection of two factors that represent both critical areas of uncertainty and the greatest impact on construction jobs and skills: the extent of task automation and industry innovation culture. These factors formed two axes or continuums of possibility. Crossing these factors forms a two-by-two matrix and four plausible scenarios for Queensland's construction industry (Figure 21).

4 scenarios for the year 2036



Figure 21: Scenarios for Queensland's construction industry jobs and skills in the year 2036

Recently highlighted in CSIRO|Data61's report *Tomorrow's Digitally Enabled Workforce* (Hajkowicz, Reeson et al. 2016), task automation is about how much of today's human labour could be substituted by machines and robots. Consistent with this report, both ends of the continuum see a world where construction work is more automated than today; however, the extent of automation could vary depending on how rapid robotics and artificial intelligence can advance over the coming decades. At one extreme, the world is dominated by smart robots, where the promise of artificial intelligence comes to fruition. This future sees robot labour working more productively and safely than humans, shifting human construction workers into fundamentally new knowledge and skill areas. On the other end, human labour in traditional construction jobs is still central, but supported by sophisticated information and communication technologies, big data flows and limited machine and robotic assistance for difficult, dull and dangerous tasks.

The other key uncertainty, innovation culture, relates to how the industry responds to landscape pressures and the solutions (sometimes transformational) that develop to cope with those pressures. Innovation culture in this context relates to the dominant values, beliefs and norms that underpin how the industry approaches novelty and risk taking (Tesluk, Farr et al. 1997). A culture for innovation shows up in various aspects of the industry, from government policies and regulations, management decision-making, risk management and investment practices, through to education and training programs. All shape the extent to which novel construction methods, tools, materials and technologies, as well as business models, working arrangements and human resource management practices, are developed and embraced in Queensland. On one end, the industry adopts a cautious 'wait-and-see' strategy: 'let others elsewhere (in Australia or globally) bear the innovation risk and only change when new solutions have been resolved'. The other end sees the industry taking a bold and proactive approach, based on broad recognition of critical trends, looming risks and possible transformations over the coming decades.

4.1 Horizontal axis – extent of task automation

The horizontal axis relates to the extent of task automation in the future construction industry. Both ends of the axis portray a world where today's jobs and skills are altered. It is implausible to conceive of a future where job profiles have not changed. Development of new tools and technologies to boost productivity, efficiency and safety have been a mainstay throughout human history, gathering pace since the industrial revolution. However, significant

uncertainty lies in the extent of task automation: how far will smart robot and AI technology progress over the next 20 years?

4.1.1 Limited task automation

In a limited task automation future, technology to replace human labour is still under development, but better tools to support a safer and more productive workforce are available. For example, information and communication technologies, such as BIM and online peer-to-peer marketplaces can maximise the utilisation of equipment and people, and optimise project scheduling. This future is easy to imagine as these tools are already in use today, but not widely adopted.

This future also sees notable advances in personal protective equipment (PPE) or wearable technology that build on digitally enabled productivity and safety systems. For example:

- clothes made with fabrics that keep workers cool
- sensors that provides constant monitoring of body vitals and the surrounding environment
- augmented reality visors that keep workers updated on changes to their environment and provide auditory and visual warning signals when in danger
- exosuits that support workers with heavy lifting and operation of machinery.

Advanced manufacturing and robot technologies may appear mature in this future, but they are too problematic to cope in the construction environment. Safety and reliability are key concerns as robots and autonomous vehicles are not sophisticated enough to operate in dynamically changing job sites, and there is poor interoperability between rival equipment manufacturers. At best, human operators can use some automated operations. For prefabricated buildings and infrastructure from automated factories, the main issue is low market acceptance.

4.1.2 Substantial task automation

A future with substantial task automation sees construction transformed into a high-tech industry. Advanced manufacturing techniques (e.g. 3D printing), AI systems and smart humanoid robots do much of the work historically done by humans. In this world, demand for workers is in the field of robotic engineering and AI programming, creative design professions and project management. New ecosystems of knowledge-based jobs are supporting further development and deployment of AI, robotics, advanced materials and manufacturing.

What makes this future plausible is the tremendous R&D effort in robotics and AI by the world's largest economies

and corporations—it's a global race. The Japanese Government is backing the country's top robotics capability and subsidising industrial robot costs to address their skills shortage and massive aged care needs (METI 2015). Japan's top automakers have been investing in AI and robotics for decades; Toyota recently announced US\$1 billion to establish a research and development facility in Silicon Valley (Guizzo and Ackerman 2015). South Korea and China are also ramping up their output of industrial robots. On the other side of the Pacific, the US Government is funding a 'National Robotics Initiative' (NSF 2016). The Department of Advanced Research Projects Agency is sponsoring the world's leading robotics and AI research groups to develop robust and reliable disaster response robots (DARPA 2015). Silicon Valley has also seen a jump in start-ups and venture capital funding for AI technology, and tech giants Google, Facebook and Apple have been buying up robotics and AI companies and expertise globally in their drive to maintain global leadership in the expanding digital age (Mercer 2016).

Other drivers of the substantially automated future include construction costs and declining costs of automation in adjacent sectors, particularly manufacturing. A recent study by Boston Consulting Group projects a 22% fall in costs of advanced industrial robots between 2014 and 2025 (Sirkin, Zinser et al. 2015). Labour costs are one of the main drivers of construction cost increase in Australia. It's not surprising that the first autonomous mining machines were introduced in Australia during the mining boom when wages soared. Cost-cutting incentives can push construction down the automation path. At the same time, the industry might be influenced to change current practices and adopt new technologies and materials in response to transformation in other industries.

4.2 Vertical axis—extent of the industry's innovation culture

The vertical axis relates to the extent to which Queensland's construction industry supports and leads innovation. Innovation is about putting new ideas into practical use, such as new products and services (Gurteen 1998). **Industry innovation culture** is the shared norms, values and beliefs that determine the development and implementation of new ideas, risk-taking and experimentation.

The concept of innovation culture stems from the field of organisation and management studies. According to Schein (2010) organisations develop a distinct culture through the shared experiences of workers as they tackle the problem of survival and consistency. Senior managers, directors and business owners are crucial in setting the culture for innovation. This happens through the way they interpret the industry and business environment and decide to what extent they will support innovation through human resources practices, work structures, organisational policies and physical work arrangements (Tesluk, Farr et al. 1997). For entire industries, decision-makers include government policymakers, company managers and executives, and also customers and communities, who collectively demonstrate their attitude to risk taking and exploration through the goals they set and the way they reward goal attainment (Tesluk, Farr et al. 1997).

High innovation cultures can be observed in particular geographic areas (e.g. countries like Israel and sub-national regions like Silicon Valley) and industries (e.g. computer and biomedical). National and sub-national (state, local or provincial) governments and industry groups play an important role in terms of investing in training, research and research partnerships, which can impact innovation output. Sophisticated and demanding markets are also a key ingredient, pushing companies to continuously improve products and services. (Porter 1990).

Geographic clustering (or agglomeration economics) promotes ease and cost effectiveness of inter-firm collaboration and recruitment (Fan and Scott 2003). Related industries can collocate and develop networks to foster information flows and knowledge exchanges. Universities and research institutes play a critical role in clusters by providing high-quality human resources and a hub for knowledge creation and dissemination (Doloreux 2004).

Complex and dynamic industry environments, characterised by rapid change in technology and market preferences, offer vast opportunities for creativity and innovation (Gordon 1991). There is a future where the construction industry aggressively pursues innovation to cope with market shifts to sustainable, climate adapted and affordable building systems. Promising technologies are already in the works, but these are largely based in Europe, East Asia and North America. What could support this level of innovation in Queensland?

The declining resources sector in recent years has prompted Australian governments to refocus on innovation policy strategies as a means of driving greater economic diversity and vigour. The Queensland Government, in particular, has invested in new programs to drive innovation in the state, including major industries such as construction (Queensland Government 2016). There is a future in which this innovation turn leads to a shift in the construction industry's culture.

However, the construction industry has historically been risk averse, and more of a follower in terms of adoption of new materials, tools and methods. As indicated by Australia's relatively weak innovation performance, 'playing it safe' seems to be ingrained in the psyche of Australian businesses. Thus, it is equally plausible to see a future where the industry has changed little in terms of its appetite for funding, developing and implementing new ideas and solutions.

4.2.1 Cautious innovation culture

At the cautious end of the innovation axis, Queensland's industry follows the historic 'wait-and-see' approach with new construction materials, methods and technologies as well as business models and management practices. Being risk averse continues to be seen as prudent and economically efficient in an industry of tight margins and a predominantly conservative domestic 'late adopter' market. Home and asset owners prefer to stick with products and methods that are 'tried-and-true'. In this world, customers see traditional construction methods and products as a sound basis for investment decisions, and companies invest in innovations only when proven in Australia and the local market shows clear signs of shifting.

Companies and construction workers are making incremental improvement in performance and safety through adopting digital technologies, such as BIM and augmented reality communication systems. New and emerging digital solutions do not necessarily question the status quo of industry structure, but rather enable existing workers to improve project management and delivery, allowing the industry to bolster its value proposition. Also, new levels of trust between clients and industry players are facilitated by peer-to-peer platforms that bring greater transparency and competition in terms of worker rates and quality. While locally delivered buildings and infrastructure are not necessarily cheaper than products offered by overseas players, the domestic market is happy to pay extra for 'Australian made' quality.

At the national economy level, investment in R&D and partnerships between private and research sector is among the lowest in the OECD. The construction industry emphasises incremental improvement on core competencies and Queensland cities have a low global ranking on innovation. Trades are modernising gradually as regulations slowly change and VET providers update their training products in step with the industry. The workforce is older with a similar gender mix to 2016.

4.2.2 Bold innovation culture

In a bold innovation culture, the industry recognises signs and signals of critical trends and shifts in market preferences, construction methods and technologies, with implications for global competitiveness and jobs. Being 'first mover' is viewed as a necessary strategy to adapt effectively to global change, characterised by rapid technological development. Queensland has a relatively large and buoyant early adopter market, which is demanding new solutions that push the boundaries in terms of climate resilience, sustainability, amenity and affordability.

There is wide recognition in the industry of the increasing mobility of human and financial capital in an economically interconnected world, and the need to create institutional conditions that are attractive to innovative firms and high-calibre people. The Queensland Government, industry, training and research sectors are working together to develop world-class capabilities and incentives that attract international talent and investment from the world's best firms and research institutes. Private sector investment in R&D and research partnerships is among the highest in the OECD. There is a belief that Queensland's economic and job prospects will rest on policies and commercial practices that promote experimentation and early adoption of new solutions for the construction industry.

Despite the ageing population, the workforce median age has changed little since 2016, as more young people are attracted to the entrepreneurial dynamism of the industry. Vocational training providers are creating new pathways for bright school leavers looking for exciting alternatives to university education. Exciting job prospects are available to females who make up an equal share of the workforce. Further penetration of online and industry-based education has transformed the VET sector itself. Online platforms facilitating peer-to-peer relations help to improve transparency of construction and real estate markets.

This section describes four plausible futures for Queensland's construction industry over the coming two decades, with a focus on impacts for jobs and skills. Each scenario consists of a description of Queensland's construction industry in the year 2036, a narrative of how the scenario came about, and a commentary on plausibility from today's industry.

Scenario narratives differ in terms of the interplay between the three sociotechnical layers—landscape pressures, regime and niche innovations. Within each scenario different catalytic events pressure the industry to change or adjust in some way. The resulting problems and regime responses and the role of niche innovations vary according to the level of task automation and innovation culture experienced in each scenario.

Based on the industry background and trends analysis, we identified seven landscape pressures that could have a transformative impact on the future of the industry:

- Climate change related extreme weather events (heatwaves and storm events), particularly in tropical regions, with significant economic costs and human impacts.
- Housing unaffordability in Australia driven by sustained demand as household size continues to decrease and the population grows from overseas migration, forcing the market/consumers to seek low-cost housing alternatives.
- Increasing cost of infrastructure construction and maintenance adding to the burden of public and private expenditure, stimulating a demand for cost-effective solutions.
- Ageing workforce and the health implications for older workers performing physically demanding site-based jobs in the industry.
- Urban growth pressures on sensitive environmental systems and raising environmental awareness shining the spotlight on poor environmental practices and the impact of cities.
- Emerging Asian economies, along with population growth and rapid urbanisation, creating an unprecedented need for speed in construction.
- Boom-bust economic cycles, a mainstay in the industry, producing unexpected shocks with major impacts on capital flows, market demand and employment.

05 The scenarios



5.1 Scenario 1

The Digital Evolution

‘Robot labour’ technologies have not progressed as quickly as expected. Little has changed in the industry, but wide adoption of digital technology (e.g. BIM) has boosted productivity in the face of fierce competition. Parts of the workforce are using exosuits to manage challenges of an ageing workforce and extreme weather.



5.1.2 Queensland’s construction industry in 2036

The global and local economic environment is stable with Queensland (and other parts of Australia) benefitting from massive foreign investment and migration, particularly from Asia. Queensland’s cities are growing and new cities are being established, especially in tropical north Queensland where northern Australia policies are driving an infrastructure boom. Environmental and climate change concerns persist, but steady improvements are being made to address the impact of economic development and urbanisation.

Housing unaffordability and the mounting costs of developing and maintaining critical infrastructure are ongoing problems, partially masked by steady economic growth and low unemployment.

This is a future where traditional tradies and operators are in demand and highly paid. High-fidelity training simulators are used to attract a ‘gamer generation’ and fast-track apprenticeships to address skill shortages. A small number of progressive companies are managing capacity constraints through using exosuits to retain older workers and cut costs due to injury.

Industry structure and practices have changed little but diffusion of BIM and data analytics has driven improvements in efficiency, customer service, product quality and workplace safety. Such steady improvements are enabling the industry to compete internationally, and to adapt to cost pressures related to scarcity of human capital and raw materials. Manufacturing of buildings and building elements remains niche and relatively expensive, as only a few local companies tap a small low-volume market. Heavy equipment/machinery is still operated by humans with some autonomous functions to improve efficiency.

Being a cautious innovation culture means that people in the industry, as well as their customers, don’t like surprises and shun failure. Construction companies focus on delivering projects on their books, while the market gives priority to proven products and methods, seeing traditional construction as a ‘safe investment’. There is a lingering problem with waste from construction despite high material costs, and the industry is in the bottom of the OECD in terms of R&D investment and partnerships with the research sector.

5.1.3 How this scenario came about

Landscape pressures from exploding population growth, economic development and urbanisation in Asia created an unprecedented housing crisis and infrastructure gap in the region. Emerging Asian economies and companies, in partnership with established firms from China and Japan, accelerated development of rapid off-site prefabrication systems throughout the 2020s. This niche level activity

broke through the site-based building construction regime in Asia in the mid-2020s.

By the late 2020s, cheaper imports of prefabricated buildings and infrastructure components from Asia were showing up in Australia in greater quantities, although much of the domestic market was wary and did not see these products as desirable. Still, many in the trades became concerned by overseas competition and started using new digital tools like BIM to boost productivity and bring down costs. However, early adoption of BIM was dogged by interoperability issues and weak digital literacy, particularly among older workers.

In the late 2020s, severe cyclonic systems battered northern Australia, including vast urban areas of Far North Queensland. New imported building modules in these areas did not perform according to specified wind standards. Damage costs were staggering and triggered a one-off federal tax to pay for the reconstruction. This event surfaced long-standing concerns among industry and government players at the regime level about the reliability of imported building products from Asia. More reports of failed buildings and infrastructure appeared from other parts of the country.

These developments triggered a regime-led 'back to basics' approach to construction across Queensland and much of Australia. Despite strong benefits being demonstrated internationally, the presence of local manufacturing/prefabrication operations was met with scepticism in the Queensland market. Much of Australia's prefabrication was done in Sydney and Melbourne, servicing a small market. Traditional construction methods prevailed during the early 2030s and improving implementation of BIM enabled the industry to address affordability concerns, at which time the regime shifted attention to challenges of an ageing workforce and extreme heat conditions for site-based workers.

Older tradies were experiencing demand for their skills, to meet infrastructure and housing demand, but their bodies were wearing out. More frequent extreme heat events impacted on productivity and absenteeism during the warmer months of the year. Few younger men or women saw construction jobs as desirable, leading to massive skills shortages and high wages, and exacerbating the chronic affordability crisis.

In a bid to address the skills gap, a few larger Queensland firms began using autonomous vehicles and exoskeletons by the mid-2030s. High-fidelity training simulation platforms and moves to modular skills training were also introduced at this time, to help address the skills shortage by speeding up trade accreditation. However, the VET system struggled to keep pace with these developments.

R&D groups in Europe, North America and parts of Asia continued to compete for pre-eminence in new construction technologies to cope with these issues. Australian innovation in the industry received little market support throughout the last 20 years despite innovation policy initiatives being established around 2015—cultural challenges were simply not overcome. Much of Australia's innovation in the sector migrated to Asia in search of favourable funding and development conditions. Niche innovations include advanced exosuits, additive manufacturing and robotics, and artificial intelligence. These technologies remain clunky, and are viewed with scepticism by Queensland's construction industry.





Scenario 1

The Digital Evolution – the rise of software in construction

The world of The Digital Evolution is one without information bottlenecks, without the Chinese whispers and misunderstandings that plague most construction sites. It is a scenario where software has become just as important as hardware.

Building Information Modelling (BIM) has long promised a digital cure to information dysfunction in the construction industry. More than just a digital version of paper plans, BIM offers a single source of truth for every player on a project. In a total-BIM environment, there is no ambiguity, no misunderstanding, no lapses of memory or forgotten orders.

BIM advocates claim we are on the cusp of a revolution. Cynics complain that BIM is forever aspired to, never realised. But consider this: the only truly world-leading software to have come out of Australia is Aconex, a digital collaboration platform for the construction industry.

Aconex's offering is proving extremely popular. Investors have valued the company at over \$1 billion on a mere \$55 million in revenue, a sign of high confidence in the company's potential. Industry is also paying attention—Aconex already has partnerships with most of the big global construction companies, not to mention its 60,000+ other customers.

So what does the buzz around Aconex tell us about The Digital Evolution? It tells us that a lot of people think the company is onto something. Digital collaboration platforms only really begin to shine when everyone is using the same platform (think Facebook). This takes time, but a lot of construction companies and investors seem to think its time has come.

There are no guarantees, but this confidence is a strong signal that The Digital Evolution future, where information flows seamlessly throughout every project, is well within reach.

5.2 Scenario 2

Smart Collaboration

Queensland is embracing advanced manufacturing and new tools, making the construction process safer, more productive and less labour intensive. While the promise of smart robots and advanced manufacturing has not been fulfilled, the industry has built world-class innovation capacity, attracting international collaborators and investment.



5.2.2 Queensland's construction industry in 2036

Global economic upheaval in the early part of the century has given way to a new era of expansion and optimism. More stable financial systems underpin strong demand for innovative housing and infrastructure.

The industry has not yet seen full automation of repetitive, dangerous and physically demanding tasks, but Queensland is at the forefront of experimenting with new solutions to make construction safer, more materials efficient and productive. Living labs have been established to enable R&D and deployment of new materials and tools to cope with an ageing workforce, harsh climate and resource pressures. Queensland is home to a globally renowned and coveted materials and building standards system.

Queensland's strong early adopter market pushes the industry to continuously improve and experiment with new products, methods and tools. Traditional trades and professions persist but are in decline, with the employment emphasis on new jobs based on digital literacy, agile project management and prefabrication. Working with BIM, along with augmented and virtual reality technologies, is a core skill across the industry (akin to smart device use in 2016). Quality assurance and continuous improvement roles are in demand. Workers develop modular skills and competencies quickly through high-fidelity training simulators.

The workforce has fully embraced advanced exosuits, which allow older workers to continue in physically demanding trades. This technology has also allowed many women to participate in physically demanding site-based work. While assistive technologies have deskilled manual jobs, they have allowed job rotation possibilities for office-based professionals and managers who seek new experiences and insights of the construction process; a practice that fosters natural curiosity among construction workers. New opportunities for improvement and innovation are constantly cropping up; innovation management is a core competency, with most companies maintaining an innovation register, and running trials and experiments across a portfolio of projects.

Wide adoption of online peer-to-peer platforms in the industry with embedded ranking systems has been driven by consumers, and has all but eliminated 'cowboys' in the industry and boosted the quality of construction work done, especially in the maintenance sector.

Foreign companies have invested in the Queensland industry in an effort to acquire new capabilities and innovations. The state's industry has a global reputation for operating with integrity and for 'shared benefits'. Communication skills and collaboration across disciplines and ethnicities is a strength, and foreign partners value the egalitarianism that is widely evident in the state. The industry is at the top of the OECD in terms of R&D investment.

5.2.3 How this scenario came about

Landscape pressures related to globalisation and liberalisation of the banking industry set the scene for a volatile global economy in the early 2000s. Post-GFC weaknesses in the developed world came to a head in the late 2010s when a spate of high-profile corporate bankruptcies in the US and Europe caused sharp falls in global markets. Economic contraction followed and Australia's biggest trading partners, China and Japan, slowed dramatically, crushing exports. Many OECD countries were still recovering from 2008–09 GFC bailouts, which constrained their capacity to provide economic stimulus. Australia's position was much stronger and the government moved quickly to mount an economic renewal plan that invested heavily in innovation for new industries and jobs that addressed 21st century global challenges, including demand for cost-effective sustainable and climate-resilient buildings and infrastructure.

Global economic troubles prevailed throughout the 2020s, but the innovation turn in Australia steadily gained momentum as a new generation of workers brought fresh ideas and a sense of global mission. Queensland's construction industry was particularly invigorated by young overseas skilled migrants who were attracted by the state's natural beauty and relatively optimistic economic outlook.

Economic downturn exposed the problematic legacy of Australia's long-term housing affordability crisis. Property prices collapsed and credit dried up, creating the challenge of building and infrastructure delivery in a massively cost conscious market. The regime responded by developing competencies in prefabrication, and salvaging and repurposing of waste materials, such as disused shipping containers. At the niche level, construction 'tinkering' began in abandoned building yards and warehouses. By the mid-2020s a number of 'innovation zones' or precincts popped up across the state, fostering experimentation with new project management systems, autonomous vehicles, exosuits and advanced manufacturing to find more cost-effective ways of delivering both building and engineering projects. Government and industry investment flowed, with encouraging developments in these innovation zones. Leveraging a history of strong building and engineering standards and testing practices, these innovation precincts became world-renowned testing and evaluation centres; a global brand developed for climate-resilient and environmentally sustainable materials and building standards.

Digital technologies were central to this effort and the industry was proactive in addressing teething issues associated with the use of BIM and visualisation systems (augmented and virtual reality). Peer-to-peer platforms also rose to prominence as companies sought better ways of sharing resources and people.

There were many spectacular failures, but innovation management improved across the industry, which yielded a steady stream of successes. By the early 2030s, Queensland's construction workforce was digitally enabled using augmented reality visors, prefabrication was the norm, site workers operated climate-controlled exosuits and worked alongside autonomous vehicles. Most jobs in construction were office or factory based, with a remnant workforce of site-based 'assembly crews'.

In the mid-2030s, Queensland's hybrid construction industry was a major exporter of skills and products, particularly to economically dominant Asia. The state's high-calibre multicultural workforce, and high-integrity standards testing systems and facilities continue to attract world-class innovators and scientists. Queensland's standards brand for materials and buildings has become globally coveted.





Scenario 2

Smart Collaboration – Australian-led innovation

Smart Collaboration seems like a large leap for Australia's construction industry. Like The Digital Evolution, the technological advances in this scenario are relatively modest—there are no humanoid robots wandering around. The big changes are cultural and institutional: the industry transforms from its traditional 'wait-and-see' mentality, into a vibrant hub for world-leading construction innovation.

For many, the emergence of this scenario will be hard to imagine. It's true that Australia is a poor performer on the global stage when it comes to producing innovative output, like new inventions and technologies. Yet real progress is happening right now that shows Smart Collaboration is a genuinely plausible scenario.

Australia's underperformance in producing innovative output belies some very high performing innovation inputs – we are among the top 10 countries for R&D. We're just not very good at converting our R&D inputs into commercial outputs.

So the leap to Smart Collaboration, a world where Australia is a hub for pioneering bleeding-edge construction techniques, is perhaps not as far out of reach as the innovation statistics might suggest. The bedrock R&D capability is already here, and it's punching well above its weight.

Take the recent example of a group of Australian researchers who developed a vibrating vest to help helicopter pilots fly safer in dangerous conditions. This wearable tech, which could readily be applied to other changeable environments like construction, is being commercialised in the US, but its R&D roots are firmly in Australia.

Cultural and institutional factors are often the most stubborn, so Smart Collaboration is by no means a certain outcome. But Australia's researchers and universities are already well above par. What is missing is a culture of commercialisation, and mechanisms to convert innovative inputs into outputs. In many respects, this is a far easier gap to fill.

5.3 Scenario 3

Globally Challenged

Queensland's construction workforce is under pressure due to advanced manufacturing and robotics internationally. Overseas entrants are introducing new construction technologies and methods, and local companies and operations are competing through outsourcing to sophisticated low-cost producers in Asia.

5.3.2 Queensland's construction industry in 2036

This scenario sees Australia struggling economically. The country has fallen behind the global transformation of construction, characterised by widespread adoption of advanced manufacturing techniques and smart robot technology. Overseas entrants are dominant in the Australian market, which is struggling with a high cost base. An Asian company is Australia's number one home builder.

Some Australian companies are outsourcing large components of projects to overseas fabricators to stay competitive with new entrants. This survival strategy, along with a short-term project focus, means that important strategic decisions are overlooked. Many Australian companies are either being bought out or are going out of business. Newspaper headlines tell the story of an industry in decline (much like headlines about the Australian auto industry in 2016). The workforce is a mere 10% of what it was in 2016. High unemployment is being addressed through extensive (albeit reactive) retraining programs to improve job prospects for vast numbers of workers.

The giants of construction are Japanese, Korean and Chinese corporations that were preeminent car manufacturers of the late 20th and early 21st centuries. While robots are not allowed on site in Australia, most building and infrastructure delivery is carried out remotely by highly automated facilities in Southeast Asia, and then assembled on site by foreign workers with corporate training certifications (e.g. Toyota certified technician). Dramatic cost breakthroughs are enabling home buyers and asset owners in Australia to acquire high-quality buildings and infrastructure within available capital constraints.



Wages of the remnant industry have plummeted from the highs of the early 2000s. Automated recycling of old buildings and low cost for new builds has confined renovation activity to heritage-listed buildings. The depressed economy and low-cost real estate and wages in Australia (and Queensland) is attracting some overseas companies to invest in new production facilities as part of a global expansion. This investment is bringing new opportunities for the old construction workforce to pivot into technical jobs for agile manufacturing operations, and reinvigorating domestic expertise in mass customisation. Associated niche industries are emerging in 'smart' design to help home buyers and assets owners unlock the potential of advanced manufacturing and digital technology.

5.3.3 How this scenario came about

At the landscape level, rapid urbanisation, economic development and population growth in Asia, particularly the tropical zone, drove a meteoric rise in demand for more climate-resilient, environmentally friendly and cheaper buildings and infrastructure. Drawing on decades of robotics R&D, Japan and South Korea emerged as powerhouses of fully automated prefabrication systems for residential and commercial buildings, and autonomous vehicles and machinery for engineering projects.

In the late 2010s, a few companies in Queensland began experimenting with new additive manufacturing methods to site-based infrastructure and building projects, particularly in booming northern Australia. Industry players were wary of this technology and lobbied against the introduction of robotics on site. A few high-profile site accidents occurred with malfunctioning robotic systems, which caused the deaths of several workers. Pressure mounted on government to pass legislation prohibiting the use of robots on site, and confining R&D to the lab.

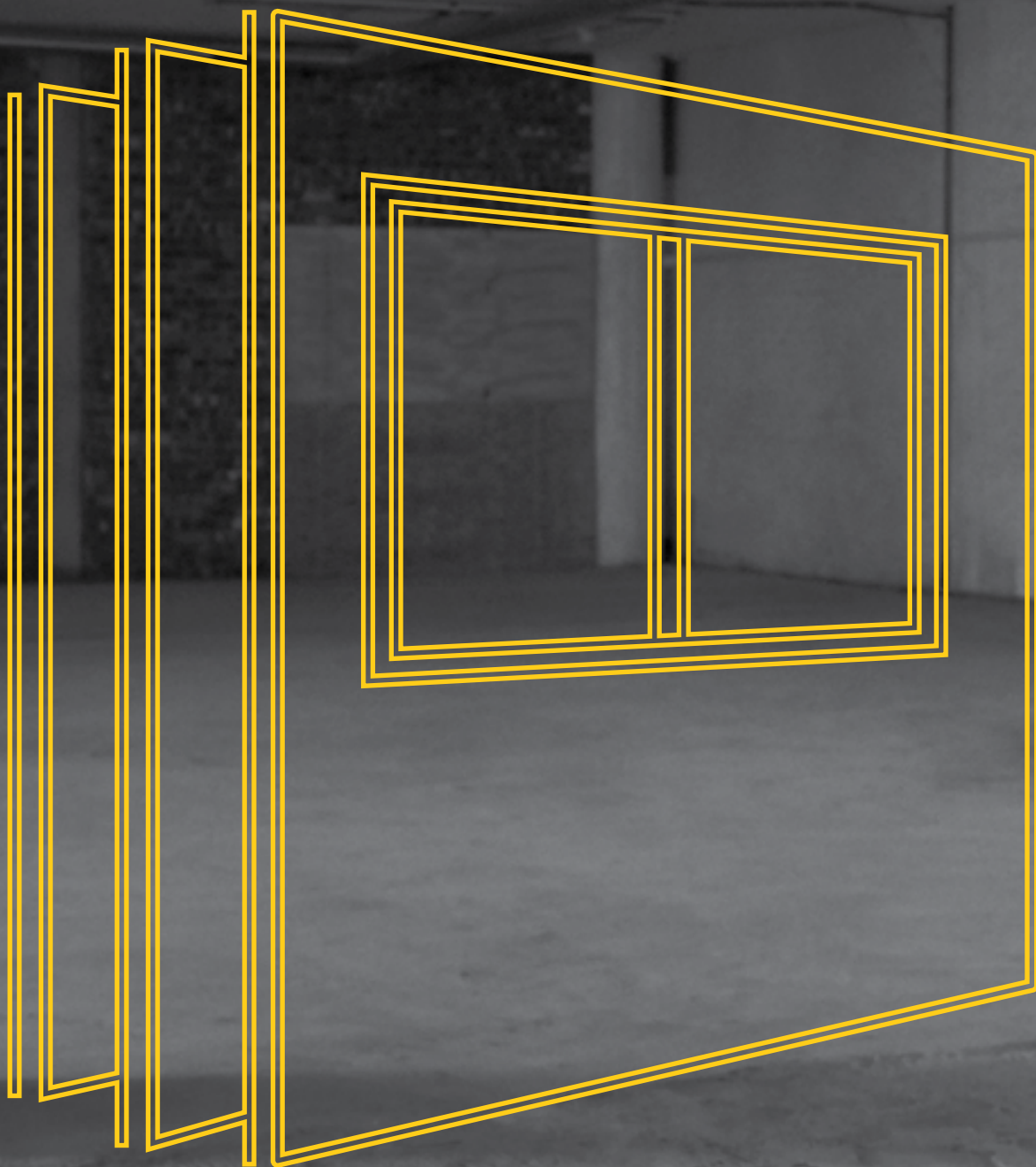
Climate change related natural hazard events in Southeast Asia during the 2020s caused widespread damage and homelessness. Development aid and reconstruction funds flowed from an alliance of Asian countries, which proved effective in managing the crisis.

Following promising technological developments of smart humanoid robots for the Fukushima disaster in the early to mid-2010s, a special Asian innovation fund was set up to accelerate application of smart robots for reconstruction

of storm-ravaged tropical cities. Cities in Indonesia and the Philippines emerged as hot beds for innovation in the reconstruction effort. By 2030, several Southeast Asian cities were world-class innovation hubs for a new high-tech construction industry, with capabilities in low-cost resource efficient and climate adaptive buildings and infrastructure.

Over this time Australia's declining exports from traditional industries brought economic hardship. Queensland was particularly hard hit, drying up investment for construction. While Australia had invested in soft aspects of the digital economy, the preeminent innovation in hardware robotics and autonomous equipment was in Asia. Ultimately, software engineers and programmers coalesced around these Asian innovation hubs. Young Australians looked abroad to Asian eco-cities and smart-cities for exciting study and career opportunities.

The Australian workforce declined and high unemployment ensued; wages plummeted to pre-boom levels. While economic conditions were poor, Queensland tourism remained strong, supporting some construction activity. Construction carried out by imported crews based in Asia became the norm by the mid-2030s. Low wages and ailing domestic companies attracted Asian firms to invest in Australia to acquire market knowledge and introduce advanced manufacturing and robotics. This foreign investment created low-wage jobs domestically, leaving high paid knowledge intensive roles for Asian head offices.





Scenario 3

Globally Challenged – offshoring construction

‘Offshoring’—the relocation of business processes from one country to another—is usually associated with IT, manufacturing and service industries. Work that is not easily separated from its place, like hospitality and health care, has largely been immune from the trend.

Construction is often assumed to be in the ‘immune’ category, because buildings always exist at a specific place, and people generally need to be present to erect them. Unlike many commodities, a building can’t easily be constructed on one continent and shipped to another. Yet the Globally Challenged scenario envisions a future where even the business of building has been offshored.

The recently announced plan by construction heavyweight, LendLease, to prefabricate \$1 billion worth of building components is a signal that there is some plausibility to this scenario. The purpose-built factory will use cross-laminated timber, or ‘CLT,’ a modern, highly engineered timber product used widely throughout the world, but virtually unknown in Australia.

The move to prefabrication is not itself a harbinger of a Globally Challenged future; prefab need not involve offshoring at all. What is striking about LendLease’s initiative is that it has been forged without a local supply chain. Faced with no home-grown capability, the company opted to offshore key elements of the solution—both the CLT itself and the high-tech skills to work with it.

This is a case study in this scenario’s key characteristic: a stagnant Australian industry under pressure from global innovation. Globally Challenged is all about global forces penetrating the local market and imposing change on the industry instead of it emerging from within. The end result is economic benefit being drained offshore, and a depletion of local industry.

The story is of course familiar; many Australian industries have felt the effects of offshoring. How vulnerable is construction to these forces? LendLease’s approach to prefabrication suggests the place-dependent nature of construction may not be the permanent bulwark it is often assumed to be.

5.4 Scenario 4

Rise of the Robots

Automation is mature and Queensland has emerged as a global construction innovation hub, shaping the transformation. The state is the go-to place for testing and refining exosuits, intelligent robots, and advanced manufacturing and materials, attracting massive foreign investment and exciting high-tech jobs.



5.4.2 Queensland's construction industry in 2036

The developing world, particularly Southeast Asia, has been battling major natural hazard events and associated impacts on vast urban populations. Australia has also been impacted by natural disasters, but relatively low government debt has afforded the flow of funds for reconstruction. With one of the world's highest innovation rankings, Australia is an integral part of a Southeast Asian-Oceania Union (akin to the European Union), which is fostering coordinated responses to the crisis.

AI and robotics has transformed construction globally, and Queensland is at the forefront of developing and using this technology. The state's construction industry is central to a regional implementation of smart robots to natural disaster hit areas. Living labs are dotted around the state, testing and evaluating new generations of disaster recovery and reconstruction robots, and new sustainable and climate adaptive materials and infrastructure. Queensland's 'climate resilience' standards are globally respected. Know-how in sustainable and climate resilience engineering is a significant export, along with new products and services to support new and reconstructed cities.

Historical trades and jobs have given way to a workforce of technicians and knowledge professionals in robotics engineering and programming. Construction is a science with significant data flows and real-time feedback to construction workers and clients. Enabled by smart sensor technology, AI optimisation is offered throughout the design and construction process, and beyond to the maintenance and operations of buildings and infrastructure.

Queenslanders are demanding early adopters, expecting the most advanced, cost-effective, environmentally sustainable and climate-resilient products. Restoration and renovation work is limited to historical buildings; it's far cheaper to demolish and recycle materials into new, better performing buildings.

Queensland's proximity to Asia, political stability, strong innovation culture and high-trust environment is attracting foreign investment and world-class scientists and inventors. As a cultural melting pot, the state is also renowned for embracing and benefitting from cultural diversity through an egalitarian approach in the workplace.

5.4.3 How this scenario came about

This scenario was shaped by severe climate change impacts. A series of natural disasters swept across Southeast Asia in the 2020s. Over the course of the decade, extreme storms battered Papua New Guinea, Indonesia, the Philippines and Malaysia. A humanitarian crisis unfolded, compounded by failed crops and shortages of clean drinking water across the region. Civil unrest ensued, and many millions fled to Australia's northern seaboard for refuge.

Initially, the Australian Government managed the crisis by redirecting boats to processing facilities in the Pacific, but by the mid-2020s refugee numbers overwhelmed these facilities and the military was directed to construct temporary camps near major northern Australian towns and cities. With better infrastructure and good rainfall, camps were larger in Far North Queensland. Over the next few years, many professionals and tradespeople from Queensland were involved in construction of refugee facilities and came face-to-face with the problem of temporary settlements in the tropics. Extreme heat and rain events were particularly brutal for refugees, and made traditional construction practices impractical.

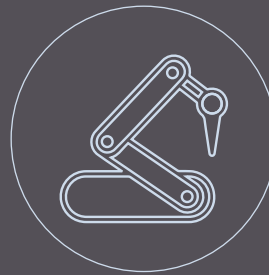
To cope with these issues, niche innovations developed to experiment with sophisticated exosuits and other assistive technologies. Others continued experimenting with existing off-site manufacturing methods. Refugee camps became accidental 'living labs' for these new tools and methods. World-leading roboticists and scientists began visiting Queensland to gain first-hand experience with post-disaster reconstruction, and the challenges of tropical cities. AI and robotics assisted construction, and R&D hubs popped up around the refugee camps. Government assistance and private sector investment converged to accelerate this technology. By the late 2020s, most physically demanding and dangerous construction could be automated, and Queensland was at the forefront of adapting training and regulation to support the roll out of the new technologies and methods. The industry was proactive in managing the transition from human to machine labour. New training and career transition programs were established to support emerging high-tech construction and manufacturing methods.

A culturally diverse and mission-driven industry emerged in Queensland by 2030, attracting international interest. New construction systems, training methods and problem focused R&D spawned exciting new materials and methods. Temporary refugee settlements gave rise to more permanent villages and towns that incorporated leading edge sustainable and climate-resilient infrastructure and buildings. Exports of these solutions and know-how were growing for the Southeast Asian market, as development funds flowed into the region to aid with recovery and reconstruction.

By the mid-2030s, Queensland's construction industry had retooled to become a global leader in construction innovation for tropical cities. The evolved industry capitalised on strengths in engineering standards and testing, setting up 'living lab' sites to support trialling and ongoing monitoring and evaluation of new materials, technologies and methods. The industry was also fostered public-private collaboration and used these test facilities to explore new and emerging technologies, while simultaneously resolving workforce, regulatory and governance issues. Reforms in standards, regulation and strong integration across disciplines and building processes are delivered the full cost and efficiency benefits of BIM, resulting in one of the highest concentrations of construction tech start-ups in the world. Queensland is the 'go-to' destination for testing and standards of cutting edge materials and technology, with a standards brand that is highly respected and coveted globally.

The industry has established high-profile development funds and international collaborations. Queensland is internationally recognised for the capacity to collaborate across cultures and disciplines. Queensland cities are among the most innovative in the world.





Scenario 4

Rise of the Robots – machines displacing core tasks

Rise of the Robots is perhaps our most eyebrow-raising scenario—a world where high technology meets high innovation to put intelligent machines at the core of construction work.

A construction site is a very unpredictable and hazardous place. Robots generally thrive in exactly the opposite circumstances – highly controlled, highly predictable environments, like factories. So the development of robotic technology to the point that it can be widely implemented in construction is by no means a sure thing.

Yet this is an exciting area. Autonomous machines are maturing at an astonishing pace. The last decade has been particularly productive, giving machines the senses, dexterity and intelligence to perform tasks once thought too delicate or uneconomical to automate.


A compelling example of what's possible is found in construction's cousin industry, mining. Rio Tinto is a company that has made extraordinary leaps forward in automating large-scale mining operations in a relatively short period of time. The company operates a fleet of autonomous trucks that move around the ore mined by its matching fleet of autonomous drilling and explosives rigs. Soon, Rio Tinto says, driverless trains will join the humanless operation to transport the ore to seaports.

Rio Tinto's robotics programme operates with 70% fewer humans in the danger zone compared to conventional practices. Instead, a much smaller number of high-tech roles in an operations centre 1500 km from the mine itself choreograph the entire operation.

It's easy to see the applications of this technology in construction. Earthmoving tasks, in particular, seem ripe for the picking. Indeed, the Japanese company Komatsu is already heavily invested in this space. The company's latest technology pairs driverless bulldozers with drones to measure, doze and grade a site, all without human intervention. Komatsu's technology is currently only available in Japan, where it is helping to overcome a severe shortage of construction workers due to the country's ageing workforce.

While our industry continues to rely heavily on traditional manual labour, automating large parts of the construction process is rapidly becoming less an engineering problem, and more a business strategy question. Under the right conditions, a world where smart machines dominate the industry is certainly conceivable.

06 Implications for jobs and skills.



The aim of developing scenarios for Queensland's construction industry was to explore alternative futures that are plausible and could have profound implications for job profiles and skills requirements in the state. The scenario space was formed by two factors identified as having the most uncertainty and impact on construction jobs and skills: task automation and the industry's innovation culture. The scenarios are not predictions, but stories that capture what could happen at the extremes of these two axes. In reality, the future will be more complex and is likely to reflect some combination of all four scenarios.

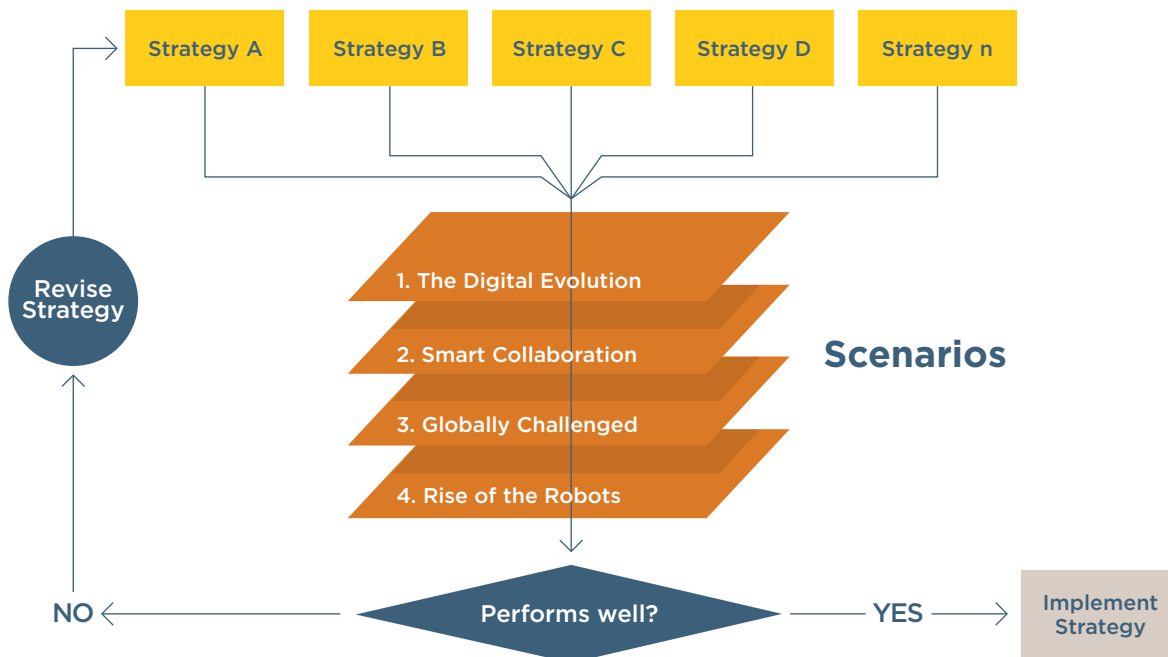


Figure 7. The scenarios 'wind tunnel' for testing strategic responses

Trends analysis and scenario narratives are only useful if they prompt deeper reflection about the focal issue, and stimulate robust strategy debate and development. The robustness test for any strategic response is whether it can maximise opportunities and minimise threats across the range of futures (see Figure 7). To support the search for sound strategy, this section discusses important implications of the trends and scenarios. These are areas where targeted strategic actions can help transition Queensland's construction workforce toward a prosperous future. While reading the discussion, consider the following questions: What would a prosperous future for Queensland's construction industry look like? What could the industry do to align with that future? What could be done to prepare for shocks and surprises?

6.1 Job competencies

Regardless of which scenario seems more likely, the nature of construction work is set for a step change over the next 20 years. New competencies and jobs will emerge, and others will fall away. The following competencies may become more prominent across construction disciplines and trades.

Digital literacy and tech savviness: While the disruptive impact of digital technology is yet to be felt in the construction industry, it is playing an increasing role in the economy as a whole. Tradespeople and knowledge professionals alike will need to be well versed in the use of apps and tools that boost productivity, quality and safety. The virtues of BIM are being touted for major projects, but what about application to small projects, such as housing construction and renovation? Furthermore, with technological development accelerating over time, task automation might become sudden and unpredictable. Workers will need to maintain awareness of the latest developments to avoid being blind-sided.

Innovation management and entrepreneurship: Seizing new opportunities and translating diffuse ideas into practical and useful solutions involves complex problem solving, and seeking help and funding from others. At some point, teams of professionals with complimentary skills need to be assembled and managed to keep up momentum and stay focused on delivery. Innovation is a difficult process involving collaboration, leadership and emotional intelligence. There are twists and turns along the way, and innovators need to maintain composure and show resilience to setbacks. These soft skills will become increasingly

important for construction managers as companies big and small begin to integrate innovation processes into project operations. Success for future construction workers might involve engaging with personal development programs that foster soft skills. More companies might build a culture of innovation by adopting new work practices such as job rotation and continuous improvement, which would require workers diversifying their skills.

Cultural awareness and inter-cultural communication:

As the Queensland (and Australian) population continues to age (people living longer) and grow (through overseas migration), and foreign investment expands, the construction industry will increasingly face new markets and customers with preferences reflecting very different values and cultural norms. For example, the recent influx of direct investment from China into Australian real estate is heavily focused on high-rise development, perhaps reflecting the compact nature of cities in China, and therefore preferences for living in built-up centres. Understanding different cultural preferences for housing, transportation and urban amenity could unlock new opportunities for adding value, or solving problems facing urban dwellers in rapidly growing and urbanising Asia.

6.1.1 Possible jobs of the future in construction

While we can predict the future of current jobs (e.g. in terms of probability of being automated), accurate forecasts of new jobs are difficult. We do not have statistical or modelling techniques to make such predictions, and so we must rely on the imagination and making connections with concepts outside the industry. Here are a few examples of possible construction jobs in 2036.

Building assembly technician: Someone who oversees robotic systems and examines data feeds throughout a project, optimising workflows and AI programming, or making adjustments based on real time feedback from clients about design and/or changes to materials.

Online property profile manager: The real estate market could operate entirely from an online platform—no agents in the traditional sense. Some sellers will be able to do it themselves, but many will require someone to upload data about properties, and answer requests from potential buyers. Such professionals might administer sophisticated lifestyle surveys with interested buyers, to help them more efficiently match buyers with suitable properties.

Construction artist: More industrial designer than architect, these professionals are highly paid for their ability to convert the possibilities of additive manufacturing into extraordinary works of art. Buildings and infrastructure look more like structures that have been grown in a forest, or

poured out of a tin, than pieced together with standardised components. Like famous paintings today, buildings and houses by certain designers may attract ridiculous sums of money. ‘Knock off’ designs might be licenced to the mass market to ensure the original remains one of a kind!

Virtual/augmented reality trainers: Breakthroughs in VR and AR technology could provide low-cost immersive environments where apprentices and trainers can meet virtually in any training situation, such as worksite, factory, design studio—the possibilities are endless! A new breed of trainers and training organisations will be at the vanguard of creating dynamic high fidelity digital experiences that accurately match the skill level of students, build motivation and a sense of wonder and curiosity.

Building drone operators: These professionals control and program drones to carry out complex tasks, such as site inspections, deliveries and maintenance. Such operators will be based in offices thousands of kilometres from work sites, yet provide construction and asset managers timely on-the-ground support. The sky in 2036 could be teaming with drones, necessitating new air-traffic control capability, especially in high density urban areas.

Robot resource manager: We’re familiar with human resource managers, but a robot future will need someone to take care of commissioning, software programming, maintenance, and repurposing or recycling of robotic parts. It’s a complex job that requires a comprehensive knowledge of many robotic systems, and endless materials and components of different vintages. Keeping track of this exploding field of technology will be a key challenge for the role. An artificial intelligence interface is likely to be an essential support to humans in this role; think J.A.R.V.I.S., the fictional artificial intelligence system developed by Tony Stark to manage all things technology in the blockbuster comic-movie series *Iron Man*.

6.2 Education and training system

The trends identified throughout this study raise important questions about how construction training will need to be conducted in the future and how the secondary education, VET and tertiary sectors will respond to emerging skills needs and ensure that graduates can participate in the future economy.

Regardless of the specific scenario that ultimately unfolds for Australia’s construction industry, it seems almost inevitable that the current school, VET and tertiary systems will need to innovate and adapt to keep pace with the evolving skills needs of the building and construction industry over the next 20 years.

**How do you
prepare
people for
jobs that
don't exist
yet?**



In particular, the national VET system will need to deliver outcomes, whether they are full qualifications, courses or skill sets that match changes in job roles, construction techniques and technology.

The construction industry still relies heavily on the apprenticeship model as an entry pathway for many occupations, especially licensed trades. Even as the skills required of construction workers have changed, the trades themselves have remained well-defined and homogenous. This stability meant that apprenticeships have remained an excellent model for skills formation.

Yet the stability of construction occupations is being eroded, and this is likely to accelerate in the coming years and decades. The erosion is being driven by two ongoing disruptions in the industry: an increase in the specialisation of construction occupations, and the fragmentation of the industry into small, often self-employed, subcontractors (Toner 2006).

It is not uncommon today for a contractor to specialise in one very narrow aspect of their trade. This occupational specialisation is making it increasingly difficult to sustain homogeneous definitions of construction occupations. As a result, these specialised contractors often find it difficult to expose their apprentices to the full range of skill opportunities needed to satisfy the requirements to complete a traditional apprenticeship.

This trend is likely to accelerate as technology increases specialisation, and economic conditions emphasise networks of autonomous workers. This presents a clear challenge to the apprenticeship model, which rests on the premise that construction occupations are standardised and broad-based, while at the same time relying on work placements being offered by employers who are less likely to have capacity to offer the full scope of work required.

The apprenticeship model, if it is to survive, will need to modernise and be designed to reflect the workplace now and be flexible to continue to adapt to meet the needs of the future workplace.

We have already seen examples of complementary apprenticeship models that have been developed to trial flexible approaches to the structure and delivery of apprenticeships. Models such as the institutional-based and front-end training approaches where underpinning skills and knowledge are completed before entering employment to obtain experience and demonstrate competency in the workplace, seasonal apprenticeships, school-based apprenticeships and the Registered Trade Skills Pathways model, which has been trialled in the construction industry.

However, a range of factors have limited the spread of flexible training arrangements throughout industry.

Having said this, the focus of future trade and skills pathways should be on the needs of industry, employers and the economy, not the parameters of the existing, traditional apprenticeship model. Already the ‘... nature of construction jobs is changing due to the introduction of new technologies and prefabrication. This is leading to altered work practices which no longer guarantee that traditional career paths will generate the mix of skills needed to meet the future demands of the industry’ (MBA 2015).

The training system in itself has capacity to respond to new approaches to skills formation that support individuals and industry—it is a system underpinned by a national framework for qualifications that provide mobility and recognition of skills for individuals, based on competency-based training and completion, with multiple entry and exit points, underpinned by a national system for quality. While much attention has been on the quality issues within and the complexity of the system, it still remains that there is a vehicle that can be adapted—the challenge is the speed with which it can adapt.

Competency and skills need to reflect the requirements of industry, therefore industry needs to be heavily involved in defining the skill requirements for the workforce. The reform agenda for VET has for some time now focused on placing industry at the centre of the system but this is predicated on industry having a unified position on skills and training for their industry.

At the centre of the training system are the training products—national training packages, qualifications and learning resources (curriculum). Key challenges are to ensure that training products keep pace and continue to reflect a modern workplace, and that those delivering the training (training providers, trainers and assessors) maintain industry currency and keep pace with changes, so they can deliver training that reflects the skills needed to do new jobs.

This has been recognised by both state and federal governments in their attempts to focus training product development on the new skills industry needs to capitalise on advancements in technology, keep pace with new ways of working and reflect new jobs in the economy.

But skills formation and reskilling can also occur outside of the national training system. There are many lessons from other industries that have embraced skilling models such as continuing professional development and proprietary certification schemes. A comparison can be drawn with the IT industry, where technology suppliers operate training and certification schemes around their own platforms. These schemes sit outside the traditional regulatory frameworks, but are highly valued within industry. This is also seen in the automotive industry and has featured in some small ways in the construction industry itself (e.g. Clipsal’s C-BUS).

It is conceivable that suppliers of new construction technologies will play a growing role in ongoing skills formation, particularly if the pace of technology outstrips the ability of formal qualification frameworks to adapt to these changes. The potential growth of supplier installation certification regimes underpinned by proprietary training delivered by the suppliers could be a feature of how workers are skilled for new roles.

The big question remains—how do you prepare people for jobs that do not yet exist?

The provision of strong basic education at the schooling level supplies the building blocks for future participation in employment and further skills development. It is increasingly acknowledged that in order to seize opportunities, training and skills development, whether in schools or along other pathways, should be an essential complement to general education (ILO 2010).

The UK report on *The Future of Work: Jobs and Skills in 2030* (UK CES 2014), put forward some suggestions that government, educators, industry, employers and individuals will need to consider that may apply to the construction industry, including:

- businesses placing talent development, talent diversity and future workforce strategy front and centre to their growth
- employers and individuals committing to lifelong learning
- public and private strategic approaches to wholesale reskilling of existing workforces throughout their lifecycle
- cross-industry collaboration, including strategic redeployment across industries
- increased individual responsibility for skills development
- focus on development of key foundation skills and attributes that will be at a premium in future, including resilience, adaptability, resourcefulness, enterprise, cognitive skills (such as problem solving), and the core business skills for project-based employment
- education and training providers being prepared to adapt to the continuing disruption of established learning and business models, and to invest continuously in new modes and content of provision
- fostering a flexible and dynamic public skills investment environment that is aligned to private skills investment, and enables people and businesses to build their capacity to innovate and compete, and maximises outcomes that contribute to jobs and growth
- empowering individuals through access to high-quality careers and training information and advice.

Skilling, reskilling and upskilling will be critical and it will not be the responsibility of one stakeholder alone—it will rely on the culmination of a partnership between industry, government, employers, training providers and the potential/existing workers themselves.

6.3 Data infrastructure


Construction workers of the future are likely to require increased skills to interpret and use digital data relating to buildings, materials, technologies and infrastructure. Regardless of which scenario, or combination of scenarios, comes to fruition, construction activities will be more data intensive in the future. Data-driven and evidence-based decision-making for the industry requires technical data to be systematically collected, stored, analysed and made available upon request. For Queensland to be at the forefront of innovation in the industry, data management is a challenge that needs to be examined and acted upon today. Being responsive to challenges and opportunities will require accessible and relevant data.

Technical information on buildings and infrastructure can be effectively stored and managed today and will be crucial for tomorrow. Such data underpins BIM systems, and in the future, the capacity for automation, including the use of robotics and artificial intelligence systems. Building and infrastructure maintenance, property management, response to natural disasters and other trends can be facilitated by analysis of big data. Furthermore, the Internet of Things will continue to expand and a vast network of sensory devices will generate enormous quantities of data relevant to construction.

Advances in the field of data science and machine learning are likely to improve the usefulness of the vast quantities of data being created in the construction industry. The field of big data science barely existed a decade ago. However, today there are many dedicated research organisations developing new and improved tools for data interrogation. In Australia, a merger between the National Information and Communications Technology Association (NICTA) and CSIRO's Digital Productivity research capabilities has created the newly formed Data61—the Southern Hemisphere's largest dedicated research organisation focused on solving problems via data analysis. This organisation, and many others, will help convert the masses of construction data into useable information.

A black and white photograph of a modern, multi-story apartment building with large glass windows and balconies. A curved street lamp is visible in the foreground, and a sign that reads "END SHARED ZONE" is partially visible. The building is surrounded by trees and a sidewalk with bollards.

07 Trends impacting on the construction industry.



This section reviews 25 trends that were identified as most influential for construction jobs and skills over the next 20 years. Part of our analysis involved categorising these trends into STEEEP categories—social, technological, environmental, economic, educational and political—with the aim of assessing and demonstrating breadth of coverage. Of course, these trends are more complex and interconnected than the categories suggest. The scenario narratives were developed to capture some (but not all) of the real-life complexity and interconnectedness of these issues.

7.1 Social trends

Ageing population is impacting on construction industry workforce. By 2034/35, 6.2 million (or 19.4%) Australians are projected to be aged 65 or over (Treasury 2015). An increasing share of construction workers will move to the older age brackets over this time. The number of construction workers aged 55 and over in Queensland has increased from 8% of full-time workers in 1992 to 14.2% in 2014 (ABS 2015). Some occupations might be more prone to ageing than others. According to the Queensland Building and Construction Commission (QBCC), in 2014 the median age of licenced bricklayers was 52 years and builders was 53 years, while carpenters were among the youngest with a median age of 35 years (Figure 9) (Hope 2015).

An ageing workforce is likely to increase the need for less physically demanding jobs. Technology and automation of construction processes might address this issue, which will require new training programs. Older workers will have to be prepared to learn and apply innovative approaches to day-to-day practice. At the same time, construction site management might face a need to provide personalised adjustment of working conditions, determined by the health need of ageing workers (limited physical capacity, higher occupational risks (Hoonakker and van Duivenbooden 2010)) to ensure their continuing inclusion in the workforce (Marchant 2013, NG and Chan 2015). Furthermore, healthcare arrangements, preventative care, flexible hours, more automation and generous superannuation might become more and more important for employee attraction and retention.

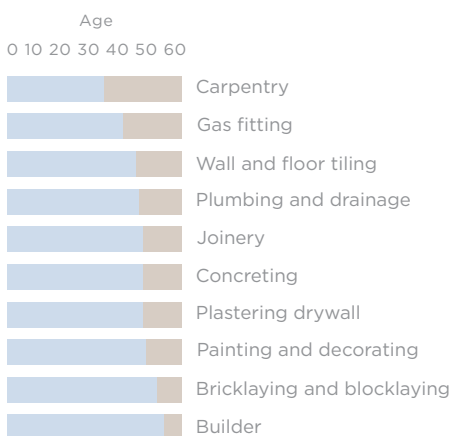


Figure 9: Median age of the most populous trade occupations, based on licenced operatives data. Source Hope (2015)

The industry is becoming more male dominated, particularly among traditional trades. Female participation in the Australian labour force has significantly increased since the 1970s, reaching nearly 60% in 2015, up from 43% in 1978 (ABS 2015). The traditionally male-dominated construction industry has not yet been a part of this trend. At the end of 2015 nearly 90% of workers were male, and the number of male employees has been growing at a higher rate over the past two decades (ABS 2015). The gender gap is also associated with the pay gap which is estimated to be 18% in the Australian construction industry (WGEA 2015). Industry worker profiles also differentiate by gender. The majority of male workers represent technicians and trade workers, followed by labourers and managers; whereas the majority of women in the industry work in clerical and administrative roles, followed by managerial and professional roles (Figure 10).

Recent studies suggest that administrative and clerical jobs are prone to automation (PWC 2015), putting female-occupied jobs at risk. However, increasing automation of heavy and dangerous tasks might open new opportunities and accelerate female participation in the future workforce, in line with increasing female participation in the wider economy. Public initiatives that target increasing female participation and promotion of gender equity in the industry (e.g. National Association of Women in Construction (NAWIC), Lady Tradies Australia, Industry Women Central) already observe a growing number of 'lady tradies' (Sibthorpe 2016) (MBA n/d). However, the working environment and perception of construction as being a 'job for men' are major barriers for women. Unless this perception changes, the gender gap is not likely to close.

Change of culture is also likely to improve job opportunities for minorities such as Indigenous groups and people with disabilities. For example, in 2011 construction was the top industry of employment for Aboriginal and Torres Strait Islander men (ABS 2013).

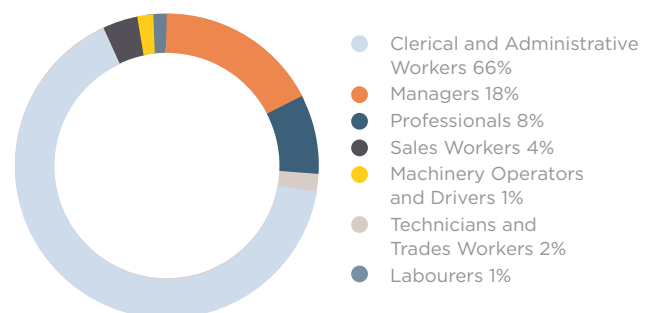


Figure 10: Women employed in Queensland construction industry by occupation (February quarter 2015) Source: ABS (2015)

Australian households are increasing in number, but shrinking in size.

Since the beginning of the last century, Australian households have significantly changed in size and composition. The number of private households increased from 894,400 in 1911 to 7.6 million in 2006, while the average number of persons per household declined from 4.5 to 2.6 (Figure 11). Increasing numbers of one- and two-person households, as well as decreasing completed family size, are key drivers of this trend (ABS 2012).

By 2036, the number of households in Queensland is projected to increase by 60%, reaching 2.7 million compared to 1.7 million in 2011, yet the average household size is projected to drop further. The number of family households is projected to grow by 55% whereas the number of lone-person households is projected to grow by 76%. Increasing share of one-person households fuelled by ageing population, longer female life expectancy and later marriages is likely to further affect the demand for housing in Queensland.

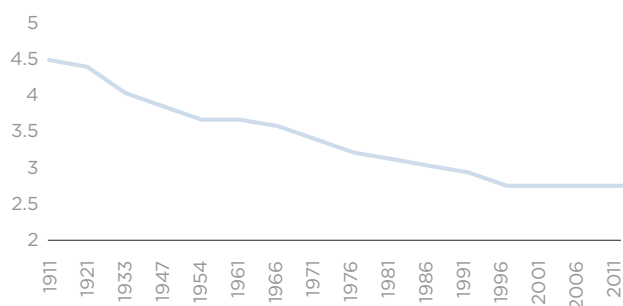


Figure 11: Average household size in Australia (number of persons)
Source: AIFS (2011)

High-density living is on the up. Although the majority of Queenslanders live in detached houses, high-rise development is booming and historic views of the Australian dream is shifting (Zhou and Walsh 2015) (see Figure 12). Trends toward compact urban form are being driven by growth management planning (e.g. Queensland Regional Plan) (DIP) and affordability issues. Housing prices and lifestyle preferences are shifting demand for flats and townhouses, among young people in particular: of 25–34 year olds purchasing property, 93.4% would buy a detached house in 1981, but only 78.8% would in 2011. The trend is similar for the 34–45 year old cohort (94.8% in 1981 to 87.2% in 2011) (Burke, Stone et al. 2014).

Land sizes for detached housing are also decreasing due to property price growth. In Australia, the average median new lot size decreased by 11.4% over 2009–15 to 474 square metres but the average median price of land for new home buyers increased by 40% since 2009 and reached \$527 per square metre in 2014 (Figure 13) (UDIA 2015). Floor area of new houses has increased over the 1985–2009 period (ABS 2010).

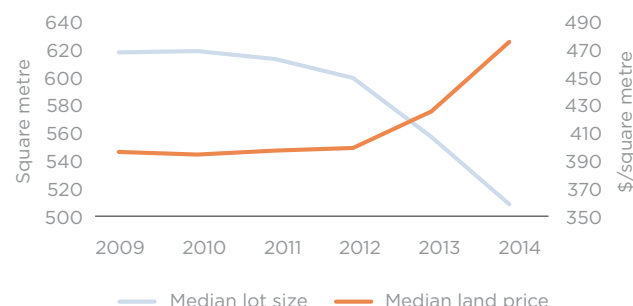


Figure 13: Median land size and price for new land lots in South East Queensland. Source: UDIA (2015)

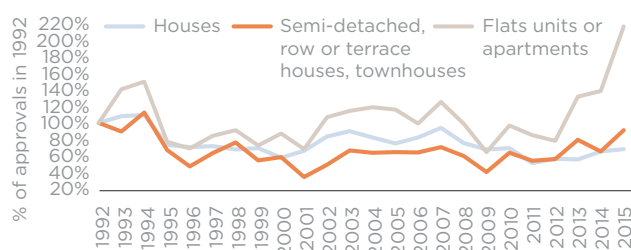


Figure 12: Dwelling approvals by type in Queensland (indexed, 1992 = 100%) Source: ABS Building Approvals (2015)

Australians are demanding larger and personally designed living spaces. Architecture divisions of institutions and companies are gradually exploring the prospect of robotics in construction and manufacturing (ROB|ARCH 2016) and its potential in mass customisation (as compared to mass production) for flexible design and architecture (Paoletti and Naboni 2013).

Increasing demand for compact living is likely to affect the portfolio of projects for construction companies. The Australian dream might equate to owning a unit in the city centre, affordable and with easy reach of public transport. Changing consumer preferences, affordability concerns and decreasing household size, coupled with increasing demand for single person accommodation due to ageing population, are likely to create a suitable environment for prefabrication and modular construction to enter Australian cities for good. At the same time, personalised design is not likely to be dropped off the 'wish list' of the future consumers making mass customisation a growing field of development.

7.2 Technological trends

The uptake of information and communication technology is growing. In the past few decades, information and communication technologies (ICT; the Internet, wireless networks, mobile phones, and other communication mediums) have provided society with a vast array of new communication capabilities. In this time, computer power has increased exponentially, and there has been a significant decrease in its cost (see Figure 14), which has substantially increased the accessibility and availability of ICT (Nordhaus 2007). While historical growth rates are not indicative of future growth, this trend is the driving force of recent technological and social change.

ICT is changing the way we communicate and gather information, and is enabling new business models

Cloud computing is where a network of remote servers, hosted on the Internet, is used to store, manage, and process data, rather than a local server or a personal computer. 'The cloud' enables convenient, on demand access to a shared pool of computing resources no matter where you are in the world, making it possible for geographically dispersed groups of workers to collaborate and share files, data, and information.

(See also Platform Economics and P2P in section 4.4). Smart phones, for example, have rapidly become an integral part of everyday life for many people, with many embracing them as an 'everything hub'. In 2014, an estimated 12.07 million Australian adults (74%) were using smart phones as compared to 11.19 million (64%) in 2013 (ACMA 2014). Smart phone technology offers access to a whole new world of 24/7 connectivity that is in itself changing the way people work and live day-to-day (see also IoT and Visualisation and digitisation of information systems below).

ICT means businesses and the general public are increasingly becoming more and more interconnected, particularly with social media enabling immediate and significant connections. The arrival of cloud computing is another ICT advancement that will change how individuals and businesses in the construction industry work (Deloitte 2016). With tools in the construction industry increasingly

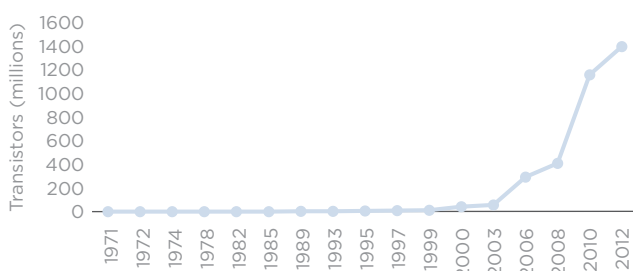


Figure 14: Number of transistors on an integrated circuit at the same cost (Moore's Law) Data source: Intel (2012)

becoming digital and data driven (Heaton 2014), it will be important that workers in the construction industry have the skills and know-how to implement ICT to create better, more streamlined processes and systems.

Information systems are being digitised and visualised.

Digitisation is the process of converting information (objects, text, sound, images or audio) into a digital format. The construction industry is becoming more and more digitised, and the humble building plan is receiving significant attention. While computer-aided design (CAD) has long been taught at universities and trade schools, in most cases computer drawings are still generally converted to paper blueprints for the construction site. The implementation of an all-encompassing Building Information Model (BIM) system might see this change in the future, and digital blueprints could become common on the construction site.

While BIM is still in the early phases of adoption (Sun, Jiang et al. 2015), a number of factors are accelerating its uptake:

- **Growing IT infrastructure capacity:** Cloud-based data-storage and computing, as well as the capacity of computers to develop and display 3D models based on large databases (see Growth in the uptake of ICT above) reduces technical barriers to BIM adoption.
- **Complementary technologies:** Development of and integration with complementary technologies, such as augmented reality and mobile laser scanning, makes BIM adoption a more attractive prospect by offering additional utility.
- **Productivity benefits:** BIM adoption by the construction industry could boost Australia's gross domestic product (GDP) by up to \$7.6 billion with a social benefit cost ratio of 10:1 (ACG 2010).
- **Government support:** The Productivity Commission has recommended BIM adoption in tender designs and procurement due to time and cost savings, transparency, efficiency and improved quality of the final product. The UK Government has mandated that all centrally-funded work is to be undertaken using BIM by April 2016 and the Queensland Government has stated that it will progressively implement the use of BIM into all major state infrastructure projects by 2023.

Such a transition will require participation from everyone involved in the building process, from clients/asset owners, designers, builders and product manufacturers (Davies 2010). Workers from across the construction industry will need to be knowledgeable and skilful in BIM and associated visualisation technologies.

Building Information Modelling (BIM)

BIM is a digital representation of the physical and functional characteristics of a facility that can be used as a data and knowledge repository throughout the entire building lifecycle, from design and engineering right through to decommissioning (Vähä, Heikkilä et al. 2013). While traditional building is reliant on two-dimensional technical drawings (plans, elevations, etc.), BIM uses imaging software to present a 3D visualisation of a building. However, BIM extends beyond 3D imaging and includes time as a fourth dimension for scheduling, and cost control as a fifth dimension. More recently, facility management has been added as a sixth dimension and energy performance monitoring as a seventh dimension. More 'dimensions' may be added yet (Eastman, Tiecholz et al. 2011).

Augmented reality is a live, copied view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input. Using a smart phone, a tablet or glasses with augmented reality software, users will be able to view the 3D model in the real environment in real time from multiple perspectives.

Mobile laser scanning combines high resolution photography with a highly accurate laser and, in most cases, a very highly accurate GPS system, producing detailed information, including measurement analysis, which cannot be replicated by traditional surveying. It is an innovative technology that is a major advancement and has the potential to significantly change the way survey information is captured (Australian Parliament 2016).

CSIRO has recently produced the world's first lightweight, handheld 3D laser mapping system, Zebedee, which is self-contained and does not rely on external positioning systems. Zebedee generates a 3D map as the operator walks through a site. The system offers a unique combination of portability, efficient data collection, accuracy in areas with no GPS, rapid scanning of large areas, and automatic data processing (CSIRO 2016).

Machine support

Exosuits are wearable machines designed to augment the user's strength and agility. Both powered and unpowered exosuits have been specifically designed for workers that operate heavy tools and machinery. Exosuits can help workers with heavy lifting. They are predominately used by the US military, but applications relevant to the construction industry are being promoted (Lockhead 2016).

Autonomous vehicles are capable of sensing the environment and navigating without human input, detecting their surroundings using radar, lidar, GPS, odometry and computer vision instead. Driverless Google Cars have already driven over 1 million miles (1,609,344 km) and are currently out on the streets of three states in the US (Google Car Project). Similar examples can be found in the UK, Europe and Japan. China is also investing enormously in this space.

Drones are aircraft without a human pilot aboard, also known as unmanned aerial vehicles (UAVs). Drones have applications in the construction industry given their ability to venture where humans and heavy machinery cannot. The use of drones for monitoring sites, conducting remote surveying work and collecting site-specific aerial data can improve safety and reduce operational costs (Deloitte 2016).

Artificial intelligence is the intelligence exhibited by machines or software to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making and translation between languages.

Forces are pushing construction towards automation and robotics.

Reduction in labour for safety reasons, reducing construction time, reducing production costs, and increasing architectural freedom are forces driving the construction industry towards automation and the use of robotics (Lim, Buswell et al. 2012). Shortages in skilled labour in certain trades, either in Australia or overseas, will also drive this trend (FLC 2013), which will also develop with advancements in BIM, laser scanning and sensor technologies (Vähä, Heikkilä et al. 2013) (see digitisation trend above).

Although adoption of automation in the building construction sector has been slow to date, there are already plenty of examples of automation and robotics use in the Australian construction industry. Bricklaying robots, for example, have been developed by a Perth-based company and are expected to be rolled out for commercial use by 2017 (Price 2015). Research at Harvard University's Design Robotics Group (DRG) is focused on robotic tile placement (King, Bechthold et al. 2014) and the University of Southern California is busily demonstrating additive manufacturing or 3D printing for building construction. The principles of industrial automation are also applicable to both building construction and civil engineering, and to prefabrication of construction components (Vähä, Heikkilä et al. 2013) (see Growth in prefabricated building manufacturing).

Forces from outside of the industry, and outside of Australia, are likely to spill over into construction in Queensland. The ageing population (see section 4.1) is a particular force accelerating robotic innovation in Japan, where it is driving demand for machine assistive technologies, or exosuits, so that older workers can stay employed and injury free. Similarly, population growth and urbanisation, particularly in developing nations, is demanding rapid construction methods, and is acting as a catalyst for future automation and robotic applications (FLC 2013) (see population growth in section 4.1). Autonomous vehicles and drones are examples that are becoming mainstream. Add artificial intelligence (AI) in the mix, and you have a smart robot; a robot that can think and make judgements based on pre-programmed goals.

With the world's major economies and corporations investing billions in automation and robotics research and development, it is hard to dismiss the possibility that technical breakthroughs will be made that could displace much of today's human labour. Across the workforce, current estimates suggest 40–50% of jobs are at risk of automation (Frey and Osborne 2013, PWC 2015, Hajkowicz, Reeson et al. 2016). Automation is likely to complement some occupations and tasks in the construction industry, but will substitute others. Workers who have skills which are complementary to technology will command better wages and job opportunities while those without such skills, and those that have skills which

are considered routine (i.e. follow well-defined procedures), will be most impacted as they can be replaced by the technology (Acemoglu and Autor 2010, Cowen 2013, Brynjolfsson and McAfee 2014, Akerman, Gaarder et al. 2015).

Prefabricated building manufacturing is growing. While prefabricated buildings have been around for more than 50 years, the methods of factory-based modular construction have and will continue to improve, producing better quality and significantly cheaper buildings than those built on-site. Prefabricated buildings, as opposed to traditional building methods, are recognised as having a number of potential advantages, particularly in terms of efficiency and reduced environmental impacts. This is driving support for this approach to construction (see section 4.3).

In 2014, the global prefabricated buildings market was valued at US\$96 billion, up from US\$90.1 billion in 2012 and US\$60 billion in 2011. Asia-Pacific was the largest regional market, with 49.3% (US\$44.4 billion) of the global market and it recorded a review-period compound annual growth rate (CAGR) of 16.23%, outperforming all other regional markets. China constituted the largest share of the Asia-Pacific market with 61% in 2012, followed by Japan, Australia and Indonesia with respective shares of 22.3%, 6.8% and 5.1% (Green and Newman 2014).

While the current prefabricated building market in Australia is still comparatively small, with only \$4.5 billion of the total \$150 billion construction industry (3%), it is expected to contribute to the affordable housing stock requirement (see Housing affordability in section 4.4) and is set to take a much greater share, particularly for multi-storey buildings (Green and Newman 2014). Although Australian developers and construction firms have lagged behind international developments in this approach to building, recent investments by local companies in off-site manufacturing facilities, and design and construction systems suggest Australia is following suit. The sector is expected to grow at 5% per annum out to 2023, compared to a growth rate of 2.3% for the industry as a whole (Steinhardt, Manley et al. 2013).

The workforce for prefabricated building requires skills that are usually associated with manufacturing, rather than traditional building skills. Further automation of prefabricated manufacturing could mean a minimal labour requirement, which would be limited to the point of delivery. This could fundamentally change traditional house building work patterns and reduce the need for manual labour (Steinhardt, Manley et al. 2013). Highly specialised design skills, on the other hand, are likely to increase and new, currently undefined jobs, will likely be created.

Prefabricated building can be defined as the manufacture of whole buildings, or significant components, offsite in a factory setting prior to installation or assembly onsite (Steinhardt, Manley et al. 2013).

Additive manufacturing techniques are developing rapidly—click, personalise and print!

Similar to prefabricated buildings, additive manufacturing is not new. It has been around for at least 30 years, but there has been a recent shift in accessibility and uptake in the market. Additive manufacture of full-scale construction components is still an emerging technology, but one that is becoming a reality (Lim, Buswell et al. 2012).

New materials, methods and combinations of materials and methods are being introduced to perfect the technology (Lim, Buswell et al. 2012). Various materials and processes are being used to print solid 3D objects: plastic resins, metals, wood fibre, carbon fibre, construction waste, desert sand, human tissue and many others. Large-scale additive manufacturing is a natural extension of 3D-printing technology (Barnett and Gosselin 2015). In the construction industry, techniques have improved and are evolving from a technology used to produce an architect's model. They are now delivering full-scale architectural components and elements of buildings such as walls and facades (Lim, Buswell et al. 2012). Architects and contractors around the world are beginning to build the first 3D residential structures, including houses and apartment buildings, and bridge prototypes.

As the technology is refined, 3D printing could mark a new era in building houses, where every component can be produced to exact specifications to reduce or even eliminate construction waste. Additionally, the technology allows for the production of complex shapes, helping to create sturdier structures using less materials and meeting a growing consumer preference for personalised design. The cost of transporting materials could also be reduced and, with some designs and final buildings, could be dismantled and moved in units, or completely recycled (Mayer 2013).

While 3D printing has the potential to significantly reduce the cost of construction, through shorter project times and fewer wasted resources, this technology could substitute for a number of labour-intensive trades (PWC 2014). 3D printing does, however, require new jobs in robotics and software programming, and design and engineering skills that can exploit the potential of new materials and forms (PWC 2014).

The 'Internet of Things' (IoT) is growing rapidly. Ten years ago there were six billion connected devices online. Today there are 15 billion. According to Intel, by 2020 there will be 200 billion connected devices. This means that the next five years will see the number of connected devices increase by 13 times (Intel 2015).

Construction is a sector in which the IoT could have a transformative impact. Rapid development of ICT and projected growth of the IoT will require buildings, both commercial and residential, to operate smart devices, grids and systems. Buildings, infrastructure (e.g. roads, rail, pipes

Additive manufacturing, also known as 3D printing, additive fabrication, or freeform fabrication, is the process of joining materials to make objects from Computer Aided Design (CAD) model data, usually layer upon layer, as opposed to subtractive manufacturing methods.

and bridges) and, in fact, whole cities are likely to become interconnected and 'smarter'.

A recent report by the McKinsey Global Institute reveals IoT applications that leverage ubiquitous (everywhere) connectivity, big data and analytics are enabling Smart City initiatives all over the world (Manyika, Chui et al. 2015). New applications are introducing new capabilities such as the ability to remotely monitor, manage and control devices, and to create new insights and actionable information from massive streams of real-time data (Manyika, Chui et al. 2015).

The 'smart' technology is being rapidly adopted by cities and by business, bringing increased efficiency, cost savings and helping to manage machines, improve safety and track inventory, and is likely to reach households in the near future (Intel 2015). Smart devices will need to be installed and connected at the construction stage. Installation and connection of the rapidly growing number of devices and equipment will require ICT know-how from construction workers (Deloitte 2016). Builders and infrastructure workers will need to be equipped with necessary skills to install the smart equipment (CITT, TITAB et al.). Additional training programs might be required to meet the skills needs of builders in the digital economy. Given the dynamic nature of technology change, this training is likely to be modular, on-going, and even lifelong (Hajkowicz, Reeson et al. 2016). IoT technology may also be adopted to improve the safety of construction workers. Wearable devices can, for example, offer biometric measurements such as heart rate and perspiration levels, or monitor their location and alert them and others to dangerous situations. The ability to sense, store and track biometric measurements over time and then analyse the results is just one interesting possibility. However, security and privacy have been identified as key challenges associated with IoT technologies, which influence the rate and extent of uptake.

7.3 Environmental trends

Our climate is changing. It is widely acknowledged that climate change is occurring and is caused by human activity (IPCC 2013) and while Queensland is quite accustomed to unpredictable and severe weather conditions, climate change is expected to increase the frequency and severity of extreme weather events. Scientists warn that Queensland will increasingly be affected by changes in temperature, rainfall, sea level and extreme weather events (Queensland Government 2016).

Current predictions suggest Queensland can expect average temperatures to continue to increase in all seasons (predicted with very high confidence), including more hot days and warm spells (predicted with very high confidence) (CSIRO 2015). Physical outdoor labour is characteristic of the construction industry, therefore actions to mitigate the risks associated with rising temperatures will become increasingly important to workplace safety, especially to vulnerable groups such as older workers. Safety concerns related to working in harsh environments may stimulate solutions to this problem, including but not limited to, automation and robotics, prefabricated building and wearable technologies (Yi, Chan et al. 2016) (see section 4.2).

Changes to rainfall in Queensland are also possible but unclear, but increased intensity of extreme rainfall events is projected with high confidence. There will be fewer but more intense tropical cyclones (predicted with medium confidence) and some climate zones in Queensland may also experience a harsher fire-weather climate in the future (predicted with high confidence). Mean sea level will continue to rise and the height of extreme sea-level events will also increase (predicted with very high confidence) (CSIRO 2015). Impacts from sea-level rise are particularly pertinent, as Queensland has been identified as the state with the greatest combined risk, in terms of both quantity and replacement value for a sea-level rise of 1.1 metres, out of all of the states and territories in Australia (Department of Environment 2011).

Climate change adaptation will therefore be an increasingly important consideration for building design and standards, and also town planning (Snow and Prasad 2011). Policy decisions on future developments, particularly in areas highly exposed to the impacts of climate change, will likely avoid increasing exposure to such risks. There will also be a large legacy risk from existing buildings and infrastructure which will require attention (Department of Environment 2011). Skills to retrofit and design buildings and infrastructure that offer reduced vulnerability to extreme weather impacts will be required and in demand (Snow and Prasad 2011). These skills will not only be for application in Queensland, but also our Pacific and Asian neighbours, where climate adaptation and resilience will also be a key priority.

The Internet of Things (IoT)

The Internet of Things (IoT) refers to the network of physical objects— including smart phones, cars, computers, televisions, even refrigerators— that are embedded with software or sensors, are connected to a network, and are capable of sending and receiving data. Making traditionally ‘dumb’ things ‘smart’ and enabling everything, from machine to machine communication (M2M) through to the most sophisticated predictive modelling (Intel 2015).

Big data is a term for data sets that are so large or complex that traditional data processing applications are inadequate. With the cost of computing (both processing and storage) falling and the speed and ease with which data can be transferred rising with ever-faster processor speeds, applications that draw on ‘big data’ are proliferating. Data is collected from a variety of sources, including business transactions, social media and information from sensor or machine-to-machine data. Big data can be analysed for insights that lead to better decisions and strategic business moves.

Smart grid is an electrical grid that combines advanced communication, sensing and metering infrastructure with the existing electricity network. Smart grids have enormous potential to improve the efficiency of Australia’s electricity sector and transform the way Australians use energy in their homes and businesses (DIIS 2014).

Smart City is an urban development vision to integrate multiple information and communication technology (ICT) solutions in a secure fashion to manage a city’s assets.

**The
challenge is
to shape the
workforce to
fit the future.**



Demand for environmentally friendly products and buildings is accelerating.

Global green building continues to double every three years, with emerging economies like Brazil, India, Saudi Arabia and South Africa driving this growth (DDA 2016). Increasing consumer demand has pushed the world's green building market to a trillion-dollar industry, a surge that has led to a corresponding increase in the scope and size of the green building materials market, which is expected to reach \$234 billion by 2019 (DDA 2016). Australia has a mature green building market, but growth in green implementation in Australia is still expected to increase. Interest in the positive impact of green buildings on health is more notable in Australia than in other countries (DDA 2016).

The greening of the building sector calls for new approaches to construction, use of sustainable materials and new methods of minimising adverse environmental impacts. Traditional occupations are likely to undergo significant changes in the context of green building: for example, tradespeople will need to keep up with the booming and rapidly advancing fields of water conservation, wastewater recycling and treatment, energy efficiency and electric vehicles in grid-connected and off-grid power systems, including electric vehicle (Martinez-Fernandez, Hinojosa et al. 2010). Some occupations will be more affected than others. Carpenters (insulation work), plumbers (installation of solar water heating), heating engineers, painters and plasterers (insulation, roofs and walls), roofers (solar photo-voltaic unit and thermal installation) and electricians will all see significant changes (Strietska-Ilina, Hofmann et al. 2011).

Building design, national regulations and managers' skills are set to meet the sustainability challenge. As in other countries, Australian governments have been implementing policies to reduce emissions and drive energy efficiency for more than two decades, including labelling and minimum performance standards for appliances, changes to building codes, restrictions on land clearing and market-based schemes such as the Renewable Energy Target (Australian Government 2014).

In addition to environmental regulation and government energy policies, major industrial and commercial businesses in the construction and building sector are encouraged to adopt a broad range of measures to deliver long-term environmental improvement. The Green Building Council of Australia (GBCA) has developed a comprehensive, national, voluntary environmental rating scheme, called Green Star, to evaluate environmental performance of buildings. Currently, more than 7.2 million square metres of building space has been certified and a further 8 million is registered with Green Star (Azzi, Duc et al. 2015).

While policies around the world already support sustainable construction, there is evidence to suggest that standards

are going to become more stringent. According to European Union regulations, after 2020, any new housing that fails to meet *passive house* standards will not be granted a construction permit. The German Government requires all new buildings achieve 'zero emissions' by 2020. Sweden also requires all new construction to shift away from reliance on fossil fuels (BASF 2016).

Sustainable design of built infrastructure, efficient energy usage and ecological adaptation not only reduce the impact on the environment and save running costs, but also create a sense of wellbeing and health for building occupants, resulting in increased productivity in the long run. The demand for sustainable buildings is increasing worldwide and many companies are vying for business in the design and construction of green buildings (Azzi, Duc et al. 2015).

Green building can boost employment through energy-efficient operations and maintenance, the expansion of renewable energy sources, green building refurbishment and tangential activities, such as recycling and waste management (Kaderják, Meeus et al. 2012, Ferreira and Almeida 2015)

Given the increasing prioritisation of issues such as sustainability, environmental protection and climate change, the role of the project manager may need to evolve. As the industry changes, project managers find themselves confronted by new issues and will need to undertake roles that have not traditionally been part of their responsibility (Edum-Fotwe and McCaffer, 2000), including functions with non-engineering knowledge and skills (Ceran and Dorman 1995; Russell et al. 1997).

The tropical climate zone is undergoing a massive population and economic boom.

The tropic zone is commonly defined as the region of the Earth surrounding the Equator within the latitudes of the Tropics of Cancer and Capricorn at +/- 23.5 degrees. While the tropic zone only comprises 40% of the world's surface area, it contains 80% of its terrestrial biodiversity and more than 95% of its mangrove and coral reef-based biodiversity. It is home to 40% of the world's population, and 55% of the world's children under five years old. By 2050, some 50% of the world's population and close to 60% of the world's children are expected to reside in the tropic zone. The economy in the tropic zone is growing 20% faster than the rest of the world (SoT 2014).

About half of Queensland's land area is in the tropic zone, and with more than half of the world's population expected to be living in the tropic zone by 2050, there are growing export opportunities for the state's building design and construction know-how in nearby South-East Asia, Papua New Guinea and the Pacific Islands (ATC 2015). Opportunities also exist for engineers who have developed high levels of renewable energy expertise through creating

solutions for off-grid communities, and substantial expertise in the area of water treatment and waste water management (Aliento 2014). Tropical urbanism is beginning to develop, and that work is being undertaken to engage with industry and government on a range of issues, including master planning, water sensitive urban design appropriate for Far North Queensland and public transport.

While there are opportunities associated with being located in this zone, there will also be some serious challenges, and experiencing the impacts of climate change earlier than other locations is one. A study undertaken by scientists at the University of Hawaii, and published in *Nature*, provides an index of the year when the mean climate of any given location on Earth will shift continuously outside the most extreme records experienced in the past 150 years. The study reveals that under a business-as-usual scenario, the average location on Earth will experience a radically different climate by 2047. Under an alternate scenario, with greenhouse gas emissions stabilisation, the global mean climate departure will be 2069, but areas located in the tropic zone would shift earlier than other locations, with some locations in the zone shifting outside the most extreme records experienced by 2020 (Mora, Frazier et al. 2013).

7.4 Economic trends

The sharing economy is likely to impact current business practices in the industry. The peer-to-peer (P2P) economy is rapidly developing and transforming markets and businesses across various industries globally. Uber in the taxi industry, eBay in retail and Airbnb in the rental property market are just a few famous examples. Although P2P has not taken hold in Australian construction, the industry is likely to become a part of the sharing economy in the near future. There are signs of it happening already. Numerous websites offer ranking and reviewing for trade workers. HiPages, for example, offers an online marketplace connecting trusted local tradespeople with customers. The resource is visited by over 1.5 million people monthly and a job is posted every 29 seconds (HiPages 2016).

Start-ups like EquipmentShare.com offer platforms for contractors to lend and rent equipment at a lower price (Mansfield 2015). Operating in the US and New Zealand, EquipmentShare.com allows contractors to earn money by renting out their unused equipment. The company itself takes care of insurance, delivery and maintenance (EquipmentShare 2016). Tool libraries are another example of the emerging sharing economy in the industry. Tool libraries offer hand tools, power tools, garden tools, etc. for rent to subscribers. The Brunswick Tool Library (BTL) has been operating in Melbourne since 2013 (BTL 2016), and

a tool library was opened in Ipswich after the floods in 2011 to help flood-affected households (O'Keeffe 2011).

The scope and pace of growth of these platforms is likely to transform the way housing construction and renovation is managed, from design and approvals through to selling and conveyancing.

Infrastructure costs in Australia are high by international standards (Langston 2012). High costs are an underlying cause of a growing infrastructure deficit (PC 2014). A recent estimate of the gap between existing and required stock of infrastructure was \$300 billion (IA 2013). Labour and land acquisition costs are among key drivers of infrastructure construction costs in Queensland. Other contributors include energy and transport costs. Land acquisition accounts for 5–20% of the project costs in urban areas (Queensland Government 2014). Land value in Brisbane has been growing at an average rate of 8.9% annually between 1993 and 2012, outpacing the growth rate of Sydney and Melbourne (URBIS 2013). Labour cost in construction has been mostly outpacing the average growth across industries in Australia between 1998 and 2015 (ABS 2015). Infrastructure construction costs were also driven by the mining boom in Queensland and are expected to continue rising with the growth of the energy sector, and liquefied natural gas in particular (Queensland Government 2014). At the same time, the capital costs per unit of capital in the construction industry appear to have been falling since the 1990s (PC 2014).

Increasing labour costs coupled with falling capital costs in the industry create economic incentives to substitute capital for labour and use automation technology to ensure productivity growth. Population growth and rapid urbanisation, as well as the rise of Asia, are likely to create an increasing demand for the services provided by infrastructure, and could contribute to supply bottlenecks. According to the Productivity Commission, the reserves for productivity growth in infrastructure delivery lie in project management, regulation and innovation. Realising these reserves is crucial for the industry to move forward (PC 2014).

Housing is becoming less affordable in Australia. Over the past two decades, the growth of property prices in Australia outpaced the growth of income, resulting in deterioration of housing affordability. Since the 1960s, the real housing price per capita growth was broadly in line with GDP, but took off sharply in the 1990s, outstripping income growth (IMF 2015). The gap in affordability between Australia and the OECD observed in 1970–80 subsequently closed during the early 2000s, and at the end of 2014 the price to income ratio in Australia exceeded the OECD aggregate level (Figure 14) (OECD 2016).

**Developing
a bold
innovation
culture is
essential.**



Research by Master Builders Australia (MBA) demonstrated that by 2012 none of the Australian states could any longer be qualified as affordable for housing (MBA 2015). The housing affordability ratio in Queensland increased from 4.6 to 6.7 over 2001–11, exceeding the affordable housing ratio of 5 and less. Between 2006 and 2011, the number of households whose payments to buy a house exceed 30% of income, increased by 17.8% (Senate 2015). Shortage in housing supply is often referred to as one of the drivers of house price increases. Some estimates suggest that the current shortage reaches 250,000 dwellings (Scutt 2016). Limited land release and excessive tax burden also affect housing affordability.

Affordability is affected by taxes and regulation. Low interest rates have been positively affecting housing affordability, although not evenly across population groups (RBA 2015). Negative gearing encouraged a rapid growth of household debt, was a catalyst for private investment in housing, and contributed to house price rises (Hyland 2016). Debt-to-income ratio in Australia tripled between 1990 and 2014, reaching an historic high 154% (IMF 2015). Stamp duty as a taxation mechanism is an oft cited barrier to market growth and undermining affordability. The Housing Industry Association recently estimated that stamp duty adds \$11,600 to \$45,300 to mortgage repayments in Queensland (HIA 2015).

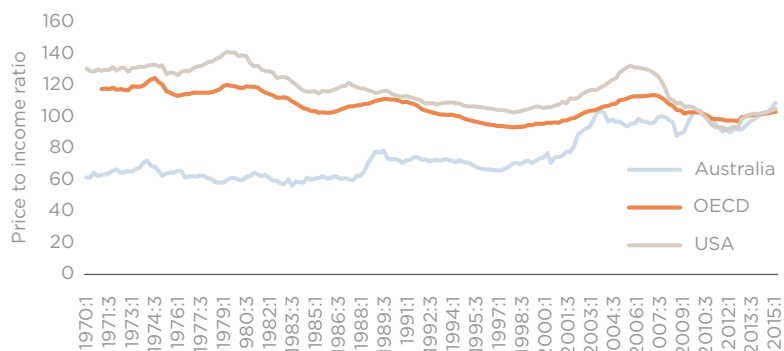


Figure 14: Nominal house price to nominal disposable income per person ratio.
Source: OECD (2016)

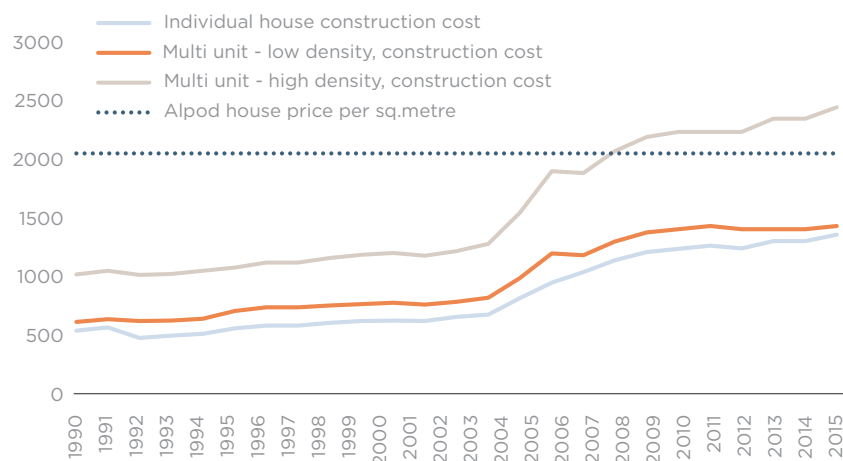


Figure 15: Construction cost in Brisbane (\$/sq. metre, low cost series, current prices) in comparison with the proposed price of Alpod house. Source: Rawlinsons (n/d), Robarts (2015)

Declining affordability is driving demand for affordable housing, creating favourable conditions for increased competition and new products in the property market, such as modular and prefabricated products from foreign and domestic home manufacturers.

Construction costs have jumped across all dwelling types.

Since 1990, the average construction cost of detached houses has increased in Brisbane 2.5 fold. Similarly, the cost of apartments in multi-unit dwellings increased 2.3 times, and over two times for high-rise office buildings. In 2015 the cost of construction of a detached house in Brisbane was estimated between \$1400 and \$1510 per square metre, while multi-unit, multi-storey, high-standard-finish accommodation was in the order of \$2525 to \$2720 per square metre (Rawlinsons n/d).

High construction costs underpin the price of housing (purchase price and rental rates). Increasing construction costs could make new solutions and materials (e.g. prefabrication, modular construction, 3D printing) cost competitive, creating a market niche for new entrants. For example, a modular housing product called Alpod is expected to be priced at \$2120 per square metre (Robarts 2015), which is below the cost of multi-unit construction, and is expected to be well below the market price of houses in Brisbane (Figure 15). Alpod is playing in a burgeoning field of modular home manufacturers. As the market booms, these products are likely to improve in quality and reduce in cost, further outcompeting conventional building methods.

7.5 Educational trends

The industry workforce is upskilling. Queensland's construction industry exhibits an upskilling trend, as does the labour market in Australia in general. Employment shares of high-skilled labour are increasing, while middle and low-skilled jobs are falling (or only slightly increasing) (Coelli and Borland 2015). This trend is anticipated to persist across Australian industries (2015).

Dynamics of the hours worked by occupations in Queensland construction confirms the upskilling trend (ABS 2015). Over the past 20 years (1995–2015), the share of hours worked by employees of high-skill roles (construction managers, building and engineering technicians) doubled. The share of medium-skilled labour (tradies) increased by 27%, while lower-skilled and unskilled employees (labourers) faced a decrease in the share of worked hours by 35% (Figure 16)(ABS 2015).

In line with this trend, economic modelling by PwC suggests that lower-skilled jobs in Australia face the highest risk of being automated. In construction, jobs carried out by glaziers, plasterers and tilers are estimated to have an 81.4% probability of being automated in the next 20 years (PWC 2015). At the same time, construction managers and engineers are among jobs with the lowest chance of being automated over the 20-year horizon—8.2% and 4.2% respectively (PWC 2015).

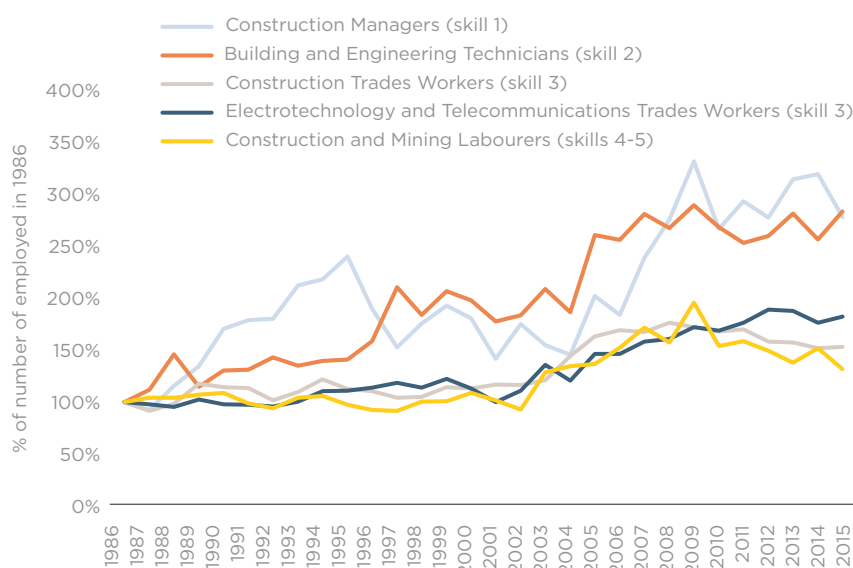


Figure 16: Examples of employment dynamics by occupation groups in the Queensland construction industry (indexed, 1986 = 100%). Source: ABS (2015)

Labour dynamics in the industry demonstrates a clear trend towards increasing demand for higher skilled workers in construction occupations. Higher skilled labour is likely to enjoy a continuing rise in the number of available jobs and associated wage premiums, whereas low-skilled occupations are more likely to face shrinking job availability over the next 20 years. The key issue then is how prepared the industry is for the transition to a future of higher skilled jobs and whether businesses and individual workers are ready to invest time, effort and money in upskilling today.

The industry is facing a shortage of professional and soft skills. Building and construction is facing a shortage of skilled labour (PC 2014). Over the 10-year period to 2014, nine years were marked by a shortage of stonemasons and roof tilers, eight years for civil engineering professionals and electrical engineers, and six years for civil engineering draftspersons and technicians (DOE 2014). The number of engineers in the construction industry entering Australia via skilled migration (permanent visas) is increasing, but at a slower pace than engineers in total, and has plateaued in recent years (Figure 17).

On the other hand, demand for engineers in construction is a function of experience. Australian civil engineering graduates with a lack of experience face barriers to entry and uncertainty about future earnings (PC 2014) and find it difficult to obtain a job. A shortage of skills and experience in the construction industry can impact projects, reducing the quality and quantity of work done, and increasing project costs, time frames and risks. Some evidence suggests that serious incidents like the Lane Cove Tunnel collapse might be associated with a shortage of engineers

(PC 2014). Although, according to Engineers Australia, the end-of-resource-boom-associated contraction of mining construction and infrastructure development slow-down could have resulted in the collapse in the demand for engineers in the industry which is not yet captured by the national statistical figures (Engineers Australia 2015).

At the same time the industry is facing a growing demand for 'soft skills', including leadership and management skills. The number of managers employed in the industry in 2015 has increased by nearly 70% since 1991 (ABS 2015). ConstructionQ Blueprint (Queensland Government 2015b) defines project management and communication skills of construction employees as one of the components of the resilient and innovative future of the Queensland construction industry (Queensland Government 2015b).

New attraction and retention strategies will be required to cope with the competition with other industries for qualified, knowledgeable, skilled and experienced professionals. Innovation in construction methods and materials will also require strong leadership capabilities to realise benefits in terms of efficiency and quality. Complex problem-solving, a 'life-long learning' orientation and communication skills are critical elements to the future of construction.

Completion rates of construction-related vocational education and training programs in Queensland is low.

The number of student completions of government-funded construction and property vocational education and training (VET) programs increased significantly since 2009 in Queensland and peaked in 2011. There was then a sharp decline between 2011 and 2013. Queensland was

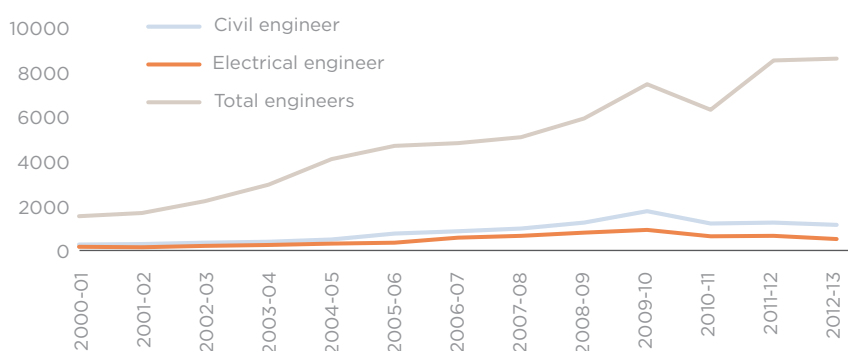


Figure 17: Number of engineers in the construction industry entering Australia via skilled migration. Source: Engineers Australia (2014)

producing the largest number of graduates in Australia in 2009–11; it has since fallen behind New South Wales and Victoria (Figure 18). The number of 15–19 year olds in Australia completing VET programs in construction and property services has doubled since 2003. Although this still only represents 20% of graduates, the number of young graduates is growing. However, the program completion rate in architecture and building over the past five years has been below average for government-funded VET programs (Figure 18) (NCVER 2015).

Female participation in construction-related VET programs is decreasing. In 2003, 25% of graduates from government-funded VET programs in Queensland were female. The number has dropped to 9.2% in 2013 (NCVER 2015). At the same time, the proportion of females obtaining higher education degrees in the field of architecture and building remained relatively constant over the past 10 years in Queensland, at the level of 40% (DET 2015).

Low completion rates for VET programs and falling share of females raise concerns for the future supply of skilled labour. While proposed VET reforms are expected to improve this situation, with new standards for training organisations, inducement banning, enhancing information transparency for new and ongoing students, etc. (DET 2015), the broader reform needed to meet the emerging needs of innovation is probably yet to appear on the agenda of educational providers and industry entities.

International education and training delivery trends might transform the VET sector. There has been a downward trend for conventional campus delivery of VET programs in Queensland. Other program delivery methods, such

as online access and employment-based training, has increased proportionally, although campus-based delivery is still favoured (NCVER 2015). In higher education, massive open online courses (e.g. Coursera, edX) are becoming increasingly popular (Norton 2014). Microlearning (short courses), gamification and personalised learning programs that account for personal interests, experience and abilities of individual students are gaining momentum and are likely to transform the traditional way of teaching and learning (Kapp 2016). Emerging virtual and augmented reality technology can offer immersive learning environments, new ways of assessing competency, and potentially speed up and improve the quality of the learning process (UNSW 2010, Welch 2016).

New asset sharing initiatives in education and training could improve access to a wider range of equipment and inter-disciplinary teaching and research (Universities UK). Research equipment sharing between UK universities, for example, now comprises over 40 higher educational providers and over 11,000 of pieces of equipment (Equipment.Data 2016).

Overall, international trends in the educational sector suggest the VET system is likely to be transformed in the future to support the needs of a flexible workforce and rapidly changing industry.

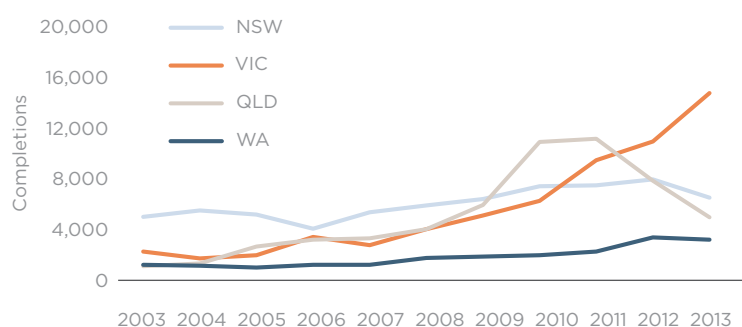


Figure 18: Government-funded VET program completions in construction and property services. Source: NCVER (2015)



**Skilling,
reskilling
and
upskilling
will be
critical.**



7.6 Political trends

Asia is booming and overseas migration is growing.

Despite global economic weakness in recent years, China and South-East Asia continue to express extra-ordinary economic and population growth, including a rapid rise of the middle class. As a result, the global economic centre of gravity has shifted from the mid-Atlantic in 1980 to the Middle East today, and is projected to be between India and China by mid-century (Quah 2011). China's population exceeded 1 billion people in 1982 and has since increased to 1.4 billion (OECD 2016). GDP per capita in current prices increased 33 times over that period (OECD 2016). China is Australia's largest trading partner, with ongoing mutual interest highlighted by the China-Australia Free Trade Agreement that was brought into force in December 2015 (ATC 2016).

Over the past five years, close to 50% of Queensland's population growth has been driven by international migration. Net overseas migration into Queensland has ranged from 34,000 to 36,000 people per year, making up 47% of population growth (Figure 19).

The rise of Asia and the transition of the Asian giants to service and knowledge economies, coupled with Australia's transition to the post-mining boom era, are likely to create space for knowledge workers and innovation experts in the construction industry. As east Asia becomes the dominant economic centre in the world, Queensland construction will be faced with threats and opportunities from international trade relations in the region. Queensland's growing multicultural population will increase the importance of workplace diversity and cultural awareness to capture the opportunities of the Asian century.

Foreign investment in Australian real estate is skyrocketing.

Since 2010, foreign investment in real estate has grown more than two fold, outpacing all other industries in the national economy (ABS 2014). According to the Foreign Investment Review Board, real estate was the largest industry by value of approvals in 2013-14 (FIRB 2015). However, investment in construction activities has not kept pace with the growth of total investment and was mostly below industry averages. In 2014, 7% of international investment in Australia was made into the real estate sector and 3% in construction (Figure 20).

Foreign purchases in the Australian residential sector concentrate on new dwellings, typically medium to high density in inner Sydney and Melbourne (Gauder, Houssard et al. 2014). Foreign demand for residential dwellings has contributed to the increase of dwelling supply, stimulating construction activity. On the other hand, as the Reserve Bank of Australia concludes, the demand increase may have also contributed to house price growth (Gauder, Houssard et al. 2014).

Australia is among the major recipients of direct investment from China—in 2014 it was the second largest recipient after the US. Nearly half (46%) of direct outbound investment from China went to commercial real estate and another 21% to infrastructure (KPMG and The University of Sydney 2015). Chinese buyers account for 12% of new residential property supply in Australia or \$5 billion in purchases per annum. The latter figure is expected to grow by \$44 billion between 2013 and 2020 (Credit Suisse 2014).

Booming foreign investment in real estate creates opportunities for growth in the construction industry. Accelerating the construction process and incorporating new cultural preferences for urban density might become more important in the future.

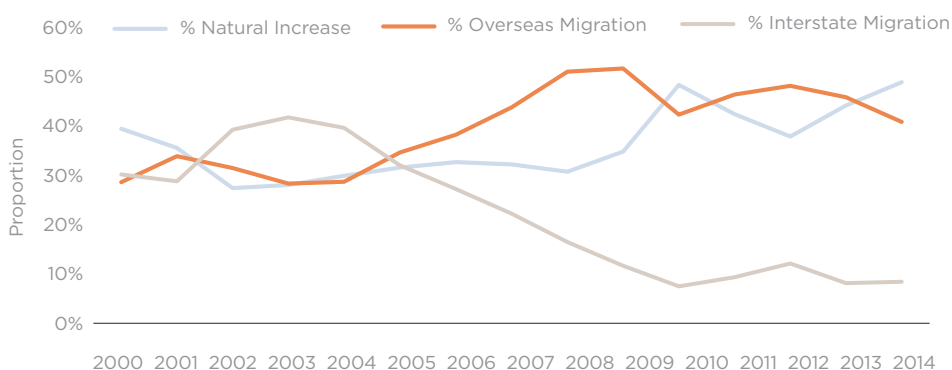


Figure 19: Proportion of net population increase in Queensland.
Source: ABS (2014).

Regulations in safety and environment protection come at a cost.

Regulation underpins the development of the industry and is set to protect workers and consumers, as well as the broader community and environment. However, the problem of complex unsynchronised regulation in the construction industry is oft cited as limiting development and innovation opportunities for the industry (Victorian Government 2015) as well as efficiency (Queensland Government 2015b). Standards and requirements, including safety and environment, might be creating additional market entry barriers in the industry, limiting competition and making it susceptible to collusion (OECD).

Compliance with regulation contributes to the construction cost increase. According to the Productivity Commission, compliance with workplace safety and environmental regulation affects productivity in infrastructure construction as it requires more employees to perform the jobs. For example, biodiversity standards for infrastructure projects require approximately four times the land size of the infrastructure object (DIRD 2014). Another aspect of cost related to regulation compliance is time required for project development, from proposal to start-up. A recent estimate, based on 17 projects, suggests that average approval time is 37 months (PC 2013).

Streamlining of regulation in the industry might open up opportunities for productivity growth (PC 2014, Victorian Government 2015).

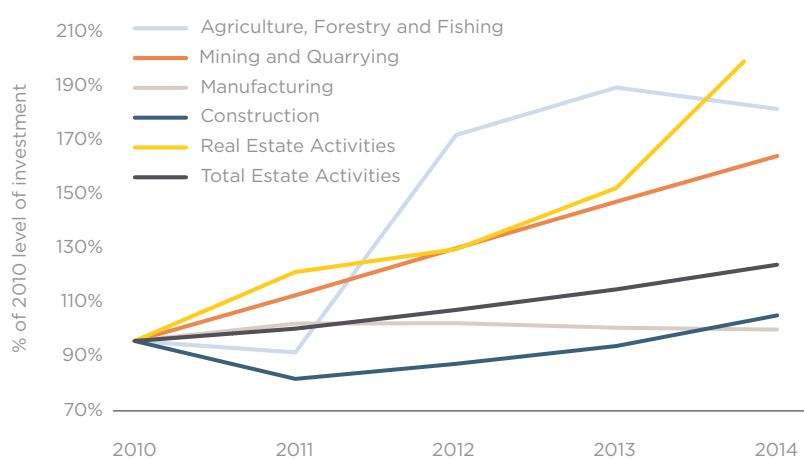


Figure 20: Foreign investment in construction and selected industries in Australia, as a % of 2010 investment. Source: ABS (2014)

08 Conclusion

Social and technological change holds the potential to create many new markets and jobs for Queensland's construction industry. However, change is needed to enable the industry to survive and thrive in an era of global disruption. Disruption is not new, but each generation and century throws up new challenges and opportunities. Exploding and ageing population, urbanisation, increasing globalisation, the rise of Asia, housing affordability and infrastructure cost concerns, environmental decline and climate change are key landscape factors reaching their zenith. The 21st century promises to bring new catalytic events that will reshape whole economies as well as industries. This report explored four plausible scenarios for Queensland's construction industry over the next 20 years. These narratives were based on detailed analysis of 25 critical trends and the opinion of 80 professionals from industry; and by all accounts, construction is set to transform. The nature and extent of the transformation is uncertain, and careful strategic thinking is needed to navigate the transition.

We have already seen major shifts in other industries. Agriculture, mining and manufacturing have experienced marked declines, while the service sector has flourished. Globalisation and digital connectivity is now starting to give rise to intense competition from overseas workers in the service sector. While considerable segments of the construction industry have been largely hedged against global labour markets, the door is opening with the advent of prefabrication and modularisation. Like cars, we may end up importing most of our buildings and infrastructure in the decades to come. This is occurring already, albeit at the niche level.

Changing technology will impact the availability and nature of jobs—many jobs may disappear, while new jobs are created. Jobs involving repetitive and routine tasks are most at risk of being automated, whereas jobs involving creative design, complex reasoning, social interaction and emotional intelligence are likely to proliferate. The digital age will bring new complexity, which will require humans to exercise judgement and decision-making that reflects human values and aspirations; a task that is well beyond the most aspirational artificial intelligence systems.

The extent and reach of task automation may be uncertain, but all scenarios highlight the growing importance of eliminating human labour for dangerous and difficult tasks, particularly in light of the ageing workforce. Some measure of automation will occur. The challenge for the industry is to shape the transition and create economic opportunity for tomorrow's workforce. New competencies and strengths in innovation management and digital technology, automation and artificial intelligence will be needed to grow jobs in the future. Such competencies are only likely to arise in an environment that embraces new ideas and develops them into useful products and services, as well as provides incentives and opportunities for lifelong learning.

Developing a bold innovation culture is ostensibly Australia's biggest conundrum. Many contributors to our interviews and workshops suggested that shifting the construction industry's cultural set-point on innovation will require a significant external force. Then, a constellation of enablers is needed from the nurturing of a sophisticated early adopter market, to significant investment in innovation process, and from protected spaces for exploration and field testing, through to supportive and appropriate government and regulatory oversight. Enhanced capacities to seize new markets and collaborate across inter/national and sectoral boundaries will be needed to ensure that the state is home to a dynamic and healthy construction industry. New skills in leadership and innovation management, digital literacy, creativity, collaboration and communication, and cultural awareness will become important competencies for the construction workforce of the future.

While pressures will intensify at the global scale over the coming years, the Queensland construction industry is well-placed to respond and offer exciting job opportunities. This report offers a sound starting point to grapple with the many powerful trends at play in the industry. We hope it proves useful in gaining better insights to steer the workforce through the next 20 years.



09 References

- ABS (2000). Employee Earnings, Benefits and Trade Union Membership, Australia, March 2001. Catalogue Number 6310.0. Canberra, Australian Bureau of Statistics.
- ABS (2010). Feature Article: Average Floor Area of New Residential Dwellings. Building Approvals, Australia, Feb 2010. Catalogue Number 8731.0. Canberra, Australian Bureau of Statistics.
- ABS (2012). Year Book Australia, 2012. Households and Families. Catalogue Number 1301.0. Canberra, Australian Bureau of Statistics.
- ABS (2013). Aboriginal and Torres Strait Islander peoples' labour force outcome. Australian Social Trends, November 2013. Catalogue Number 4102.0, Australian Bureau of Statistics.
- ABS (2013). Employee Earnings, Benefits and Trade Union Membership, Australia, August 2013. Catalogue Number 6310.0. Canberra, Australian Bureau of Statistics.
- ABS (2013). Information Paper: Towards the Australian Environmental-Economic Accounts, 2013. Catalogue Number 4655.0.55.002. Canberra, Australian Bureau of Statistics.
- ABS (2014). Australian Demographic Statistics. Catalogue Number 3101.0. Canberra, Australian Bureau of Statistics.
- ABS (2014). International Investment Position, Australia: Supplementary Statistics. Catalogue Number 53520. Canberra, Australian Bureau of Statistics.
- ABS (2015). Australian National Accounts: State Accounts. Catalogue Number 5220.0 Canberra, Australian Bureau of Statistics.
- ABS (2015). Building Approvals, Australia, Dec 2015. Catalogue Number 8731.0. Canberra, Australian Bureau of Statistics.
- ABS (2015). Construction Work Done, Australia, Preliminary. Catalogue Number 8755.0 Canberra, Australian Bureau of Statistics.
- ABS (2015). Counts of Australian Businesses, including Entries and Exits, Jun 2011 to Jun 2015. Catalogue Number 81650 Canberra, Australian Bureau of Statistics.
- ABS (2015). Labour Force, Australia, Detailed. August 2015. Catalogue Number 6291.0.55.003. Canberra, Australian Bureau of Statistics
- ABS (2015). Labour Force, Australia. Catalogue Number 6202.0. Canberra, Australian Bureau of Statistics.
- ABS (2015). Wage Price Index, Australia, Dec 2015. Catalogue Number 6345.0. Canberra, Australian Bureau of Statistics.
- Acemoglu, D. and D. Autor (2010). "Skills, Tasks and Technologies: Implications for Employment and Earnings." NBER Working Paper No.16082.
- ACG (2010). Productivity in the buildings network: assessing the impacts of Building Information Models. Sydney, Allen Consulting Group.
- ACMA (2014). Communications Report 2013-2014. Canberra, Australian Communications and Media Authority.
- Ai Group (2015). Australia's Construction Industry: Profile and Outlook, Ai Group Economics Research. July 2015.
- AIFS (2011). Households in Australia: Source Data., Australian Institute of Family Studies, Australian Government.
- AIFS (2014). Fly-in fly-out workforce practices in Australia: The effects on children and family relationships. CFCA Paper No.19 - February 2014, Australian Institute of Family Studies, Australian Government.
- Akerman, A., I. Gaarder and M. Mogstad (2015). "The Skill Complementary of Broadband Internet." NBER Working Paper No.20826.
- Alianto, W. (2014). How to Build for the Tropics - JCU and Tropical Building Network team up.
- ASBEC (2009). Submission 318 to the Senate Select Committee on Climate Policy. Australia, Australian Sustainable Built Environment Council.
- ATC (2015). Northern Australia: Emerging opportunities in an advanced economy, Australian Trade Commission
- ATC (2016). China-Australia Free Trade Agreement (ChAFTA), Australian Trade Commission.
- Australian Government (2014). Australia's policies on climate change, in Targets and Progress Review: Final Report, Chapter 5: Climate Change Authority. Canberra, Australian Government.
- Australian Industry Group (2008). State of Play: The Australian Construction Industry in 2008. North Sydney, Australian Industry Group.
- Australian Parliament (2016). Smart ICT: Report on the inquiry into the role of smart ICT in the design and planning of infrastructure. Canberra, Standing Committee on Infrastructure, Transport and Cities, The Parliament of the Commonwealth of Australia.
- Azzi, M., H. Duc and Q. P. Ha (2015). "Toward sustainable energy usage in the power generation and construction sectors—a case study of Australia." Automation in Construction 59: 122-127.
- Bain & Company (2015). Management Tools & Trends. Boston MA, Bain & Company.
- Barnett, E. and C. Gosselin (2015). Large-Scale 3D Printing With A Cable-Suspended Robot. Additive Manufacturing 7: 27-44.
- BASF (2016). Future of sustainable construction. BASF Website (www.basf.com).

- Brynjolfsson, E. and A. McAfee (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*, WW Norton & Company.
- BTL (2016). News. Melbourne, Brunswick Tool Library Webpage (<http://www.brunswicktoolibrary.org>).
- Burke, T., W. Stone and L. Ralston (2014). *Generational change in home purchase opportunity in Australia*, AHURI Final Report No.232. Melbourne, Australian Housing and Urban Research Institute.
- Ceran, T. and A. Dorman (1995). "The Complete Project Manager." *Journal of Architectural Engineering* 1(2): 67-72.
- CIE (2011). *Effects of a carbon price on the building and construction industry*. Report prepared for Master Builders Australia. Australia, Centre for International Economics.
- CITT, TITAB and ADTIA *What impact will Digital Convergence and "Internet of Things (IoT)" have on "inpremise" workforce skills and training?*, CITT, TITAB, Australian Digital and Telecommunications Industry Association (ADTIA).
- Coelli, M. and J. Borland (2015). *Job polarisation and earnings inequality in Australia*, Department of Economics, University of Melbourne.
- Cornell University, INSEAD and WIPO (2015). *The Global Innovation Index: Effective Policies for Development*. Fontainebleau, Ithica and Geneva.
- Cowen, T. (2013). *Average Is Over: Powering America Beyond the Age of the Great Stagnation*. New York, The Penguin Group.
- Credit Suisse (2014). *The Chinese Property Boom Down Under*. Sydney, Credit Suisse Australia.
- CSIRO (2015). *Impacts and Adaptation Information For Australia's NRM Regions*, Commonwealth Scientific and Industrial Research Organisation.
- CSIRO (2016). *Zebedee: handheld laser scanner*, Commonwealth Scientific and Industrial Research Organisation.
- DARPA (2015). *DARPA Robotics Challenge*. DARPA Website (<http://www.theroboticschallenge.org>), US Defense Advanced Research Projects Agency.
- Davies, K. (2010). *Benchmarking computer use in the NZ construction industry*, Unitec Research Committee Research Report.
- DDA (2016). *World Green Building Trends 2016: Developing Markets Accelerate Global Green Growth SmartMarket Report*, Dodge Data & Analytics.
- Deloitte (2016). *Australia's Digital Pulse: Developing the digital workforce to drive growth in the future*, Deloitte Access Economics, Deloitte Australia.
- Deloitte (2016). *Tech Trends 2016: Innovating in the digital era*, Deloitte University Press.
- Department of Employment (2015). *Employment Outlook to November 2019*, Department of Employment,.
- Department of Environment (2011). *Climate Change Risks to Coastal Buildings and Infrastructure: A Supplement to the First Pass National Assessment*, Department of Environment, Australian Government.
- DET (2015). *VET FEE-HELP Reform. Factsheet updated 3 July 2015* Department of Education and Training, Australian Government.
- DI (2014). *Australian Innovation System Report 2014*, Department of Industry, Australian Government.
- DIIS (2014). *Smart Grid, Smart City*, Department of Industry, Innovation and Science, Australian Government.
- DILGP (2016). *State Infrastructure Plan. Part B: Program*. March 2016. Brisbane, Department of Infrastructure, Local Government and Planning.
- DIP (2009). *South East Queensland Regional Plan 2009-2031*. Brisbane, Department of Infrastructure and Planning, Queensland Government.
- DIRD (2014). *Submission 64 by the Department of Infrastructure and Regional Development to the Productivity Commission Inquiry on the Public Infrastructure*, Department of Infrastructure and Regional Development.
- DOE (2014). *Indicative Department of Employment Skill Shortage Ratings - 1986 to 2014*, Department of Employment, Australian Government.
- Doloreux, D. (2004). "Regional Innovation Systems in Canada: A Comparative Study." *Regional Studies* 38(5): 479-492.
- Eastman, C., P. Tiecholz, R. Sacks and K. Liston (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors* (2nd ed.). Hoboken, John Wiley.
- Edum-Fotwe, F. T. and R. McCaffer (2000). "Developing project management competency: perspectives from the construction industry." *International Journal of Project Management* 18 (2): 111-124.
- Engineers Australia (2014). *Skilled Migration and the Supply of Engineers, 2014*. ACT, Engineers Australia.
- Engineers Australia (2015). *The Engineering Profession: A Statistical Overview*. Twelfth Edition, November 2015. Barton ACT, Engineers Australia.
- Equipment.Data (2016). *Equipment.Data portal - Enabling access to UK HE research equipment*, Equipment.Data Website (<http://equipment.data.ac.uk>).
- EquipmentShare (2016). *About, EquipmentShare.com Website* (<https://equipmentshare.com/>).

- Fan, C. C. and A. J. Scott (2003). "Industrial Agglomeration and Development: A Survey of Spatial Economic Issues in East Asia and a Statistical Analysis of Chinese Regions." *Economic Geography* 79(3): 295-319.
- Ferreira, M. and M. Almeida (2015). "Benefits from energy related building renovation beyond costs, energy and emissions." *Energy Procedia*, 6th International Building Physics Conference, IBPC 2015.
- FIRB (2015). *Foreign Investment Review Board Annual Report 2013-14*. Canberra, Foreign Investment Review Board, Australian Government.
- FLC (2013). *Robotic Tiling Demonstrator*, Future Cities Laboratory.
- Frey, C. B. and M. A. Osbourne (2013). *The future of employment: How susceptible are jobs to computerisation?* Oxford.
- Gauder, M., C. Houssard and D. Orsmond (2014). "Foreign Investment in Residential Real Estate." *Reserve Bank of Australia Bulletin* June Quarter 2014.
- Geels, F. W. (2002). "Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study." *Research Policy* 31(8-9): 1257-1274.
- Geels, F. W. (2005). "The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860-1930)." *Technology analysis & strategic management* 17(4): 445-445.
- Gordon, G. G. (1991). "Industry Determinants of Organizational Culture." *Academy of Management. The Academy of Management Review* 16(2): 396.
- Green, J. and P. Newman (2014). *Building a housing industry from the relics of a car industry*.
- Guizzo, E. and E. Ackerman (2015). *Toyota Invest \$1Billion in AI and Robots, Will Open R&D Lab in Silicon Valley*. IEEE Spectrum. Online, IEEE.org.
- Gurteen, D. (1998). "Knowledge, creativity and innovation." *Journal of Knowledge Management* 2(1): 5-13.
- Hajkowicz, S. A., A. Reeson, L. Rudd, A. Bratanova, L. Hodggers, C. Mason and N. Boughen (2016). *Tomorrow's Digitally Enabled Workforce: Megatrends and scenarios for jobs and employment in Australia over the coming twenty years*. Brisbane, CSIRO.
- Heaton, A. (2014). *Construction Workers Becoming Tech Gurus*, Masonry Contractors Australia Ltd.
- HIA (2015). "HIA Stamp Duty Watch. The latest developments in stamp duty on home purchases." *Housing Industry Association Stamp Duty Watch* Summer 2015.
- HIA (2015). *Renovations Roundup*. A quarterly update on Home Renovations Market. Winter 2015, Housing Industry Association.
- HiPages (2016). *HiPages Journey*, Home Improvement Pages Website (<http://www.homeimprovementpages.com.au>).
- Hoonakker, P. and C. van Duivenbooden (2010). "Monitoring working conditions and health of older workers in Dutch construction industry." *American Journal of Industrial Medicine* 53(6): 641-653.
- Hope, P. G. (2015). *Contractor profile. Ten most populous licence types*. January 2015. Brisbane, Queensland Building and Construction Commission.
- Hyland, A. (2016). "'Ponzi scheme' or vital investment tool: Business divided on negative gearing" *Financial Review* 17 February 2016.
- IA (2013). *National Infrastructure Plan June 2013*. Canberra, Infrastructure Australia, Australian Government.
- IBM - Melbourne Institute (2010). *Innovation Index of Australian Industry 2010*. Melbourne, The University of Melbourne.
- ILO (2010). *A Skilled Workforce for Strong, Sustainable and Balanced Growth: A G20 Training Strategy; PART I: Global drivers of change: opportunities and challenges for training and skills development*. Geneva, International Labour Organisation.
- IMF (2015). *Australia. Selected Issues*. Washington, D.C., International Monetary Fund.
- Intel (2012). *Intel Chips Timeline*, Intel Website (www.intel.com).
- Intel (2015). *A Guide to the Internet of Things*, Intel Website (www.intel.com).
- IPCC (2013). *Summary for Policymakers. A report of Working Group I of the Intergovernmental Panel on Climate Change*. T. F. Stocker, D. Qin, G. K. Plattner et al. Cambridge, Cambridge University Press: 1-30.
- Kaderják, P., L. Meeus, I. Azevedo, P. Kotek, Z. Pató, L. Szabó and J.-M. Glachant (2012). *How to Refurbish All Buildings by 2050*. Think Project. Topic 7. Firenze, Italy, European University Institute.
- Kapp, K. M. (2016). "5 Learning Tech Trends to Watch in the Next 5 Years." *Association for Talent Development Website* (www.td.org) Wednesday, 3rd of February.
- King, N., M. Bechthold, A. Kane and P. Michalatos (2014). "Robotic Tile Placement: Tools, Techniques and Feasibility." *International Journal of Automation in Construction* 39: 161-166.
- KPMG and The University of Sydney (2015). *Demystifying Chinese Investment in Australia*. Featuring commercial real estate analysis by Knight Frank. May 2015 Update, KPMG.

- Langston, C. (2012). "Comparing international construction performance. Working Paper." Mirvac School of Sustainable Development, Bond University.
- Lim, S., R. A. Buswell, T. T. Le, S. A. Austin, A. G. F. Gibb and T. Thorpe (2012). "Developments in construction-scale additive manufacturing processes." *Automation in Construction* 21: 262-268.
- Lockhead, M. (2016). FORITS Exoskelton.
- Mansfield, A. (2015). "Feeling Generous? Construction Equipment Sharing Startups Hope So." *The FieldLens Blog* (<http://fieldlens.com/blog>) May 14, 2015
- Manyika, J., M. Chui, P. Bisson, J. Woetzel, R. Dobbs, J. Bughin and D. Aharon (2015). *Unlocking the potential of the Internet of Things*.
- Marchant, T. (2013). "Keep going: career perspectives on ageing and masculinity of self-employed tradesmen in Australia." *Construction Management and Economics* 31 (8): 845-860.
- Martinez-Fernandez, Hinojosa and Miranda (2010). *Green jobs and skills: the local labour market implications of addressing climate change*, OECD.
- Mayer, B. (2013). *How to Explore the Potential and Avoid the Risks of Additive Manufacturing*.
- MBA (2015). *Master Builders Australia Submission to the Senate Economics References Committee Inquiry (Submission 48). As cited in the Economics References Committee report "Out of reach? The Australian housing affordability challenge"*, Master Builders Australia.
- MBA (2015). *Towards 2020 - Policy for Australian Apprenticeship Reform*. ACT, Master Builders Australia.
- MBA (n/d). *Women in the Construction Trades*, Master Builders Australia, Construction Apprenticeship Mentoring Scheme.
- Mercer, C. (2016) "Apple, Google and Facebook are investing in artificial intelligence: What is their plan and who are other key players." *techworld*.
- METI (2015). *Japan's Robot Strategy was Compiled METI Website* (www.meti.go.jp), Ministry of Economy, Trade and Industry, Japan.
- Mora, C., A. G. Frazier, R. J. Longman, R. S. Dacks, M. M. Walton, E. J. Tong, J. J. Sanchez, L. R. Kaiser, Y. O. Stender, J. M. Anderson, C. M. Ambrosino, I. Fernandez-Silva, L. M. Giuseffi and T. W. Giambelluca (2013). "The projected timing of climate departure from recent variability." *Nature* 502(7470): 183-187.
- NCVER (2015). *Australian vocational education and training statistics: the likelihood of completing a government-funded VET program, 2009-13*. Adelaide, National Centre for Vocational Education Research.
- NCVER (2015). *Government Funded Students and Courses Data Set*. South Australia, National Centre for Vocational Education Research.
- NG, J. Y. K. and A. H. S. Chan (2015). "The Ageing Construction Workforce in Hong Kong: A Review." *Proceedings of the International MultiConference of Engineers and Computer Scientists IMECS 2015*, March 18 - 20, 2015, Hong Kong.
- Nordhaus, W. D. (2007). "Two centuries of productivity growth in computing." *J. Econ. Hist.* 67, no. 01: 128-159.
- Norton, A. (2014). *Mapping Australian higher education 2014-15*, Grattan Institute.
- NSF (2016). *National Robotics Initiative*. NSF Website (www.nsf.gov), National Science Foundation.
- O'Keeffe, A. (2011). "Ipswich Tool Library opens." *ABC Brisbane* 15 April 2011.
- OECD (2010). *Construction Industry*. OECD Journal: Competition Law and Policy 10(1).
- OECD (2016). *Analytical house prices indicators*. OECD Website (stats.oecd.org), OECD. Stat.
- OECD (2016). "Gross domestic product (GDP) (indicator). China. ." OECD.Data.
- OECD (2016). *Population (indicator). China*. OECD.Data, OECD.
- Paoletti, I. and R. S. Naboni (2013). *Robotics in the Construction Industry: Mass Customization or Digital Crafting? Advances in Production Management Systems. Competitive Manufacturing for Innovative Products and Services: IFIP WG 5.7 International Conference, APMS 2012, Rhodes, Greece, September 24-26, 2012, Revised Selected Papers, Part I*. C. Emmanouilidis, M. Taisch and D. Kiritsis. Berlin, Heidelberg, Springer Berlin Heidelberg: 294-300.
- PC (2013). *Major Project Development Assessment Processes, Research Report*. Canberra, Productivity Commission 2013.
- PC (2014). *Public Infrastructure, Inquiry Report No. 71*. Canberra, Productivity Commission.
- Porter, M. E. (1990). "The competitive advantage of nations." *Harvard Business Review* 68: 73-93.
- Price, B. (2015). *Rise of the bricklaying machines*. ScienceNetwork Western Australia.
- PWC (2014). *3D printing and the new shape of industrial manufacturing*.
- PWC (2015). *A smart move: Future proofing Australia's workforce by growing skills in science, technology, engineering and maths (STEM)*. Sydney, PricewaterhouseCoopers.

- Quah, D. (2011). "The Global Economy's Shifting Centre of Gravity." *Global Policy* 2(1): 3-9.
- Queensland Government (2014). Queensland Government submission to the Productivity Commission Public Infrastructure Inquiry Report (submission DR203).
- Queensland Government (2015a). Queensland Budget 2015-16. Jobs Now, Jobs for the Future. Queensland Government Employment Plan. Queensland Budget 2015-16.
- Queensland Government (2015b). ConstructionQ Blueprint 2014-2034.
- Queensland Government (2016). Adapting to climate change.
- Queensland Government (2016). Advance Queensland: Jobs now, jobs for the future. Advance Queensland (www.advance.qld.gov.au).
- Queensland Treasury (2013). Queensland Regional Database (QRSIS): Queensland Government population projections, 2013 edition. , Queensland Treasury, Queensland Government.
- Quezada, G., G. Grozev, S. Seo and C.-H. Wang (2014). "The challenge of adapting centralised electricity systems: peak demand and maladaptation in South East Queensland, Australia." *Regional Environmental Change* 14(2): 463-473.
- Quezada, G., A. Walton and A. Sharma (2016). "Risks and tensions in water industry innovation: understanding adoption of decentralised water systems from a socio-technical transitions perspective." *Journal of Cleaner Production* 113: 263-273.
- Rawlinsons (n/d). Australian Construction Handbook, Various editions. Perth, Rawlhouse Publishing.
- RBA (2015). Reserve Bank of Australia Submission 14 to the Senate Economics Committee Inquiry on the Australian Housing Affordability. Canberra, Reserve Bank of Australia.
- ROB|ARCH (2016). International Map of Robots in the Creative Industry. ROB|ARCH Webpage (www.robotsinarchitecture.org), Association for Robots in Architecture.
- Roberts (2015). "Alpod mobile home shows its metal." *Gizmag* December 16, 2015.
- Schein, E. H. (2010). *Organizational Culture and Leadership*, Wiley.
- Scutt, D. (2016). "Australia's 'significant' housing shortage." *Business Insider Australia* 23 March 2016.
- Senate (2015). Out of reach? The Australian housing affordability challenge. Canberra, Economics References Committee, The Senate.
- Sibthorpe, C. (2016). "Lady tradies: the good and the bad in a male-dominated industry " *The Canberra Times* January 2016.
- Sirkin, H. L., M. Zinser and J. Rose (2015) "How Robots Will Redefine Competitiveness." *bcg.perspectives*.
- Snow, M. and D. Prasad (2011). Climate Change Adaptation for Building Designers: An Introduction, Environment Design Guide Website (www.environmentdesignguide.com.au)
- SoT (2014). The State of the Tropics Report: 2014 Report. Cairns, State of the Tropics.
- Steinhardt, D. A., K. Manley and W. Miller (2013). Reshaping housing - the role of prefabricated systems. Brisbane, Queensland University of Technology.
- Strietska-Ilina, O., C. Hofmann, M. Durán Haro and S. Jeon (2011). Skills for Green Jobs: Synthesis Report based on 21 country studies. Geneva, International Labour Organisation.
- Sun, C., S. Jiang, M. J. Skibniewski, Q. Man and L. Shen (2015). "A literature review of the factors limiting the application of BIM in the construction industry." *Technological and Economic Development of Economy*.
- SWA (2015). Work-related Injuries and Fatalities in Construction, 2003 to 2013. Canberra, Safe Work Australia.
- Tesluk, P. E., J. L. Farr and S. R. Klein (1997). "Influences of organizational culture and climate on individual creativity." *Journal of Creative Behavior* 31(1): 27-41.
- Toner, P. (2006). "Restructuring the Australian construction industry and workforce : implications for a sustainable labour supply." *The economic and labour relations review* 17, No 1: 171-202.
- Treasury (2015). 2015 Intergenerational Report. Australia in 2055. Canberra, The Treasury, Australian Government.
- UDIA (2015). The 2015 UDIA State Of The Land Report. National Land Supply Study, Urban Development Institute of Australia.
- UK CES (2014). The Future of Work: Jobs and skills in 2030, Evidence Report 84 Rotherham, London, UK Commissioner for Employment and Skills.
- Universities UK (2015). Efficiency, effectiveness and value for money. London, Universities UK.
- UNSW (2010). Construction Safety in Virtual Reality Training (Brookfield Multiplex). UNSW Website (www.niea.unsw.edu.au), National Institute for Experimental Arts, University of New South Wales.
- URBIS (2013). Review of historic land value growth in East coast capital cities. Prepared for Infrastructure Australia. July 2013. Sydney, URBIS.
- Vähä, P., T. Heikkilä, P. Kilpeläinen, M. Järviuoma and E. Gambao (2013). "Extending automation of building construction — Survey on potential sensor technologies and robotic applications." *Automation in Construction* 36: 168-178.

Victorian Government (2015). Victoria's Future Industries. Construction Technologies. Discussion Paper. Melbourne, Victoria State Government, Department of Economic Development.

WA (2015). The impact of FIFO work practices on mental health. Education and Health Standing Committee. Report No. 5. Perth, Legislative Assembly Parliament of Western Australia.

Welch, B. (2016). Simulation training: The future of our industry BLSC Website (www.blsc.com.au), Building Leadership Simulation Centre.

WGEA (2015). Gender Pay Gap Statistics. Australia, Workforce Gender Equality Agency, Australian Government.

Wilkinson, A. and R. Kupers (2013). "Living in the futures." Harvard Business Review(May).

Williams, W. and D. Lewis (2005). "Convergent interviewing: a tool for strategic investigation." Strategic Change 14: 219-229.

Yi, W., A. P. C. Chan, X. Wang and J. Wang (2016). "Development of an early-warning system for site work in hot and humid environments: A case study." Automation in Construction 62: 101-113.

Zhou, C. and A. Walsh (2015). "The evolution of the Australian dream: High property prices alter home ownership dreams." Domain Website News (www.domain.com.au)(3 August 2015).

At CSIRO we shape the future

At CSIRO, we do the extraordinary every day. We innovate for tomorrow and help improve today – for our customers, all Australians and the world.

Our innovations contribute billions of dollars to the Australian economy every year. As the largest patent holder in the nation, our vast wealth of intellectual property has led to more than 150 spin-off companies.

With more than 5,000 experts and a burning desire to get things done, we are Australia's catalyst for innovation.

CSIRO. We imagine.

We collaborate. We innovate.

Stronger futures in construction

At Construction Skills Queensland we believe that a successful industry relies on a combination of world class capability and access to the best knowledge. We are taking a sustainable long-term approach to training that matches demand, is resilient, flexible and provides industry with confidence and certainty.

CSQ

